Reseacrh Article
The Journal of Turkish Phytopathology
fitopatoloji.org.tr

Determination of Fungal Pathogens Causing Root-Rot on Bean Plants in Bean Production Areas of Nevşehir Province, Turkey

Abdullahi Isaq OMAR[1] Ali ERKILIÇ[1] Mohammed Ahmed MOHAMMED[1]

[1]Çukurova Üniversitesi, Ziraat Fakültesi, Bitki Koruma Bölümü, Adana

ABSTRACT
The current study was conducted with the aim of determining fungal pathogens that cause root-rot disease on bean (*Phaseolus vulgaris* L.) in Yazıhüyük and Suvermez districts, Nevşehir province, Turkey. Field surveys, molecular characterizations, and pathogenicity tests were carried out during the growing season of 2018. The most prevalent isolates obtained from the bean cultivation areas were *Fusarium* (62.5%) followed by *Rhizoctonia* (27.5%) and *Rhizopus* (4.8%). The lowest mean frequency rates were found for *Epicoccum* (0.7%), *Penicillium* (2.1%), and *Alternaria* (2.4%). *Fusarium oxysporum* (Y1A) had the highest virulence followed by *Fusarium solani* (Y1B) and *Rhizoctonia solani* AG-4 (Y8). The pathogenicity test on all bean varieties revealed that the disease severity rates of *F. oxysporum, F. solani* and *R. solani* AG-4 were ranging from 48.3%–91.7%, 33.3%–95.0%, and 26.7%–50%, respectively. Overall, the Adzuki bean cultivar was the most susceptible to the three pathogens followed by İspir, Gezin/Elazığ-1 and Kidney Bean cultivars.
Keywords: Fungus, *Fusarium* spp., Pathogenicity, *Phaseolus vulgaris*, root-rot, Turkey

ÖZ
Nevşehir İli Fasulye Alanlarında Kök Çürüklüğüne Neden Olan Patojenlerin Saptanması
Nevşehir ilinindeki (*Phaseolus vulgaris* L.) Yazıhüyük ve Suvermez köylerinde fasulye bitkisinde kök çürüklüğüne neden olan fungal patojenlerin saptanması amacıyla 2018 yılında survey çalışmaları gerçekleştirilmiştir. Fasulye yetiştirme alanlarından elde edilen en yüksek izolatlar *Fusarium*'dur (%62.5). Bunu takiben *Rhizoctonia* (%27.5), *Rhizopus* (%4.8), *Alternaria* (%2.4), *Penicillium* (%2.1) ve *Epicoccum* (%0.7) elde edilmiştir. En yüksek virülensliğe sahip izolatların (Y1A, Y1B ve Y8) patojenite testinde kullanılan *F. oxysporum*, *F. solani* ve *R. solani* izolatlarına sırasıyla ait olduğu bulunmuştur. Patojenite testlerinin sonuçları olarak, tüm fasulye çeşitlerinde, *F. oxysporum*'un hastalık şiddeti oranı %48.3 ile %91.7 arasında değişen olarak belirlenmiştir. *F. oxysporum* izolatının tüm fasulye çeşitlerinde ortalama hastalık şiddeti oranı %72.8 olarak hesaplanmıştır. *F. solani* izolatı, hastalık şiddeti oranları %33.3 ile %95.0 arasında değişen olarak belirlenmiştir. Tüm fasulye çeşitlerinde *F. solani* izolatının ortalama hastalık şiddeti oranı %70.6 olarak hesaplanmıştır. *R. solani* AG-4 izolatı, test edilen tüm fasulye çeşitlerinde ortalama %49.4 hastalık şiddeti oranı ile en düşük olarak hesaplanmıştır.
Anahtar kelimeler: Fasulye, fungus, *Fusarium* spp., kök çürüklüğü, patojenite, Türkiye

INTRODUCTION
Common Bean (*Phaseolus vulgaris* L.) is among the most important leguminous crops worldwide owing to its high commercial value, consumer use, extensive production, and nutritional value (vitamins, minerals, carbohydrates, and proteins) (Suárez-Martínez *et al.*, 2015; Ntatsi *et al.*, 2018). The crop is a basic staple food crop in many developing countries where it serves as an important plant protein source for urban and rural areas (Dursun *et al.*, 2010). In Turkey, beans are the third most important crops among legumes after chickpea and lentils in terms of production area with 84,804 ha of land producing 220,000 tons of dry beans in 2018 (TSI 2019). Nevşehir is ranked fourth among Turkish provinces with an estimated total area of 8,119 ha and 24,001 tons of production which accounts for about 10% of total bean production in the country (TSI 2019).

Bean plants are mainly affected by several biotic and abiotic factors. They are extremely prone to diseases and pests which can result in severe yield reduction (Allen *et al.*, 1998; Graham and Vance, 2003). About 200 pathogens were reported to attack beans; some of which cause significant economic losses (Schoonhoven and Voysest 1991). Among 61 described pathogenic diseases of bean plants, 31 of them are caused by fungal organisms (Hall *et al.*, 2005). Root-rot is one of the most prevalent soil-borne diseases of bean crops which is primarily associated with southern blight (caused by *Sclerotium rolfsii*), *Fusarium* root-rot (*Fusarium solani*), *Pythium* root-rot (several species of *Pythium*), *Rhizoctonia* root-rot

Article Info / Makale Bilgileri
Corresponding author e-mail: malable90@gmail.com
Received: January 4, 2021 *Accepted:* February 24, 2021
ORCID ID's of Authors in order:
0000-0001-7679-6189, 0000-0003-0159-2039
0000-0001-9200-3409
İlk yazarın Yüksek Lisans tezi ürünüdür.

ISSN 0378 - 8024 Turkish Phytopathology Society ©2021

Table 1. Location, area size, and number of samples taken during the field survey in Nevşehir Province, Turkey

Field name	Isolate code	Area of the field in decare (da)	Number of samples
Yazıhüyük	Y1-MT	30	17
	Y2-KA	50	21
	Y3-AK	40	13
	Y4-HK	30	23
	Y5-MÇ	35	11
	Y6-İB	100	21
	Y7-MK	40	13
	Y8-ÖY	20	20
	Y9-GK	30	10
	Y10-SÇ	30	19
Suvermez	S1	50	18
	S2	70	9
	S3	30	27
	S4	80	26
	S5	100	30
	S6	80	24

(*Rhizoctonia solani*), and *Aphanomyces* root-rot (*Aphanomyces euteiches*) (Singh and Schwartz, 2010; Porch *et al.*, 2014). These pathogens may act individually or often as complex combinations depending on soil and environmental conditions (Rusuku *et al.*, 1997). The interaction of root-rot pathogens may cause higher degree of disease severity than when they act independently; such examples of combinations can be seen in *F. solani* f.sp. *phaseoli* occurring concurrently with either *Thielaviopsis basicola* or *Pythium species* (Pieczark and Abawi 1978; Hatat and Özkoç 1997).

Identifying disease-causing pathogens and determining the disease incidence are important steps towards planning an effective control measure. In Turkey, various studies have been conducted to determine different disease-causing organisms on bean plants (Hatat and Özkoç 1997; Eken and Demirci 2004; Kırbağ and Turan 2006; Erper *et al.*, 2011). However, there is no information for Nevşehir province which is one of the most important areas in terms of bean production in Turkey. This study was conducted with the aim of filling this gap of information through determining fungal pathogens that cause root-rot diseases on common bean in Nevşehir province.

MATERIALS and METHODS

Survey area

The survey area of the study was determined based on bean production statistics of 2018 which were obtained from Nevşehir Directorate of the Ministry of Agriculture. Based on the data, villages where bean crops are cultivated in over 1000 ha of land, were chosen as survey areas.

Collecting plant samples

Bean plants were randomly collected from fields located in Yazıhüyük and Suvermez districts of Nevşehir Province during the growing season of 2018 (Table 1, Figure 1). A total of 350 plants with symptoms of root rot diseases were collected from bean fields during June–August 2018. Isolations were made from discolored or necrotic lesions on roots. Four or more randomly selected diseased plants per field were carefully uprooted from the soil to retain most of their root systems. The plant materials were brought to the laboratory and kept in the refrigerator until use for isolations.

Pathogen

At the end of the survey and molecular characterization, the obtained pathogens from isolates such as *Fusarium oxysporum, Fusarium acuminatum, Fusarium solani, Fusarium equiseti, Rhizoctonia solani* and *Rhizoctonia solani* AG-4 were used in a preliminary pathogenicity test in greenhouse condition. In the main and last pathogenicity test, the pathogens used were *F. oxysporum*, *F. solani* and *R. solani* AG-4.

Isolation and identification of fungal pathogens from infected bean plants

In each of the surveyed areas, individual plants were collected from each field and the plants were examined for disease severity. The plants were marked as insulated for isolation and were placed in a refrigerator with labels indicating the number of the area in which the sampling was carried out. In the isolation process, the initial diagnosis was based on symptoms in roots that are usually associated with specific root rot pathogens. In all isolations, bean roots showing symptoms were first washed with running tap water

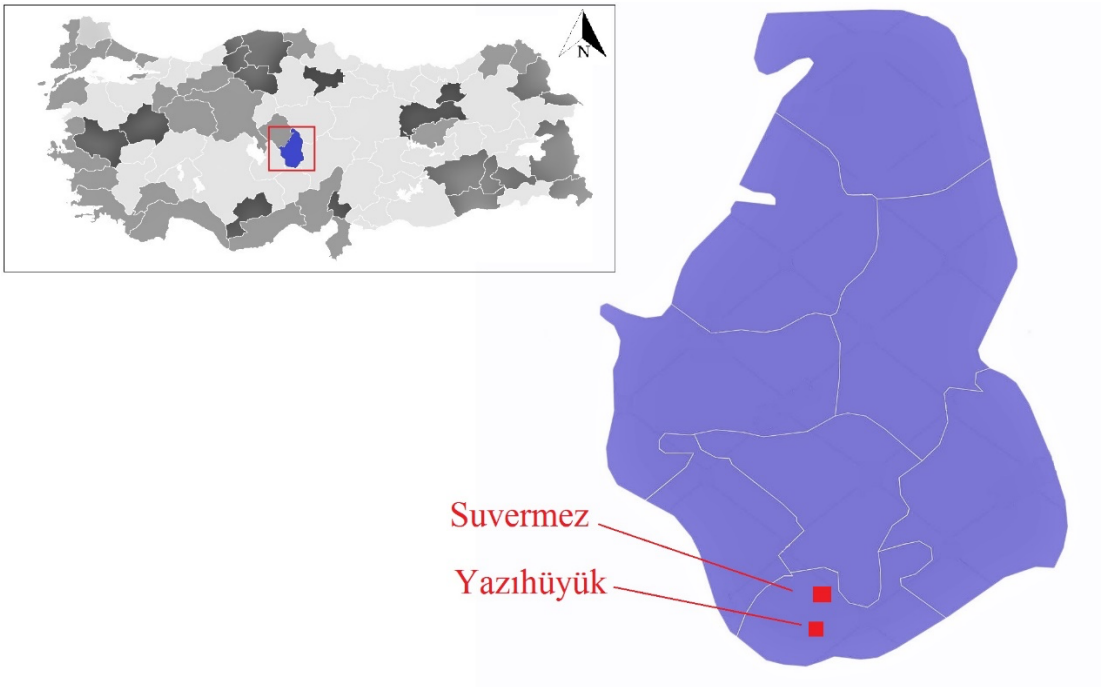

Figure 1. Location of survey and sampling area in Yazıhüyük and Suvermez districts, Nevşehir, Turkey

and cut into approximately 1-cm portions. They were then surface sterilized in 2% NaOCl for 2min, double rinsed in sterile distilled water, blot dried between sterile paper towels. Potato Dextrose Agar (PDA) medium was used in isolation. The medium was sterilized for 15 minutes at 121 °C and 1 atm pressure, and then cooled to 50 °C in a water bath, with the addition of streptomycin sulfate as an antibiotic at a dose of 200 mg/L and poured into an 8 cm diameter petri dish. The superficially sterilized plant tissues were cultured on this medium after which the plates were incubated at 25 °C under dark conditions. The isolates were examined after 2 to 15 days to determine fungi associated with the various symptoms observed. Pure cultures were obtained by sub-culturing and identification of fungi was based on colony characteristics and reproductive structures by using a binocular microscope (Domsch *et al.*, 1980; Barnett and Hunter 1987). Fungal structures of identified fungi were screened by means of a trinocular microscope and photographed by a digital camera.

Molecular characterization of isolates of fungal pathogens from infected bean plants

To confirm the species of the fungal isolates all 16 isolates were subjected to molecular techniques for verification as described by Xu and Leslie (1996). Genomic DNA was extracted using a standard CTAB method. One gene location was amplified for species-level identification of 16 isolated root rot causing pathogens on beans. An ITS4 and ITS5 for PCR amplification reaction was prepared manually for each isolate by adding 10 × Green Buffer (Thermo Scientific, EP0712) 40 µL, dNTPs 16 µL, Forward primer 8 µL, reverse primer 8 µL (ITS4 and ITS5), Taq polymerase 2 µL, nuclease-free water 310 µL (Thermo Scientific™) and the target DNA 2 µL. Amplification was done in a thermal cycler (Applied Biosystems®, Veriti® 96 Well Thermal Cycler) using the following program: initial denaturation at 95 °C for 3 min, followed by 35 cycles of denaturation at 95 °C for 1 min, annealing at 53 °C for 1:15 min, extension at 72 °C for 1:30 min, and a final extension at 72 °C for 7 min and hold at 4 °C. Reaction products were analyzed by electrophoresis on 1% agarose gels. The annealing temperature was optimized to efficiently amplify ITS4 and ITS5. The polymerase chain reaction (PCR) conditions, optimum annealing temperature, and reagents concentrations were optimized for effective amplification of ITS4 and ITS5. The NCBI BLAST was performed for the 16 isolates and sequences were submitted to NBCI GenBank.

Preparation of inoculations used in experiments

Fungal inoculations used in all experiments in greenhouse and climate chamber were prepared based on by colonizing fungi in wheat seeds that were boiled in water (Killebrew *et al.*, 1988). Primarily, wheat grains are boiled in water; the boiled grains were filtered and drained off the water and then dried on clean newspaper and filled into half autoclavable 1liter glass bottles with a screw cap. These bottles were then placed in an autoclave at 121 °C and sterilized for 60 minutes at 1 atm pressure (Figure 2). After the autoclave process, after cooling of the grains

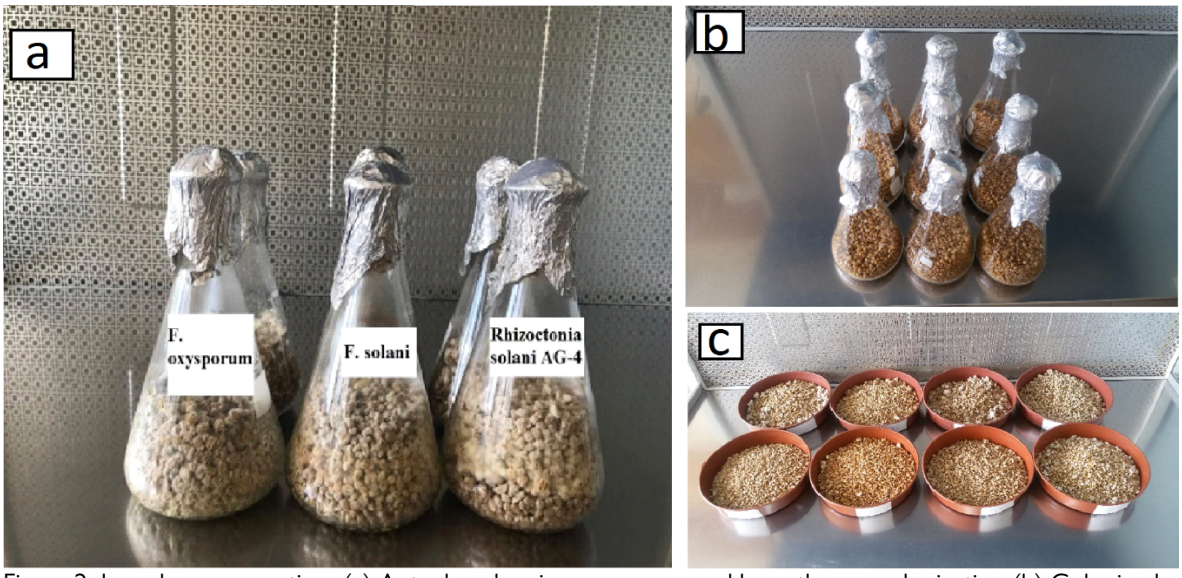

Figure 2. Inoculum preparation: (a) Autoclaved grains were prepared by pathogen colonization (b) Colonized grains (c) Ready-to-use pathogen wheat inoculum

sufficiently, 5 mm agar plates were cut from fresh fungal cultures in 5−6 days developed in PDA medium, and 6−7 pieces were put for each of these bottles. During the incubation period of 15 days at 24 °C, the grains in the bottles were shaken once every 2 days starting from the 5th day, thus ensuring homogenous colonization of all grains. At the end of the 15th day of the incubation, all wheat grains were emptied from the bottles and aired in clean plastic cuvettes for 15−20 hours in the fume hood and then stored at 4 °C.

Pathogenicity test

In order to determine the pathogenicity of fungal pathogens isolated from diseased root bean plants, a preliminary pathogenicity test was conducted by randomly selecting 14 isolates among the isolates of each species, and assessed twice in two different experiments. The bean variety "Albert Canada", which is one of the most cultivated bean varieties in the region, was used in the preliminary pathogenicity test. The experiments were arranged in a completely randomized design (CRD) with 5 replications, and disease severity ratings were based on the pre-determined scale of 0−3, as described below.

Scale		Infection rating
0	−	Healthy seedling
1	+	Very little superficial lesions in roots
2	++	Severe root rot
3	+++	Complete root rot

Based on the results of preliminary pathogenicity tests, three fungal isolates with higher virulence of disease (*F. oxysporum*, *F. solani* and *R. solani* AG-4) were selected for use in the main pathogenicity test (Table 2.) Pathogenicity of three fungal isolates on beans was assessed in the final experiment under a climate chamber. Four replications were used for each treatment and each replicate was inoculated by the fungal isolate. Treatment units that are not inoculated were used as control. A total of 13 different cultivars of beans were used for the pathogenicity test. The widely used wheat grain culture for soil-borne fungi which was previously recommended by Killebrew *et al.* (1988) was used in this study.

Host plant

Host plant rearing was conducted in mid-March, 2018. Bean plants were grown in pots containing a mixture of sandy loam soil and manure in a greenhouse (20−26 °C) located at Research and Application Site of the Department of Plant Protection, Cukurova University. About five seeds were sown to a depth of 2 cm in each pot. After reaching their seedling stage, plants were inoculated by placing 10 mg colonized wheat grains in contact with each seedling. After 7 weeks from inoculation, plants were uprooted, washed and disease severity ratings were determined based on the scales described above.

Data analysis

Disease severity data were subjected to analysis of variance (ANOVA) to determine the significance of the difference in lesions, and means were compared using Fisher's Least Significance Difference Test (LSD) at 5% significance level using Microsoft® Excel (2016).

RESULTS and DISCUSSION

Survey results

A total of 302 different isolates were obtained from 350 bean plants collected in the 2018 growing season from bean production areas in Yazıhüyük and

Table 2. Isolates used in this study, the gene regions sequenced, and their respective Genbank accession numbers

Division	Genus	Species	Isolate code	Percent identity (%)	Disease severity (%)	GenBank accession numbers of the reference sequences
Basidiomycota	*Cerrana*	*unicolor*	Y-2	100.00	100.00	MK581063
Ascomycota	*Fusarium*	*accuminatum*	Y-1	100.00	73.30	MK432763
Ascomycota	*Fusarium*	*equiseti*	Y-4B	100.00	100.00	MK780235
Ascomycota	*Fusarium*	*equiseti*	Y-10	100.00	91.10	MK168567
Ascomycota	*Fusarium*	*oxysporum*	S-2A	99.81	82.20	MK416124
Ascomycota	*Fusarium*	*oxysporum*	S-2B	99.62	64.40	MK673880
Ascomycota	*Fusarium*	*oxysporum*	S-5	96.53	86.70	MK510889
Ascomycota	*Fusarium*	*oxysporum*	Y-9	99.81	100.00	MK790099
Ascomycota	*Fusarium*	*oxysporum*	Y-1A	100.00	68.90	MK416124
Ascomycota	*Fusarium*	*solani*	Y-1B	99.46	91.10	MK734064
Basidiomycota	*Rhizoctonia*	*solani*	Y-6	100.00	75.60	MH483966
Basidiomycota	*Rhizoctonia*	*solani* AG-4	Y-8	99.85	100.00	MH172669
Ascomycota	*Trichoderma*	*hamatum*	Y-4A	100.00	100.00	MK322702
Ascomycota	*Trichoderma*	*hamatum*	Y-7	100.00	100.00	MK890773

Suvermez villages of Nevşehir province. The findings of the current study showed that root-rot disease of beans was widespread in bean growing areas of Nevşehir province. Overall, root rots were detected in bean plants in all surveyed fields. According to the results of frequency analysis of fungal pathogens in the surveyed areas, the most frequently obtained isolate from bean cultivation areas was *Fusarium* with a mean frequency rate of 62.5% followed by *Rhizoctonia* and *Rhizopus* with a mean frequency of 27.5% and 4.8%, respectively (Figure 3). *Alternaria* and *Penicillium* a had mean frequency of respectively 2.4% and 2.1% while the least isolate was *Epicoccum* with a mean frequency rate of 0.7%. Disease severity was high in all surveyed fields. Soil-borne pathogens that cause root-rot disease in the common bean are a major constraint to bean production in Turkey as well as in the world (Hatat and Özkoç 1997; Román-Avilés and Kelly 2005; Cichy *et al.*, 2007; Naseri 2008; Erper *et al.*, 2011; Nzungize *et al.*, 2012).

PCR results of the fungal isolates

The results of the ITS gene sequence show that different pathogenic fungi composed of two divisions with nine different species of fungi were obtained (Table 2). These were: *Cerrana unicolor, Fusarium*

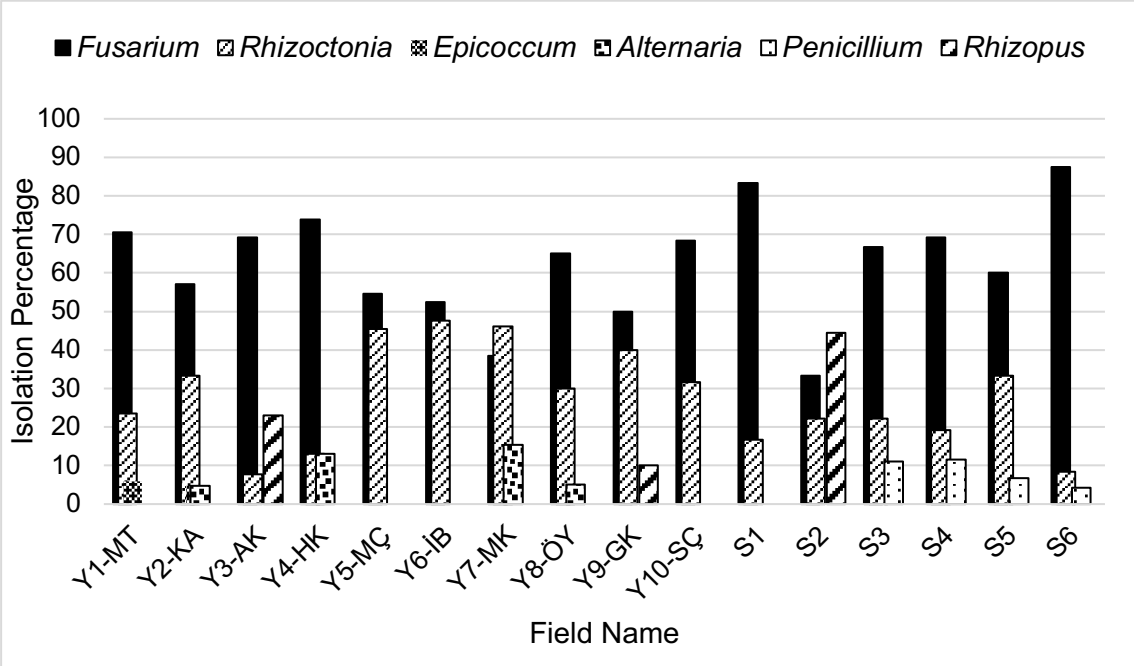

Figure 3. Percentage of fungal pathogens isolated from samples collected from fields in Yazıhüyük and Suvermez districts, Nevşehir Province, Turkey

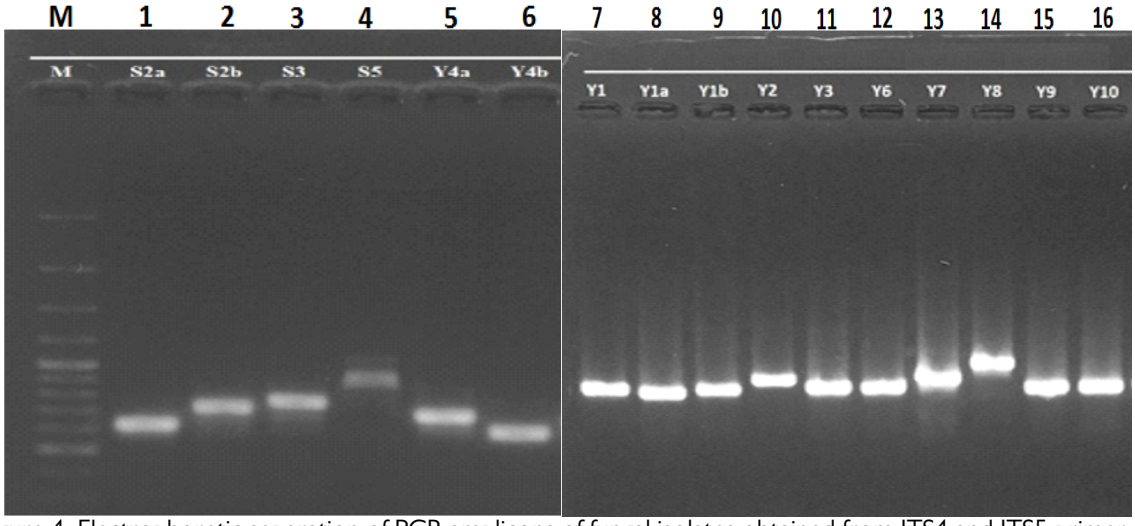

Figure 4. Electrophoretic separation of PCR amplicons of fungal isolates obtained from ITS4 and ITS5 primer pairs. Isolate origin: lanes 1−4= isolates from Suvermez; lanes 5−16= isolates from Yazıhüyük

accuminatum, Fusarium brachygibbosum, Fusarium equiseti, Fusarium oxysporum, Fusarium solani, Rhizoctonia solani, Rhizoctonia solani AG-4, and *Trichoderma hamatum* (Figure 4).

Disease severity

Our study provides detailed information on fungi organisms that are associated with root-rot disease and their overall effects on common bean plants in the surveyed fields of Nevşehir province, Turkey. In general, the mean disease severity of root-rot pathogens isolated from root samples varied slightly by field location. In this study, 13 different cultivars of common beans were used for pathogenicity testing and there was no resistant common bean cultivar against *F. oxysporum*, *F. solani*, and *R. solani* AG-4. *F. oxysporum* and *F. solani* were found to be highly aggressive against all tested beans when compared to *R. solani* AG-4 under laboratory conditions. According to the results of the pathogenicity tests, *F. oxysporum* isolate had the highest rate of disease severity (91.7%) on kidney bean cultivar (Table 3). In most of the fields, examined plant roots had lesions of varying degrees. Stunting, chlorosis, superficial lesions in roots, lesions on hypocotyls and taproot, complete root rot, and seedling death were some of the symptoms observed on bean plants in this study. Similarly, Jensen *et al.* (2002) reported that root-rot diseases caused symptoms such as defoliation of leaves and chlorosis,

Table 3. Disease severity rate (%) of root-rot ±SE of mean in green and dry bean cultivars

Cultivar name	**Disease severity (%)±SE†**		
Green bean cultivars	***Fusarium oxysporum***	***Fusarium solani***	***Rhizoctonia solani* AG-4**
Çilli Ayşe	71.7±11.1 ab*	93.3±7.70 b	46.7±3.1 a
Miray	66.7 ±11.3 ab	90.0±2.22 b	50.0±13.2 a
Simbo	86.7±10.9 b	83.3±16.78 b	40.0±17.5 a
Sarıkız	48.3±7.9 a	80.0±11.33 b	26.7±8.31 a
Alman Ayşe	90.0±6.7 b	60.0±16.3 ab	33.3±3.14 a
Turşuluk Sırık	65.0±10.6 ab	36.7±16.2 a	31.7±3.69 a
Dry bean cultivars			
Ahlat/Bitlis	73.3±13.7 a	63.3±13.5 abc	26.7±13.33 a
Gezin/Elazığ 1	83.3±14.6 a	68.3±17.0 bcd	65.0±8.53 bc
Gezin/Elazığ 2	70.0±8.0 a	33.3±5.4 a	60.0±8.31 b
İspir	71.7±13.5 a	80.0±14.7 cd	75.0±11.5 bc
Kanada Alberta	53.3±19.1 a	90.0±6.7 cd	25.0±3.69 a
Kidney Bean	91.7±3.7 a	45.0±5.8 ab	78.3±4.84 bc
Adzuki Bean	75.0±11.1 a	95.0±5.8 d	83.3±4.97 c
Mean	72.8 a	70.6 a	49.4 b

†. The standard error of the mean for percent disease severity

*. Different letters within the same column and different letters for mean values within the same row denote statistically the significant difference (LSD, $p < 0.05$).

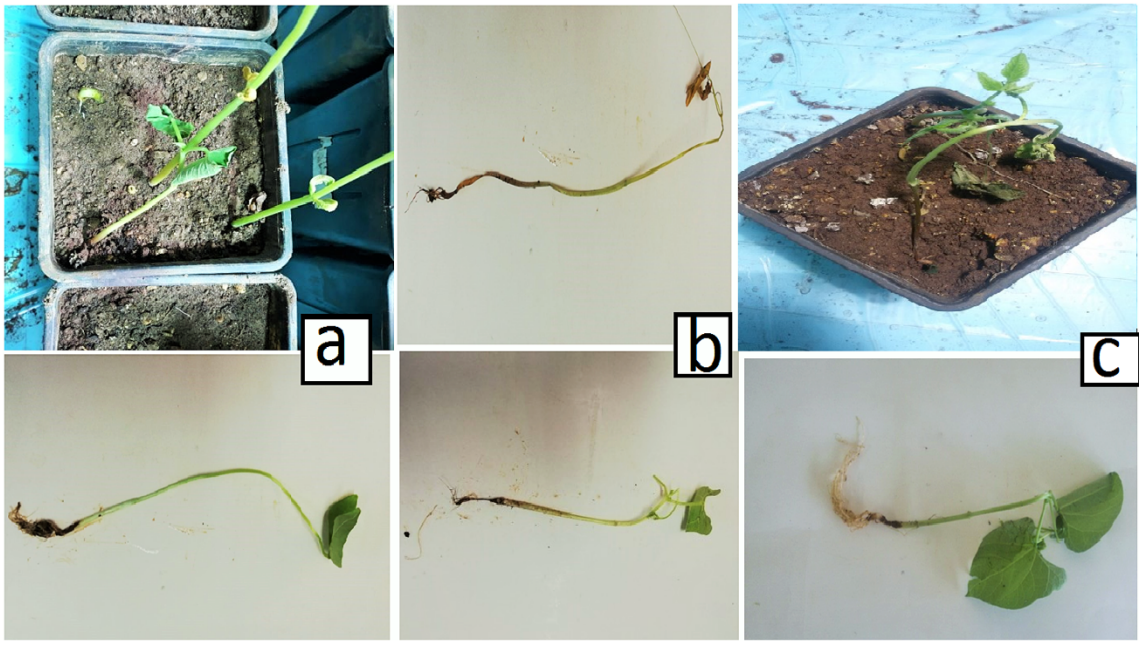

Figure 5. Symptoms of root-rot and wilting on bean seedlings (a) *Rhizoctonia solani* (b) *Fusarium solani* (c) *Fusarium oxysporum* Y1A isolate

reduced biomass, plant stunting, and seedling death which finally resulted in reduced seed yield.

On the other bean varieties, the disease severity rate of *F. oxysporum* was in the range of 48.3% and 90.0%, and the average rate of disease severity of this isolate on all bean varieties was determined as 72.8%. The highest disease severity rate (95.0%) for *F. solani* isolate was determined on adzuki bean cultivar. This isolate was also associated with symptoms such as stunting, lesions on hypocotyls and taproot, and complete root rot on bean plants in comparison to control plants. The disease severity rates by this pathogen on other bean varieties were ranged from 33.3% to 93.3% with an average rate of 70.6% disease severity on all bean varieties.

The highest disease severity rate (83.3%) caused by *R. solani* AG-4 isolate was determined on adzuki bean cultivar with the lowest value of 25% recorded on Kanada Alberta cultivar. In addition, this isolate had the lowest mean value of disease severity (49.4%) when compared to the other isolates. While there was no significant difference between the mean disease severity rate of *F. oxysporum* and *F. solani*, the mean value for *R. solani* was statistically different from that of *F. oxysporum* and *F. solani*. However, even though the symptoms differ in their rate of severity, similar disease symptoms on the bean varieties such as wilting, stunting, chlorosis, superficial lesions in roots, lesions on hypocotyls and taproot, and complete root rot were observed for *R. solani* AG-4, *F. oxysporum* and *F. solani* (Figure 5). Overall, Adzuki Bean was the most susceptible cultivar to the three pathogens followed by İspir, Gezin/Elazığ-1 and Kidney Bean.

Overall, when the green and dry bean cultivars are compared with each other, it was observed that the latter were more susceptible to *F. oxysporum* and *R. solani*, whereas green bean cultivars showed higher susceptibility to *F. solani* than the dry bean cultivars. This may indicate that root rot pathogens may exhibit different virulence potential to different form of bean seeds (green or dry).

The frequency of root-rot isolates in plant samples showed that the disease was mainly caused by two or more fungi, and this supports previous reports that soil pathogens often act as complex combinations to cause severe plant damage (Pieczark and Abawi 1978; Hatat and Özkoç 1997; Rusuku *et al.*, 1997). Similar to our study, Hatat and Özkoç (1997) reported that *Fusarium* spp. and *R. solani* were the most common fungi isolated from bean plants. Erper *et al.* (2011) also found that *R. solani* AG-4 was the most abundant group found in common bean plants in Samsun, Turkey. In addition, they reported that the highest disease severity among other *Rhizoctonia* group was determined for the AG-4 group on common bean and soybean plants. This may show that *R. solani* AG-4 is the most predominant *Rhizoctonia* group in the bean fields of Turkey. Meanwhile, *Pythium* spp. were the most frequently isolated fungi in common bean plants of Rwanda, East Africa (Rusuku *et al.*, 1997). *F. solani* was the most abundant fungus in Iranian bean fields followed by *R. solani*, *M. phaseolina*, and *F. oxysporum* (Naseri 2008). The most prevalent fungi isolated from common bean plants in Puerto Rico were *F. solani*, followed by *M. phaseolina*, and *Sclerotium rolfsii* (Porch *et al.*, 2014).

Based on the findings of the present study, it can be concluded that the root-rot disease of beans is an

important problem in Nevşehir. As it was perceived during personal communications with the local farmers in the survey area, growers generally pay less attention to a disease until it causes a total death of the plants. Hence, we recommend that farmers should implement control measures as early as possible before higher rates of disease severity occur. The findings of this study can serve as an input for farmers and pest managers in order to develop management strategies for fungal root-rot diseases in common bean growing areas of Turkish.

ACKNOWLEDGEMENTS

This research was supported by Cukurova University Scientific Research Projects Center, Project No: FYL-2019-11541. The authors gratefully thank lab and greenhouse staff members for their kind collaborations during the conduction of the study.

LITERATURE CITED

Allen, D.J., Buruchara, R.A. and Smithson, J.B. 1998. Pages 179–265 Diseases of common bean. in: The pathology of food and pasture legumes. D.J. Allen and J.M. Lenné, eds. CAB International, Wallingford, UK.

Barnett, H.L., Hunter, B.B. 1987. Illustrated Genera of Imperfect Fungi (3rd Edition). APS Press, Minnesota.

Cichy, K.A., Snapp, S.S. and Kirk, W.W. 2007. *Fusarium* root rot incidence and root system architecture in grafted common bean lines. Plant Soil, 300:233–244.

Domsch, K.H., Gams, W. and Anderson, T.H. 1980. Compendium of Soil Fungi. Volume 1, Academic Press, London.

Dursun, A., Haliloglu, K. and Ekinci, M. 2010. Characterization of breeding lines of common bean as revealed by RAPD and relationship with morphological traits. Pak. J. Bot. 42:3839–3845.

Eken, C. and Demirci, E. 2004. Anastomosis groups and pathogenicity of *Rhizoctonia solani* and binucleate *Rhizoctonia* isolates from bean in Erzurum, Turkey. J. Plant Pathol. 86:49–52.

Erper I, Karaca G. and Ozkoc I. 2011. Identification and pathogenicity of *Rhizoctonia* species isolated from bean and soybean plants in Samsun, Turkey. Arch Phytopathol Plant Protec. 2011: 44:78–84.

Graham, P.H. and Vance, C.P. 2003. Legumes: Importance and constraints to greater use. Plant Physiolog. 131:872–877.

Hall, R., Schwartz, H.F., Steadman, J.R. and Forster, R.L. 2005. Compendium of bean diseases (2nd Edition). APS Press, Minnesota.

Hatat, G. and Özkoç, İ. 1997. Bean root-rot disease incidence and severity in Samsun and fungi associated with bean roots and soils. J. Agr. Forest. 21:593–597.

Jensen, E.C., Percich, J.A. and Graham, P.H. 2002. Integrated management strategies of bean root rot with *Bacillus subtilis* and *Rhizobium* in Minnesota. Field Crop Res. 74:107–115.

Killebrew, J.F., Roy, K.W., Lawrence, G.W., McLean, K.S. and Hodges, H.H. 1988. Greenhouse and field evaluation of *Fusarium solani* pathogenicity to soybean seedlings. Plant Dis. 72:1067–1070.

Kırbağ, S. and Turan, N. 2006. Fungal agents that cause root-rot in some vegetables grown in Malatya. Fırat U. J. Eng. Sci. 18:159–164.

Naseri, B. 2008. Root rot of common bean in Zanjan, Iran: major pathogens and yield loss estimates. Australas. Plant Pathol. 37:546–551.

Ntatsi, G., Gutiérrez-Cortines, M., Karapanos, I., Barros, A., Weiss, J., Balliu, A., et al. 2018. The quality of leguminous vegetables as influenced by preharvest factors. Sci. Hortic. 232:191–205.

Nzungize, J.R., Lyumugabe, F., Busogoro, J.P. and Baudoin, J.P. 2012. *Pythium* root rot of common bean: biology and control methods. Biotech Agron. Soc. Environ. 16:405–413.

Pieczarka, D.J. and Abawi, G.S. 1978. Effect of interaction between Fusarium, *Pythium* and *Rhizoctonia* on severity of bean root rot. Phytopathol. 68:403–408.

Porch, T.G., Valentin, S., Jensen, E.C. and Beave, J.S. 2014. Identification of soil borne pathogens in a common bean root rot nursery in Isabela. Puerto Rico J. Agric. U. P. R. 98:1–14.

Román-Avilés, B. and Kelly, J.D. 2005. Identification of quantitative trait loci conditioning resistance to Fusarium root rot in common bean. Crop Sci. 45:1881–1890.

Rusuku, G., Buruchara, R.A. and Gatabazi, M., 1997. Pastor-Corrales MA. Occurrence and distribution of soil borne fungi pathogenic to the common bean. Plant Dis. 81:445–449.

Schoonhoven, A. and Voysest, O. 1991. Common beans: Research for crop improvement. CAB International, Cali, CIAT, Oxon.

Singh, S.P. and Schwartz, H.F. 2010. Breeding common bean for resistance to diseases: A review. Crop Sci. 50:199–223.

Suárez-Martínez, S.E., Ferriz-Martínez, R.A., Campos-Vega R., Elton-Puente J.E., Carbot K.T. and García-Gasca, T. 2016. Bean seeds: leading nutraceutical source for human health. CyTA – J. Food. 14:131–137.

Turkish Statistical Institute (TSI). 2019. Crop production statistics. (http://www.turkstat.gov.tr.) (Date Accessed: November 2020).

Xu, J.R. and Leslie, J.F. 1996. A genetic map of *Gibberella fujikuroi* mating population A (*Fusarium moniliforme*). Genetics, 143:175–189.