



Determination of Disease Severity of *Rhizoctonia solani* Kühn (Telemorph: *Thanatephorus cucumeris* (Frank) Donk) Isolates from Bean, Sugar Beet and Potato Planting Areas in Konya

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HIGHLIGHTS

- While some of the *Rhizoctonia*, which contain quite different groups, are mycorrhizal, some are saprophytic, many of them are economically important plant pathogens that cause disease in more than 150 agricultural products.
- Barley, wheat, rice, strawberries, beans, sugar beets, potatoes, cotton, tomatoes and cabbage are economically important crops where the disease occurs.
- The fungus can generally be isolated from all soils and is an important pathogen with a wide host range in fields such as agricultural lands, ornamental plants and forest areas.

Abstract

This study was carried out to determine the disease severity of *Rhizoctonia solani* isolates isolated from plant samples collected from bean, sugar beet and potato cultivation areas in Konya in 2020 and the anastomosis groups of the most virulent isolates. A total of 40 *R. solani* isolates were obtained as a result of the isolations made from 86 plant samples (36 beans, 25 sugar beets and 25 potatoes) showing root rot symptoms in general appearance. The number of *R. solani* isolates obtained from these plants, respectively; 10 isolates from beans, 15 from potatoes and 15 from sugar beets. Nine of the bean isolates and 14 of the potato and sugar beet isolates were determined as multinucleic. One isolate each isolated from the bean, sugar beet and potato was determined as binucleic. As a result, a total of 37 multinucleate (MN) and 3 binucleate (BN) isolates were obtained from all plants. As a result of pathogenicity tests, 3 *R. solani* isolates with the highest disease severity for each plant were amplified using ITS1F and ITS4B primers and anastomosis groups were determined. Accordingly, the anastomosis groups of Fa 3.2 (97%), Fa 2.2 (89%) and Fa 1 (86%) in beans were characterized as AG 4HGI. The isolates with the highest disease severity in potatoes (Pa 10, Pa 12.1 and Pa 15.2) were determined as AG 3 group. Disease severity was determined as 50% of Pa 15.2, 44% of Pa 10 and 42% of Pa 12.1. The disease severity of 9 of the isolates obtained from sugar beet was determined as 100%. The anastomosis group of 3 randomly selected isolates from these isolates was characterized as AG 2-2.

Keywords: Anastomosis group; Bean; Potato; Sugar beet; *R. solani*

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1. Introduction

Rhizoctonia solani, the most studied species in *Rhizoctonia* form genus, was detected on a diseased potato by Julius Kühn in 1858 (Gonzalez Garcia et al. 2006; Gondle 2018). *R. solani* Kühn (Telemorf: *Thanatephorus cucumeris* (Frank) Donk) was first recorded in Turkey by Bremer in 1948 (Yıldız and Döken 2002). Afterward, many scientists continued to work on this issue. While some of the *Rhizoctonia*, which contain quite different groups, are mycorrhizal, some are saprophytic, many of them are economically important plant pathogens that cause disease in more than 150 agricultural products. Barley, wheat, rice, strawberries, beans, sugar beets, potatoes, cotton, tomatoes and cabbage are economically important crops where the disease occurs. 27.50% of sugar beet production, 32.50% of bean production and about 7% of potato production in Turkey are realized in Konya (Soylu 2011). In recent years, yield losses have occurred in the fields where the disease has been observed in these plants, which have a significant production amount in Konya. The fungus can generally be isolated from all soils and is an important pathogen with a wide host range in fields such as agricultural lands, ornamental plants and forest areas. It is both soil-borne and seed-borne, and causes different symptoms (seed rot, stem and stolon cancer, leaf blight, yellowing of leaves, root rot and damping off) in different plants (Gonzalez Garcia et al. 2006; Çebi Kılıçoğlu 2009; Gondle 2018).

The number of nuclei in a single cell of the hyphae is an important taxonomic criterion determining whether *Rhizoctonia* species belong to multi-nucleate and binucleate groups (Kuramae et al. 2003). 14 AGs included in *R. solani* have been identified by the studies carried out so far. These are AG 1 to AG 13 and AG-BI (Ogoshi 1987; Sneh et al. 1991; Carling 1996; Carling et al. 2002a; Bienkowski 2012; Liu et al. 2019; Oladzad et al. 2019).

Although some AGs have wide host diversity, some AGs are highly host-specific (Çebi Kılıçoğlu 2009). *Rhizoctonia* groups (AG 1, AG 2-1, AG 2-2 and AG 4), which cause economically important product loss, cause diseases such as root rot, damping off, hypocotyl rot, fruit and seed rot in various vegetables. Some isolates in the same anastomosis group may show differences in terms of cultural characteristics and virulence, like isolates in different anastomosis groups. Binucleate *Rhizoctonia* isolates are grouped between AG-A to AG-S (Sneh et al. 1991; Eken and Demirci 2004) and are generally isolated from the root zone of crop plants, and they are either apathogenic or weakly pathogenic.

R. solani has been reported in every region of the world where beans are produced, and it can cause significant losses ranging from 20-100%. It forms thin, long and reddish-brown lesions of different sizes on the hypocotyl and roots of bean plants and causes softening in the roots. In the later stages of the infection, it has been reported that it causes yellowing of the leaves, stagnation in plant growth and ultimately the death of the plant. In humid periods, the agent can also infect leaves (web blight), petioles, flower, capsules and grains. *R. solani* subgroups that cause root rot in beans are AG 4 and AG 2-2 (Akarca 2013; Palacioğlu et al. 2019).

R. solani Kühn, which is seen almost everywhere where potatoes are grown, causes black scurf on tubers, stem, stolon and root cancer diseases in the plant. The disease is called stem cancer and black scurf disease. The disease causes rot in the stolon and stem of the plant, causing regression in plant development and yield losses of up to 30-40% in some regions; it also causes a decrease in quality and market value with the black scurf, cracks and malformations it forms on the tuber (Aydın 2008; Bienkowski 2012; Carling et al. 1989). AG 3 isolates from the Solanaceae family, mostly from potatoes, infect the stolons severely in the early developmental stages of the potato and cause the formation of sclerotia called 'black scurf on tubers' (Ogoshi 1987). Potato AG 3 causes necrosis on the stem and stolons of the potato and sclerotia formation on the tuber, while AG 4 causes damping off and stem necrosis in the potato (Anderson 1982; Sneh et al. 1996; Aydın 2008).

Rhizoctonia root rot disease, which is one of the most important factors limiting sugar beet production, causes crown and root rot in the plant. The pathogen damages the plant tissue and proceeds toward the crown

and root of the plant. The first symptoms in the tuber begin as localized, dark, circular lesions, and in the following periods, the lesions take a ladder-like appearance. It causes a color change from dark brown to black in the roots. It has been estimated that an average of 20% of annual sugar beet yield loss is due to *Rhizoctonia* root and crown rot, and in some it has been observed as high as 30-60% (Hanson et al. 2011). While AG 2-2 causes damping off in the seedling period, it also causes root and crown rot in later periods. AG 4 is the most virulent group that causes damping off in seedlings in the form of superficial lesions. (Scholten et al. 2001; Liu et al. 2019; Avan and Katircioğlu. 2019; Barreto et al. 2020; Şahiner 2020).

Our study, it was aimed to determine the disease severity of *R. solani* isolates obtained from economically important bean, sugar beet and potato plants produced in Konya and to determine the anastomosis groups of the most severe isolates for each plant species.

2. Materials and Methods

2.1. Materials

2.1.1. Fungal pathogen

R. solani isolates used as a test pathogen were obtained as a result of isolation from plants showing disease symptoms in bean, potato and sugar beet cultivation areas in Konya province.

2.1.2. Test plants and varieties

To determine the disease severity of *R. solani*, sugar beet, potato and bean seeds from which the pathogen was isolated were used. Varieties used in the tests; Lider in sugar beet (*Beta vulgaris* L.), Amerikan Çalısı in bean (*Phaseolus vulgaris* L.) and Brooke variety in potato (*Solanum tuberosum* L.).

2.1.3. Plant growing media and chemicals

Sodium hypochlorite was used for the surface sterilization of plant parts to isolate the pathogen. PDA (39g/1000) containing Streptomycin sulfate (100 ml/1000ml) was used as the medium. Barley culture medium was preferred for long-term storage of the pathogen.

The number of nuclei of *R. solani* was determined using Safranin O solution (3% KOH (6 ml), 0.5% safranin (10 ml), glycerin (5 ml) and distilled water (79 ml)).

Distilled water agar (WA) (10 g/1000 ml) was used for the pre-germination of seeds to be used in pot experiments. The soil to be used in pot tests was prepared to contain peat/soil/perlite (2:1:1).

2.2. Methods

2.2.1. Collection, isolation and long-term storage of *Rhizoctonia solani* isolates

In order to obtain pathogens, root, seedling and tuber parts of sugar beet, bean and potato samples showing disease symptoms were collected from Konya (Kadınhanı, Meram and Çumra Districts) in June-September 2020 and placed in paper bags. It was brought to the laboratory after the label information was written.

Plant materials were first thoroughly washed in tap water. With the help of a scalpel, 5 pieces of plant tissue were cut into 1 cm size for each sample, including the diseased and healthy parts. Then, the plant parts were kept in 1% sodium hypochlorite solution for 1 minute and surface disinfection was carried out. Then the plant materials were transferred to sterile distilled water and this process was repeated 3 times. These pieces were transferred to Petri dishes with sterile blotting papers in a laminar airflow cabinet, and after drying, they were placed in a PDA medium containing streptomycin sulfate. After 2-3 days of incubation at 25°C in dark conditions, the Petri dishes were examined macroscopically and microscopically, and an agar plate was taken

from the cultures determined to be *R. solani*, and a pure culture was obtained by transferring it to PDA medium.

Barley culture medium was used for long-term storage of *Rhizoctonia* isolates. The barley grains, which were kept in water for 1 night, were transferred to the tubes and this culture medium was autoclaved at 121°C for 20 minutes. To remove excess moisture, the tubes containing barley cultures were closed with sterile blotting papers and kept at 25°C for 1 day. Then, pure *R. solani* isolates were inoculated into this medium and incubated at 25°C for 15 days, and the growing cultures were stored at +4°C for a long time.

2.2.2. Determination of Nuclear numbers of *Rhizoctonia solani* isolates

To determine the number of nuclei of the *R. solani* isolates obtained, the isolates were transferred to Petri dishes with a diameter of 9 cm and containing 15 ml of PDA and incubated at 25°C for 5 days. After incubation, developing hyphae were stained with Safranin O and 3% KOH and counted in 25 cells for each isolate at 40X magnification under light microscope. The isolates were classified as multinucleate (MN) or binucleate (BN) according to the number of nuclei (Bandoni 1979; Martin and Lucas 1984; Avcı 2019).

2.2.3. Preparation of the inoculum and pathogenicity test

Pathogenicity tests of the obtained *R. solani* isolates were tested on the host plant species from which each isolate was obtained. *R. solani* isolates preserved in barley cultures were transferred to PDA medium to obtain fresh cultures and were expected to develop at 25°C for 7 days. An agar plate from growing fresh cultures of *R. solani* was transferred to the prepared barley culture medium for use as an inoculum and incubated at 25°C for 3 weeks. The amount of inoculum was used as 1 barley grain for each seed of bean and sugar beet. In potatoes, each pot soil was inoculated by mixing the pathogen-infected barley culture medium (at the rate of 2%) with the soil before planting the tubers.

The experiment was established as three replications for each isolate and 3 seeds were planted in each pot. 1-liter pots were used for beans and sugar beets, and 2-liter pots were used for potatoes. These pots were filled with a mixture containing peat/soil/perlite (2:1:1) and sterilized at 121°C for 60 minutes.

It was pre-germinated in bean and sugar beet seeds. The seeds were first sterilized with 2% sodium hypochlorite. After the seeds were dried at room temperature, they were placed in a water agar medium and incubated for 2-3 days at 25°C until primary root formation. Then, the germinated seeds were planted in pots and one of the barley grains wrapped in the mycelium of the pathogen was placed next to each seed. A sterile barley grain was placed next to the seed in the pots used as the control group. In the pathogenicity test of *R. solani* in potatoes, the control group was prepared by mixing 2% sterile barley into the soil. After inoculation, the plants were allowed to grow in 12 hours light and 12 hours dark climate *solani* in potato, the control group was prepared by mixing 2% sterile barley into the soil. room (65% humidity and 25°C) and sugar beet and beans were evaluated for the disease after 4 weeks and potatoes after 6 weeks. For each isolate, the pathogenicity test was provided by reisolation from diseased plants (Buhur 2014; Basbagci et al. 2019).

2.2.4. Evaluation of disease severity of *Rhizoctonia solani*

To assess disease severity, the uprooted plants were thoroughly washed under running tap water, and then all plants were examined for disease. The 0-4 scale explained in Table 1 was used for sugar beet and bean in the evaluation of disease severity (Muyolo et al. 1993).

R. solani in potatoes was evaluated according to root necrosis of the plant. For this, the 0-3 scale, which is explained in Table 2, was used (Aydın 2008).

Table 1. 0-4 scale in which the severity of the disease caused by *R. solani* in bean and sugar beet is evaluated.

Scale Value	Definition
0	Healthy seedling
1	Very small brown superficial lesions on roots or stem
2	Deep and extensive lesions on the roots or stem, regression in root development
3	Severe root rot, deep lesions surrounding the main root or stem, significantly reduced root length
4	Dead plant

Table 2. The 0-3 scale in which the severity of the disease caused by *R. solani* in potatoes is evaluated

Scale Value	Definition
0	No stem canker
1	Up to 1/3 of the stem under the ground is damaged
2	Up to 1/3-2/3 of the stem under the ground is damaged
3	Up to 2/3 or more of the underground stem is damaged

After the evaluation made according to the scale, the disease severity index was calculated according to the Townsend-Hauberger (1943) formula.

$$\% \text{ Disease Severity Index} = [\Sigma(\text{SD} \times \text{BS}) / (\text{ESD} \times \text{TB})] \times 100 \quad (1)$$

According to the formula; SD: Scale value, BS: Number of plants at the same scale value, ESD: Highest scale value, TB: Total number of plants.

2.2.5. Characterization of anastomosis groups of selected *Rhizoctonia solani* isolates

As a result of pathogenicity studies, 3 isolates of *R. solani* with the highest virulence for each plant were molecularly characterized. Studies for molecular characterization were carried out by Prof. Dr. Göksel Özer in Bolu Abant İzzet Baysal University Plant Protection Department Laboratory.

Amplification of *R. solani* isolates was performed using ITS gene region ITS-1 (5'-TCCGTAGGTGAACCTGCGG-3') and ITS-4 (5'-TCCTCCGCTTATTGATATGC-3') primers (White, et. al., 1990).

2.2.6. Statistical analysis

The data obtained as a result of the evaluations were compared with the Duncan Multiple Comparison tests in the SPSS 17.0 statistical program (SPSS Inc, Chicago, IL, USA) at p<0.05 significance level.

3. Results and Discussion

As a result of the isolations made from plant samples taken in 2020, it was determined that 10 of 36 bean samples, 15 of 25 potato samples (tuber and stem) and 15 of 25 sugar beet samples were infected with *R. solani* (Figure 1).

After all, isolates obtained were microscopically identified as *R. solani*, they were transferred to a barley culture medium.

To determine the number of nuclei of the isolates, which were microscopically found to be *R. solani*, staining was performed with safranin O (Figure 2).



Figure 1. Symptoms of *R. solani* in different plants: (a) beans; (b-c) potato; (d) sugar beet



Figure 2. The appearance of the nuclei stained with Safranin O in light microscopy: (a) Multinucleic nucleus (MN), (b) Binucleic nucleus (BN)

9 out of 10 isolates of *R. solani* obtained from beans, 14 of 15 isolates obtained from potato, and 14 of 15 isolates obtained from sugar beet were determined as multinucleate. It was determined that 1 isolate isolated from the bean, sugar beet and potato was binucleate. As a result, a total of 37 multinucleate (MN) and 3 binucleate (BN) isolates were obtained from all plants.

All of the 10 bean isolates obtained were used in the pathogenicity assay. In addition, the disease severity of Fa-2.2 (89%), Fa-1 (86%), Fa-5.2 (86%) and Fa 2.1 (83%) isolates is also quite high. The disease severity of the isolate Fa-4.2, which was found to be binucleate in the evaluation according to the number of nuclei, was determined at a rate of 17% (Table 3).

Table 3. Disease incidence and severity of bean *R. solani* isolates in bean plants.

Code of Isolates	Disease Incidence (%)	Disease Severity (%)
Fa-1	100a	86ab
Fa-2.1	100a	83b
Fa- 2.2	100a	89ab
Fa-3.1	33c	14cd
Fa-3.2	100a	97a
Fa-4.2	67b	17cd
Fa-5.2	100a	86ab
Fa-6.2	44bc	11d
Fa-7	33c	8d
Fa-8	67b	25c

P<0.05 (There is no statistical difference between the means expressed with the same letter in the same column)

As a result of the pathogenicity test carried out on potato *R. solani* isolates, it was observed that deep necrosis occurred in the stem of the test plants. Pa-15.2 (50%) was the most virulent potato isolate evaluated according to the stem necrosis scale (scale 0-3), followed by Pa-10 (44%) and Pa 12.1 (42%) (Table 4).

Table 4. Disease incidence and severity of potato *R. solani* isolates on potato plants

Code of Isolates	Disease Incidence (%)	Disease Severity (%)
Pa-1.1	64bf	39ac
Pa-2.1	67bf	25cf
Pa-3.1	73bd	33bf
Pa-4.2	57df	26cf
Pa-5.2	69be	36ad
Pa-6.2	67bf	31bf
Pa-7.2	69be	31bf
Pa-8.2	50eg	21df
Pa-9.1	79ac	36ad
Pa-10	85ab	44ab
Pa-11.2	31g	26cf
Pa-12.1	80ac	42ac
Pa-13.2	46fg	18f
Pa-14.2	62cf	28bf
Pa-15.2	94a	50a

P<0.05 (There is no statistical difference between the means expressed with the same letter in the same column)

As a result of pathogenicity tests of *R.solani* isolates obtained from sugar beet, it was observed that all isolates caused diseases in plants. After pre-germination, isolates that caused severe infection in sugar beets caused damping off in seedlings. The disease severity values of 15 *R.solani* isolates obtained varied between 67-100% and 9 *R.solani* isolates caused 100% disease severity in sugar beet plants (Table 5).

For each plant, 3 *R. solani* isolates with high disease severity were divided into anastomosis groups using. Accordingly, *R. solani* isolates (Fa 3.2, Fa 2.2 and Fa 5.2) isolated from beans were determined to belong to the AG 4 HGI anastomosis group. Anastomosis groups of the isolates of *R. solani* (ŞP 2.2, ŞP 7.2 and ŞP 11.1) isolated from sugar beet were determined as AG 2-2. Anastomosis groups of the 3 most virulent *R. solani* isolates (Pa 10, Pa 12.1 and Pa 15.2) from potato isolates were determined as AG-3 (Figure 3).

Table 5. Disease incidence and severity of sugar beet *R.solani* isolates in sugar beet plants

Code of Isolates	Disease Incidence (%)	Disease Severity (%)
ŞP-1.2	100a	100a
ŞP-2.2	100a	100a
ŞP-4.2	100a	100a
ŞP-7.2	100a	100a
ŞP-8.1	100a	100a
ŞP-11.1	100a	100a
ŞP-12.1	89a	89a
ŞP-13.2	100a	100a
ŞP-14.2	67b	67b
ŞP-15.2	89a	89a
ŞP-16.2	100a	100a
ŞP-18.1	89a	89a
ŞP-19	89a	89a
ŞP-20	100a	100a
ŞP-21.2	89a	89a

P<0.05 (There is no statistical difference between the means expressed with the same letter in the same column)

R. solani is a soil-borne necrotrophic pathogen affecting many plant families. Within *Rhizoctonia*, 14 anastomosis groups (AG) have been identified. Although some AGs have wide host diversity, some AGs are highly host specific. For example; AG 1, AG 2-2 and AG 4 infect sugar beets. While AG 2-2 causes root rot, AG 1, AG 2-2 and AG 4 infect the crown and leaves. In many studies, it has been reported that high levels of AG 2-2 are found in isolations made from sugar beet plants and especially AG 2-2 is highly virulent in more mature tubers. In another study, it was determined that the most common group was AG 2-2 IIIB (Herr and Roberts 1980; Windels et al. 1989; Çebi Kılıçoğlu 2009; Strausbaugh et al. 2011; Stojsin et al. 2011; Avan 2020; Wigg 2021). In our research, the most virulent isolates in sugar beet, coded ŞP 2.2, ŞP 7.2 and ŞP 11.1, were isolated by taking samples in the more mature stages of beet and anastomosis groups were determined as AG 2-2, similar to other studies.

AG 3 isolates, which are mostly isolated from potato, infect the stolons severely in the early or mid-development stages of the potato, causing *Rhizoctonia* canker and black scurfs disease in tubers and roots (Ogoshi 1987).

Thirteen anastomosis groups of this fungus have been identified. Of these, AG 3 causes necrosis on the stem and stolons of the potato, and sclerot formation on the tuber; AG 4 causes damping off and stem necrosis in potatoes (Anderson 1982; Sneh et al. 1996; Aydın 2008). Although *R. solani* isolates isolated from sclerot on the stem, root and tuber of potato are generally in the AG 3 group, there are also different anastomosis groups (AG 1, AG 2-1, AG 2-2, AG 4, AG 5 and AG 9) isolated from potato growing soils (Carling 1989). In our study, the disease severity of Pa-10, Pa12.1 and Pa 15.2 potato isolates was determined to be high and the anastomosis groups of these isolates were determined as AG-3 in parallel with many studies.

R. solani subgroups that cause root rot in beans are AG 4 and AG 2-2, while AG 1-IA, AG-1 IB, AG 1-IE, AG 1-IF, AG 2-2 IV and AG 4 cause web blight in beans. (Godoy-Lutz 2003; Gogoy-Lutz, 2008; Çebi Kılıçoğlu 2009; Valentin Torres et al. 2016). *R. solani* isolates isolated from beans in Turkey (AG 1, AG 2-1, AG 2-2, AG 3, AG 4, AG 5, AG 6, AG 7, AG 9, AG 10 and AG 11), binucleic *Rhizoctonia* AGs (AG-A, AG-B AG-F, AG-G, AG-I and AG-K) and *R. zeae* have also been identified in addition to these groups. AG 1 and AG 4 isolates were obtained from bean seeds, as well as AG-B, AG-E from roots and hypocotyls. The most common anastomosis group seen in beans in the world and our country is AG-4 (Demirci and Döken 1995; Karaca et al. 2002; Eken and

Demirci 2004; Erper et al. 2011). According to our research results, the most virulent Fa 3.2, Fa 2.2 and Fa 5.2 isolates were determined as AG 4 HGI.

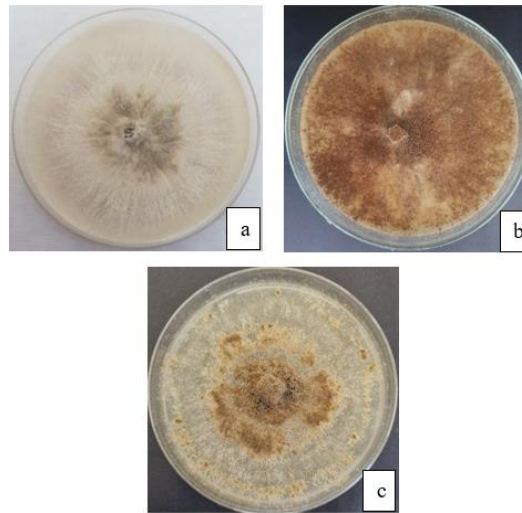


Figure 3. The most virulent *R. solani* isolates isolated from different plants: **(a)** Fa 3.2 (AG 4 HGI) isolated from beans; **(b)** ŞP 7.2 (AG 2-2) isolated from sugar beet; **(c)** Pa 15.2 (AG-3), isolated from potato.

Binucleic *Rhizoctonia* isolates, on the other hand, are grouped between AG-A to AG-S and are generally isolated from the root zone of cultivated plants, and binucleic *Rhizoctonia* is either apathogenic or weakly pathogenic. Generally, these groups are also used as biological control agents against root rot disease (Cardoso and Echandi 1987; Çelebioğlu 2009). However, some of the binucleates (BNs), such as AG-D,-E, -F and -R group isolates, are known to cause root rot or damping off disease in some plants such as beans, radishes, strawberries, sugar beets and onions (Sneh et al. 1991; Karaca et al. 2002; Eken and Demirci 2004). In our study to determine the number of nuclei, it was determined that 1 isolate in sugar beet, potato and bean was binucleate.

The fact that the disease is both soil-borne and seed-borne causes some difficulties in its control compared to other diseases. An integrated approach should be followed in the control against the disease and knowledge about the stages of the disease should be obtained. Cultural measures are very important for the control of the disease, among which methods such as the inoculum source being free from disease, the use of certified seeds, the disease-free soil, the timing of rotation, harvest time and the use of pesticides, and the regulation of soil and water management play a key role (Aydın 2008; Tsror 2010).

The most practical and economical way to control the disease is rotation and the use of resistant plants. Although there are varieties resistant to disease, these varieties have some disadvantages as they are not resistant to some other important diseases and their yield is lower than other varieties. In addition to these methods of control fungicides are also used in some cases. Due to the different effects of fungicides on *R. solani* AGs, it is important that the selected fungicides are suitable for the anastomosis group to ensure effective control of the disease. Flutolanil, azoxystrobin and prothioconazole are effective in chemical control of the disease in sugar beet (Khan et al. 2009; Bolton et al. 2010). Fungicides with active ingredients such as azoxystrobin, azoxystrobin+difenoconazole, fludioxonil, mancozeb are used against root rot in beans (Bost 2006; Knodel et al. 2016; Tvedt 2017). *R. solani* in potatoes inhibits only pencycuron and tolclofos methyl 100% *in vitro*, while azoxystrobin and pencycuron inhibit sclerot formation in tubers the most in the field. Another example is that AG 1, 3 and 5 are moderately affected by fungicides with aromatic hydrocarbons, while the

sensitivity of AG 2-1, 4, 7 and 8 is very low (Tsrör 2010). For this reason, determining which anastomosis groups of *R. solani* are virulent in which plants will be a guide in the control. In particular, it is important to know which product group was in the field examined in previous years and to follow up on the disease in the point of control decision, especially in recommending the rotation plant. Biological control studies, which are seen as an alternative to chemical control, have increased considerably in recent years. In particular, the use of commercial biological control products against soil-borne diseases as a part of integrated management will contribute to the suppression of the disease.

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References

- Akarca Z (2013). Erzincan İlinde Fasulye Bitkilerinin Toprak Üstü Aksamlarından İzole Edilen *Rhizoctonia* Türlerinin Anastomosis Grupları ve Patojenisitesi. Atatürk Üniversitesi, Fen Bilimleri Enstitüsü, Yüksek Lisans Tezi, Erzurum.
- Anderson NA (1982). The Genetics and Pathology of *Rhizoctonia solani*. *Annual Review Phytopathology* 20:329-47.
- Avan M, Katırcıoğlu YZ (2019). Şeker pancarlarında görülen *Rhizoctonia* türlerinin özellikleri, oluşturduğu hastalıklar ve korunma yolları. *Adnan Menderes Üniversitesi Ziraat Dergisi* 16(1):105-112.
- Avan M (2020). Konya Bölgesi Şeker Pancarı Ekim Alanlarında Görülen *Rhizoctonia* Türlerinin Karakterizasyonu ve Mücadelesi Üzerine Araştırmalar. Ankara Üniversitesi, Fen Bilimleri Enstitüsü, Doktora Tezi, 149 sayfa.
- Avcı Ş (2019). Samsun ili kırmızı baş lahanalarından izole edilen *Rhizoctonia* grubu fungusların anastomosis gruplarının, karakteristik özelliklerinin ve patojenitelerinin belirlenmesi. Ondokuz Mayıs Üniversitesi, Fen Bilimleri Enstitüsü, Bitki Koruma Anabilim Dalı, Yüksek Lisans Tezi.
- Aydın MH (2008). Patates yetiştiriciliğinde sorun olan *Rhizoctonia solani*'nin biyolojik savaşımı ve bunun kimyasal savaşla entegrasyonu. Ege Üniversitesi Fen Bilimleri Enstitüsü, Doktora Tezi, Bornova, İzmir.
- Bandoni RJ (1979). Safranin O as a rapid strain for fungi. *Mycologia* 71: 873-874.
- Bains PS, Bisht VS (1995). Anastomosis group identity and virulence of *Rhizoctonia solani* isolates collected from potato plants in Alberta, Canada.
- Barreto A, Paulus S, Varrelmann M, Mahlein AK (2020). Hyperspectral imaging of symptoms induced by *Rhizoctonia solani* in sugar beet: comparison of input data and different machine learning algorithms. *Journal of Plant Diseases and Protection* 127: 441-451.
- Basbagci G, Unal F, Uysal A, Dolar FS (2019). Identification and pathogenicity of *Rhizoctonia solani* AG-4 causing root rot on chickpea in Turkey. *Spanish Journal of Agricultural Research* 17 (2): e1007, 12.
- Bienkowski D (2012). Biological control of *Rhizoctonia* diseases of potato. PhD Thesis. Lincoln University.
- Bolton MD, Panella L, Campbell L, Khan MF (2010). Temperature, moisture and fungicide effects in managing *Rhizoctonia* root and crown rot of sugar beet. *Phytopathology* 100(7): 689-697.
- Bost S (2006). Root rots and seedling disease of beans and peas. The University of Tennessee Extension SP 277-O.
- Buhur N (2014). Aydın ilinde çeşitli kültür bitkilerinden elde edilen patojen *Rhizoctonia* spp. izolatlarının anastomosis gruplarının belirlenmesi. Adnan Menderes Üniversitesi Fen Bilimleri Enstitüsü, Bitki Koruma Bölümü, Yüksek Lisans Tezi.
- Campion C, Chatot C, Perrato B, Andrivon D (2003). Anastomosis groups, pathogenicity and sensitivity to fungicide of *Rhizoctonia solani* isolates collected on potato crops in France. *European Journal of Plant Pathology* 109: 983-992.
- Carling DE, Leiner RH, Westphale PC (1989). Symptoms, signs and yield reduction associated with *Rhizoctonia* disease of potato induced by tuberborne inoculum of *Rhizoctonia solani* AG-3. *American Potato Journal* 66(1): 693-701.
- Carling DE (1996). Grouping in *Rhizoctonia solani* by hyphal anastomosis reaction. In *Rhizoctonia* species: taxonomy, molecular biology, ecology, pathology and disease control. Springer, Dordrecht, 37-47.

- Carling DE, Baird RE, Gitaitis RD, Brainard KA, Kuninaga S (2002a). Characterization of AG-13, a Newly Reported Anastomosis Group of *Rhizoctonia solani*. *Phytopathology* 92 (8):893-899.
- Cardoso JE, Echandi E (1987). Biological control of *Rhizoctonia* root rot of snap bean with binucleate *Rhizoctonia*-like fungi. *Plant Disease* 71(2): 167-170.
- Çebi Kılıçoğlu M (2009). Karadeniz Sahil Şeridi'nde fasulye bitkisi ve rizosfer bölgesinden izole edilen multinükleat *Rhizoctonia* spp.'nin genetik çeşitliliğinin belirlenmesi. Ondokuz Mayıs Üniversitesi, Fen Bilimleri Enstitüsü, Doktora Tezi, Samsun.
- Das S, Shah FA, Butler RC, Falloon RE, Stewart A, Raikar S, Pitman AR (2014). Genetic variability and pathogenicity of *Rhizoctonia solani* associated with black scurf of potato in New Zealand. *Plant Pathology* (63): 651-666.
- Demirci E (1991). Erzurum yöresinde patateslerden izole edilen *Rhizoctonia solani* Kühn (*Thanatephorus cucumeris* (Frank) Donk)'nin yayılışı, bio-ekolojisi ile anastomosis grupları ve bunların patojenisitelerinin belirlenmesi üzerinde çalışmalar. Atatürk Üniversitesi, Fen Bilimleri Enstitüsü, Bitki Koruma Ana Bilim Dalı, Doktora Tezi, 70s.
- Demirci E, Döken MT (1995). Anastomosis groups of *Rhizoctonia solani* Kühn and binucleate *Rhizoctonia* isolates from various crops in Türkiye. *Journal of Turkish Phytopathology* 24(2): 57-62.
- Eken C, Demirci E (2004). Anastomosis groups and pathogenicity of *Rhizoctonia solani* and binucleate *Rhizoctonia* isolates from bean in Erzurum, Turkey. *The Journal of Plant Pathology* 8(1):49-52.
- Erper I, Ozkoc I, Karaca GH (2011). Identification and pathogenicity of *Rhizoctonia* species isolated from bean and soybean plants in Samsun, Turkey. *Archives of Phytopathology and Plant Protection* 44(1), 78-84.
- Gody-Lutz G, Steadman JR, Higgins B, Powers K (2003). Genetic variation among isolates of the web blight pathogen of common bean based on PCR-RFLP of the ITS-rDNA region. *Plant Disease* 87(7), 766-771.
- Godoy-Lutz G, Kuninaga S, Steadman JR, Powers K (2008). Phylogenetic analysis of *Rhizoctonia solani* subgroups associated with web blight symptoms on common bean based on ITS-5.8 S rDNA. *Journal of General Plant Pathology* 74(1): 32-40.
- Gondle AS (2018). Anastomosis group typing of *Rhizoctonia solani* Kühn infecting solanaceous vegetable crops. PMAS-Arid Agriculture University, Rawalpindi, Doctoral dissertation, 210.
- Gonzalez Garcia V, Portal Onco M, Rubio Susan V (2006). Biology and Systematics of the form genus *Rhizoctonia*. *Spanish Journal of Agricultural Research* 4(1): 55-79.
- Hanson LE, McGrath JM (2011). *Rhizoctonia* seedling disease on sugar beet. *International Sugar Journal* 113(1352): 584-589.
- Herr LJ, Roberts DL (1980). Characterization of *Rhizoctonia* population obtained from sugarbeet fields with differing soil textures. *Phytopathology* 70(6): 476-480.
- Karaca GH, Özkoç I, Erper I (2002). Determination of the anastomosis grouping and virulence of *Rhizoctonia solani* Kühn isolates associated with bean plants grown in Samsun/Turkey. *Pakistan Journal of Biological Sciences* 5(4): 434-437.
- Khan MF, Qandah I, Bolton MD (2009). The effect of temperature on *Rhizoctonia* disease development and fungicide efficacy in controlling *Rhizoctonia* root rot on sugarbeet. *Journal of Sugarbeet Research* 46: 101-102.

- Knodel J, Beauzay P, Endres G, Frazen D, Kandel H, Markell S, Osorno J, Pasche J, Zollinger R (2016). 2015 dry bean grower survey of production, pest problems and pesticide use in Minnesota and North Dakota E-1802. North Dakota Cooperative Extension Service Publication.
- Kuramae EE, Buzeto AL, Ciampi MB, Souza NL (2003). Identification of *Rhizoctonia solani* AG 1-IB in lettuce, AG 4 HG-I in tomato and melon, and AG 4 HG-III in broccoli and spinach, in Brazil. *European journal of Plant Pathology* 109 (4): 391-395.
- Liu Y, Qi A, Khan MFR (2019). Age-dependent resistance to *Rhizoctonia solani* in sugar beet. *Plant Disease* 103: 2322-2329.
- Martin SB, Lucas LT (1984). Characterization and pathogenicity of *Rhizoctonia* spp. and binucleate *Rhizoctonia*-like fungi from turfgrasses in North Carolina. *Phytopathology* 74(2): 170-175.
- Muzhinji N, Truter M, Woodhall JW, Van der Walls JE (2015). Anastomosis groups and pathogenicity of *Rhizoctonia solani* and binucleate *Rhizoctonia* from potato in South Africa. *Plant Disease*, 99(12), 1790-1802.
- Muyolo NG, Lipps PE, Schmitthenner AF (1993). Reactions of dry bean, lima bean, and soybean cultivars to *Rhizoctonia* root and hypocotyl rot and web blight. *Plant Disease* 77: 234-238.
- Ogoshi A (1987). Ecology and pathogenicity of anastomosis and intraspecific groups of *Rhizoctonia solani* Kühn. *Annual Review Phytopathology* 25: 125-143.
- Oladzad A, Zitnick-Anderson K, Jain S, Simons K, Osorno JM, McClean PE, Pasche JS (2019). Genotypes and genomic regions associated with *Rhizoctonia solani* resistance in common bean. *Frontiers in Plant Science* 956.
- Palacioğlu G, Bayraktar H, Özer G (2019). *Rhizoctonia* Ağ Yanıklığı Hastalığına Karşı Bazı Fasulye Çeşitlerinin Reaksiyonları. *Uluslararası Tarım ve Yaban Hayatı Bilimleri Dergisi* 5(2): 273-279.
- Scholten OE, Panella LW, Bock TSM, Lange W (2001). A greenhouse test for screening sugar beet (*Beta vulgaris* for resistance to *Rhizoctonia solani*. *European Journal of Plant Pathology* 107: 161-166.
- Sneh B, Burpee L, Ogoshi A (1991). Identification of *Rhizoctonia* Species. The American Phytopathological Society Press, St Paul Minnesota USA., 31-34.
- Sneh B, Jabaji-Hare S, Neate S, Dijst G (1996). *Rhizoctonia* Species: Taxonomy, Molecular Biology, Ecology, Pathology, Pathology and Disease Control, Kluwer Academic Publishers, s.578, Dordrech.
- Soylu S (2011). Konya ilinin bitkisel üretimdeki yeri ve önemi. *I. Konya Kent Sempozyumu*, 26-27 Kasım, 385-395.
- Stojsin V, Budakov D, Jacobsen B, Bagi F, Grimme E, Neher O (2011). Analysis of *Rhizoctonia solani* isolates associated with sugar beet crown and root rot from Serbia. *African Journal of Biotechnology* 10(82): 19049-19055.
- Şahiner A (2020). Kırşehir ekolojik koşullarında bazı şeker pancarı (*Beta vulgaris* L.) çeşitlerinin verim ve kalite özelliklerinin belirlenmesi. Kırşehir Ahi Evran Üniversitesi, Fen Bilimleri Enstitüsü, Tarla Bitkileri Anabilim Dalı, Yüksek Lisans Tezi.
- Stausbaugh CA, Eujayl IA, Panella LW, Hanson LE (2011). Virulence, distribution and diversity of *Rhizoctonia solani* from sugar beet in Idaho and Oregon. *Canadian Journal of Plant Pathology* 33 (2): 210-226.
- Townsend GR, Heuberger JW (1943). Methods for estimating losses caused by diseases in fungicide experiments. *Plant Disease Reporter* 27: 340-343.
- Tsrer L (2010). Biology, epidemiology and management of *Rhizoctonia solani* on potato. *Journal of Phytopathology* 158(10): 649-658.

- Tvedt CT (2017). Efficacy of seed treatments and in-furrow fungicides for management of dry bean root rot caused by *Rhizoctonia solani* and *Fusarium solani*, and field pea root rot caused by *Fusarium avenaceum* and *Fusarium solani*. PhD. Thesis, North Dakota State University, North Dakota.
- Valentin Torres S, Vargas MM, Godoy-Lutz G, Porch TG, Beaver JS (2016). Isolates of *Rhizoctonia solani* can produce both web blight and root rot symptoms in common bean (*Phaseolus vulgaris* L.). *Plant Disease* 100(7): 1351-1357.
- White TJ, Bruns TD, Lee S, Taylor JW (1990). Amplification and direct sequencing of fungal ribosomal RNA genes for phylogenetics. *A Guide to Methods and Applications*. Academic Press, 315-322, San Diego.
- Wigg KS (2021). Variability and Genetics of *Rhizoctonia solani* Resistance in Table Beet. PhD Thesis The University of Wisconsin-Madison
- Windels CE, Nabben DJ (1989). Characterization and pathogenicity of anastomosis groups of *Rhizoctonia solani* isolated from *Beta vulgaris*. *Phytopathology* 79(1): 83-88.
- Yıldız A, Döken T (2002). Anastomosis group determination of *Rhizoctonia solani* Kühn (Teleomorph: *Thanatephorus cucumeris*) isolates from tomatoes grown in Aydin, Turkey and their disease reaction on various tomato cultivars. *Journal of Phytopathology* 150(10): 526-528.