دانش بیماری‌شناسی گیاهی (شاپای ا: ۶۲۹۰-۲۵۸۸، شاپای چ: ۹۲۷۰-۲۲۵۱)
سال دهم، جلد ۲، بهار و تابستان ۱۴۰۰
Plant Pathology Science (eISSN:2588-6290, pISSN:2251-9270)
Vol. 10(2), 2021

Research Article

Impact of an arbuscular mycorrhizal fungus on Fusarium wilt in three tomato cultivars

MOHAMMAD REZVANJOO[1], MEHDI SADRAVI[1]✉, ALIREZA KHOSHROO[2]

1. Department of Plant Protection, Faculty of Agriculture, Yasouj University, Yasouj, Iran., 2. Department of Agronomy and Plant Breeding, Faculty of Agriculture, Yasouj University, Yasouj, Iran.

Received: 11.17.2021 Accepted: 12.29.2021

Rezvanjoo M, Sadravi M, Khoshroo A (2021) Impact of an arbuscular mycorrhizal fungus on Fusarium wilt in three tomato cultivars. Plant Pathology Science 10(2):74-81. Doi: 10.2982/PPS.10.2.74.

Abstract

Introduction: Wilt caused by the soil-borne fungus *Fusarium oxysporum* f. sp. *lycopersici* is one of the most common and harmful diseases in most tomato growing areas. The disease damage is reported up to 27% of the yield in Iran. Biological control of the disease is an effective, environmentally friendly, and consumer health management method. The ability of arbuscular mycorrhizal fungi to reduce many soil-borne diseases has been demonstrated, so this study was conducted to investigate the effect of a commercially available arbuscular mycorrhizal fungus on disease severity in three tomato cultivars. **Materials and Methods:** The commercial inoculum of arbuscular mycorrhizal fungus *Glomus geosprum* was obtained from the market. The experiment was performed in a completely randomized statistical design with four replicates for each treatment. Inoculum of *G. geosprum* was added to sterile soil in pots and then seeds of Super-Strain, Chef, and Super-Falat tomato cultivars were sown. Seedling roots were inoculated at the three to the six-leaf stage with a spore suspension of a hypervirulent isolate of *F. oxysporum* f. sp. *lycopersici*. Data on the severity of the disease, stem height, root length were collected after the appearance of wilting symptoms and analyzed with the SPSS 20 software and the means values were compared. **Results:** The severity of the disease was significantly reduced in all cultivars treated with arbuscular mycorrhizal fungus, and the stem height and root length were higher than those with no mycorrhizal fungus. **Conclusion:** The ability of *G. geosporum*, to reduce the severity of Fusarium wilt disease and increase the growth of tomato plants is reported for the first time.

Keywords: Tomato, Wilt, *Fusarium*, *Glomus*

✉ Corresponding author: msadravi@yu.ac.ir , 0000-0002-4324-131X

مقاله پژوهشی

تاثیر یک قارچ میکوریز آربوسکولی بر پژمردگی فوزاریومی در سه رقم گوجه‌فرنگی

محمد رضوان‌جو[۱]، مهدی صدروی[۱]✉، علیرضا خوشرو[۲]
۱.گروه گیاه‌پزشکی، دانشکده کشاورزی، دانشگاه یاسوج، یاسوج
۲. گروه زراعت و اصلاح نباتات، دانشکده کشاورزی، دانشگاه یاسوج، یاسوج

دریافت: ۱۴۰۰/۰۸/۲۶ پذیرش: ۱۴۰۰/۱۰/۰۸

رضوان‌جو م، صدروی م، خوشرو ع (۱۴۰۰) تاثیر یک قارچ میکوریز آربوسکولی بر پژمردگی فوزاریومی در سه رقم گوجه‌فرنگی. دانش بیماری‌شناسی گیاهی ۱۰(۲): ۸۱-۷۴.

Doi: 10.2982/PPS.10.2.74.

چکیده

مقدمه: پژمردگی ناشی از قارچ خاکزاد *Fusarium oxysporum* f. sp. *lycopersici* یکی از بیماری‌های مهم در بیشتر مناطق کشت گوجه‌فرنگی در جهان است. میزان خسارت بیماری در ایران تا ۲۷ درصد محصول گزارش شده است. مبارزه زیستی یک روش موثر و سازگار با محیط زیست و سالم برای مصرف‌کنندگان است. توانایی قارچهای میکوریز آربوسکولی در کاهش بسیاری از بیماری‌های خاکزاد گیاهان به اثبات رسیده است، بنابراین این پژوهش برای بررسی تاثیر یک قارچ میکوریز آربوسکولی که به شکل تجارتی در دسترس بود بر شدت این بیماری در سه رقم تحت کشت گوجه‌فرنگی صورت گرفت. **مواد و روش‌ها:** زادمایه‌ی تجارتی قارچ میکوریز آربوسکولی *Glomus geosprum* تهیه گردید. آزمایش در قالب طرح آماری کاملاً تصادفی با چهار تکرار برای هر تیمار اجرا شد. زادمایه‌ی قارچ میکوریز آربوسکولی به خاک سترون در گلدان‌ها اضافه شد و بذرهای رقم‌های گوجه‌فرنگی Super-Strain، Chef و Super-Falat در گلدان‌ها کاشته شدند. ریشه‌ی گیاهچه‌ها در مرحله‌ی سه تا شش برگی با سوسپانسیون هاگ یک جدایه‌ی پرآزار *F. oxysporum* f. sp. *lycopersici* مایه‌زنی شدند. پس از بروز نشانه‌های زردی و پژمردگی، داده‌های شدت بیماری، ارتفاع ساقه و طول ریشه جمع‌آوری و داده‌ها به کمک نرم‌افزار SPSS20 تجزیه واریانس شده و میانگین‌ها مقایسه شدند. **یافته‌ها:** شدت بیماری در تمام رقم‌های تیمار شده با قارچ میکوریز آربوسکولی به میزان معنی‌داری کمتر و ارتفاع ساقه و طول ریشه بیشتر از تیمارهای غیر میکوریزایی بودند. **نتیجه‌گیری:** توانایی *G. geosporum* در کاستن از شدت بیماری پژمردگی فوزاریومی و افزایش رشد بوته‌های گوجه‌فرنگی برای نخستین بار گزارش می‌شود.

واژگان کلیدی: گوجه‌فرنگی، پژمردگی، *Fusarium* ، *Glomus*

✉ نویسنده مسئول: msadravi@yu.ac.ir

Introduction مقدمه

Wilt caused by the soil-borne fungus *Fusarium oxysporum* Schltdl. f. sp. *lycopersici* W.C. Snyder & H.N. Hansen is one of the most important and common diseases of tomato (*Solanum lycopersicum* L.) in the world. The first symptoms of the disease appear in the form of vein clearing of young leaves, curling of the petals, and drying and falling of the old leaves. Diseased plants are shorter, eventually turning yellow, wilting, and dying before producing flowers and fruit. The disease is common in greenhouses or areas with hot climates and slightly acidic soils. The best temperature for disease outbreaks is 28^{o}C, and temperatures above 34^{o}C and between 17 and 20^{o}C reduce the spread of the disease (Gordon 2019).

F. oxysporum f. sp. *lycopersici* has a pink-white colony and produces three types of spores called microconidia, macroconidia, and chlamydospores (Rahimizadeh and Sadravi 2020). The disease was first reported from England in 1895 and has been reported from 32 countries on five continents. In the United States of America, the disease causes about 3 to 10 percent damage, and in some parts of France, it kills 40 to 60 percent of the tomato crop in greenhouses (Srinivas et al. 2019). The disease was first reported in Iran from Hormozgan Province, then from the Varamin region in Tehran Province with a maximum infection rate of 27.3%. So far, there have also been reports from Isfahan, Fars, Kohgiluyeh and Boyer-Ahmad Provinces (Rahimizadeh and Sadravi 2020, Amini et al. 2014, Etebarian 1992, Fasihiyani 1985).

Controlling the disease through the use of chemical fungicides can result in soil and water pollution, reduce the number of beneficial soil microorganisms, increase the risk of pathogen resistance, and have adverse impacts on consumer health and the environment. Biological control is an environmentally safe and healthy way to manage the disease (McGovern 2015). Arbuscular mycorrhizal fungi (Phylum: *Glomeromycota*) are obligate symbionts of plant roots that, in addition to spreading their hyphae around the plant roots, after penetrating the root tissues, exchange mineral nutrients such as phosphorus with carbohydrates through their arbuscules, in endodermal cells. These fungi have a symbiosis with the roots of more than 80% of plants such as wheat, barley, corn, sorghum, legumes, soybean, sunflower, alfalfa, apple, olive tree, aromatic and medicinal plants (Avazzadeh-Mehrian and Sadravi 2017, Błaszkowski et al. 2010, Sadravi 2002, 2003, 2004, 2006a, 2006b, 2006c, 2006d, 2007, Sadravi and Gharacheh 2015, Sadravi et al. 1999, 2000, Sadravi and Moshiri Rezvany 2019, Sadravi and Seifi 2002). Arbuscular mycorrhizal fungi help plants cope with fungi and fungal-like pathogens, phytopathogenic nematodes, bacteria, phytoplasma, and the physiological diseases of plants by increasing water and nutrient uptake for plants, altering plant tissue chemicals, competing with pathogens for habitat and nutrients, changing of root structure, reducing environmental pollution and increasing the population of beneficial bacteria (Sadravi 2012). Inoculation of the arbuscular mycorrhizal fungus *Glomus caledonium* (T.H. Nicolson & Gerd.) Trappe & Gerd. on cucumber root in a greenhouse increased plant growth and reduced the Fusarium wilt (Bidellaoui et al. 2019). Inoculation of a mixture

of several arbuscular mycorrhizal fungi into cucumber roots in the greenhouse enhanced their growth and reduced wilt disease caused by *Fusarium oxysporum* f. sp. *cucumerinum* J. H. Owen (Hu et al. 2010). Inoculation of an arbuscular mycorrhizal fungus, *Trichoderma harzianum* Rifai, and *Pseudomonas fluorescens* (Flügge,1886) Migula,1895, alone or in combination, reduced the severity of Fusarium wilt of tomato under greenhouse conditions (Srivastava et al. 2010).

This investigation was conducted based on the occurrence of Fusarium wilt in tomatoes in Kohgiluyeh and Boyer-Ahmad Province (southwestern Iran), and the above reports on the effectiveness of arbuscular mycorrhizal fungi in reducing the severity of Fusarium wilt in plants using a commercially available arbuscular mycorrhizal fungus.

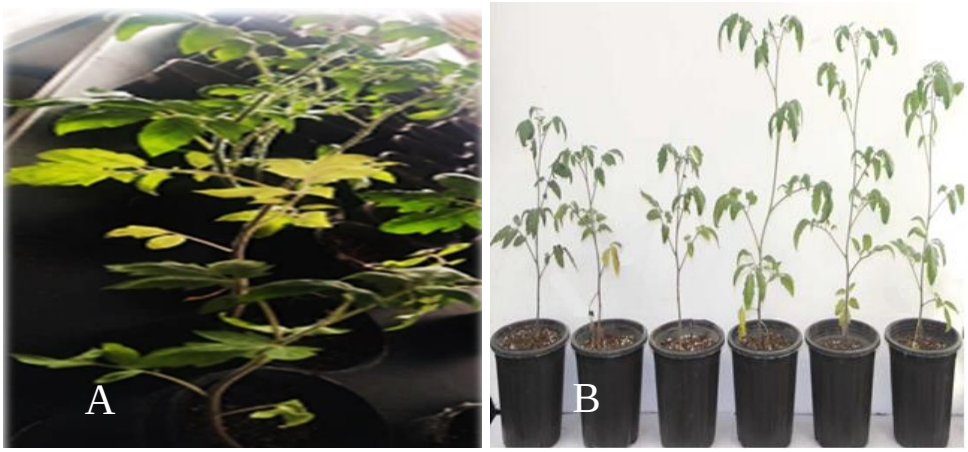
Materials and Methods مواد و روشها

Commercial inoculum of the arbuscular mycorrhizal fungus, *Glomus geosporum* (TH Nicolson & Gerd.) C. Walker (≡ *Funneliformis geosporus* (TH Nicolson & Gerd.) C. Walker & A. Schüβler), manufactured by Turan Biotechnology Company (https://turanbiotech .com) has been provided. Seeds of tomato cultivars Super-Strain, Chef, and Super-Falat were planted in pots containing sterile soil. Seedlings were removed from the pots at the three to the six-leaf stage, taking care not to damage the roots, and the roots were incubated for three minutes in a spore suspension containing 10^6 spores of a hypervirulent isolate of *Fusarium oxysporum* f. sp. *lycopersici* collected from one of the tomato production greenhouses in Kohgiluyeh and Boyer-Ahmad Province (Rahimizadeh and Sadravi 2020). Infected seedlings were transplanted into pots with *G. geosporum* inoculum according to the manufacturer's recommendations (100 g per pot) and pots without *G. geosporum* inoculum. All pots were placed in a greenhouse at 24-26°C with 70% humidity with 16 hours light and 8 hours dark. After the appearance of yellowing and wilting in plants, disease severity was determined based on the percentage of yellowed and wilted leaves (Larkin and Fravel 1998). Stem height and root length were also measured. The experiment was conducted as a fully randomized design with four replicates. The data collected were analyzed for variance using SPSS20 software and the means were compared using Tukey's test.

Results and Discussion یافته‌ها و بحث

Yellowing of leaves and wilting of plants were observed as symptoms of the disease (Fig. 1). The comparison of the mean of these treatments is shown in Table 1. Analysis of the experimental data variance showed that *G. geosporum* caused a significant reduction in the severity of Fusarium wilt and an increase in stem height and root length in all three tomato cultivars.

This study showed that inoculation of *G. geosporum* on the root of tomatoes significantly reduced the severity of Fusarium wilt disease and increased stem height and root length of the plant. Inoculation of the arbuscular mycorrhizal fungus *Glomus intraradices* NC Schenck & GS Sm. alone or in combination with *T. harzianum* and *P. fluorescens* on



شـــکل ۱. A. نشـــانه‌های زردی بوته‌های گوجه‌فرنگی تلقیح شـــده با *Fusarium oxysporum* f. sp. *lycopersici* ، B. سه گلدان سمت راست بوته‌های گوجه‌فرنگی بیمار در حضور *G. geosporum* و سه گلدان سمت چپ بوته‌های گوجه‌فرنگی بیمار بدون حضور *G. geosporum* هستند.

Figure 1. A. Yellowing signs of tomato plants inoculated with *Fusarium oxysporum* f. sp. *lycopersici*., B. The three pots on the right are the diseased tomato plants in the presence of *Glomus geosporum*, and the three pots on the left are the diseased tomato plants without the presence of *G. geosporum*.

جدول ۱. شدت بیماری پژمردگی فوزاریومی ناشی از *Fusarium oxysporum* f.sp. *lycopersici* (Fol) ، ارتفاع ساقه و طول ریشه در حضور و عدم حضور قارچ میکوریز آربوسکولی *Glomus geosporum* در سه رقم گوجه‌فرنگی*.

Table 1. Fusarium wilt disease severity caused by *Fusarium oxysporum* f. sp. *lycopersici* (Fol), stem height and root length in the presence and absence of an arbuscular mycorrhizal fungus *Glomus geosporum* in three tomato cultivars*.

Treatment	Disease severity (%)	Stem height (Cm)	Root length (Cm)
Super-Falat × Fol	21 a	18.20 c	16.83 c
Super-Strain × Fol	21 a	18.23 c	17.38 c
Chef × Fol	19 a	19.25 c	17.05 c
(Super-Strain + *G. geosporum*) × Fol	14 b	26.98 b	25.15 b
(Super-Falat + *G. geosporum*) × Fol	13 b	27.05 b	25.08 b
(Chef + *G. geosporum*) × Fol	12 b	29.03 a	26.60 a

*اعدادی که در یک ستون با حرف مشابه نشان داده شده‌اند اختلاف معنی‌داری در سطح ۱ درصد ندارند.

* The numbers shown in a column with the same letter do not differ significantly at the 1% level.

tomato also reduced the severity of Fusarium wilt (Srivastava et al. 2010). Inoculation of *G. geosporum* on cowpea roots also reduced the number of galls produced by the nematode *Meloidogyne incognita* Kofoid & White, 1919 and increased nodule formation by the nitrogen-fixing bacterium *Rhizobium* sp. (Ugwuoke and Eze 2010). Experiments on the effect of eight arbuscular mycorrhizal fungi on marigold growth have shown that *G. geosporum* can significantly increase stem height, number of flowering

branches, number of flowers, and dry flower weight (Kheyri et al. 2020). Combined inoculation of *G. geosporum, Azotobacter chroococcum* Beijerinck,1901 and *Bacillus coagulans* Hammer, 1915, increased plant biomass, uptake of N, P, zinc, copper, and quality index of Chinaberry seedlings *Melia azedarach* L. (Rajeshkumar et al. 2009). Experiments on the effect of *G. geosporum* on cucumber yield under 100% NPK fertilizers and 50% of these fertilizers showed that this fungus produces a yield equivalent to 100% fertilizers when 50% of the required fertilizers were applied to the plant (Puspitasari et al. 2016).

Conclusion نتیجه‌گیری

Wilt caused by the soil-borne fungus *Fusarium oxysporum* f. sp. *lycopersici* is one of the most important and common diseases of tomato in the world. Biological control of diseases is an environmentally friendly and healthy method for consumers of plants products. The results of this study showed that for the first time the arbuscular mycorrhizal fungus *G. geosporum* is able to significantly reduce the disease severity and maintain normal plant growth in three tomato cultivars. Therefore, as a bioproduct, it can be used in the control of Fusarium wilt in tomatoes, in soils contaminated with the pathogen, and in the production of organic yield.

References منابع

Amini J, Kazemi M, Abdollahzadeh J, Darvishnia M (2014) Identification of *Fusarium* species associated with root and crown rot of tomato in Marvdasht. Iranian Plant Protection Science 44**:**71-80. (In Persian with English abstract)

Avazzadeh-Mehrian Z, Sadravi M (2017) The effect of chemical properties of soil on the symbiosis of apple and grape with arbuscular mycorrhizal fungi. Journal of Soil Management and Sustainable Production 7(1): 115-125. (In Persian with English abstract)

Błaszkowski J, Kovacs GM, Balazs T K, Orłowska E, Sadravi M, Wubet T, Buscot F (2010) *Glomus africanum* and *G. iranicum*, two new species of arbuscular mycorrhizal fungi (*Glomeromycota*). Mycologia 102(6):1450–1462.

Bidellaoui B, Segarra G, Hakkou A, Trillas M I (2019) Beneficial effects of *Rhizophagus irregularis* and *Trichoderma asperellum* strain T34 on growth and fusarium wilt in tomato plants. Journal of Plant Pathology 101(1): 121-127

Etebarian H R (1992) Study of Fusarium wilt of tomato and its chemical control in Varamin. Iranian Agricultural Science 23:1-13. (In Persian with English abstract)

Fasihiyani A R (1985) The emergence of tomato Fusarium wilt disease in Hormozgan. Plant Disease 21:29-32.

Gordon T R (2017) *Fusarium oxysporum* and the Fusarium wilt syndrome. Annual Review of Phytopathology 55:23-39.

Hu J L, Lin X G, Wang J H, Shen WS, Wu S, Peng SP, Mao TT (2010) Arbuscular mycorrhizal fungal inoculation enhances suppression of cucumber Fusarium wilt in greenhouse soils. Pedosphere 20(5): 586-593.

Kheyri Z, Moghadam M, Moradi M (2020) Study the effect of different mycorrhizal fungi on some growth indices, photosynthetic pigments, flavonoids, and carotenoid content of pot marigold flower. Horticultural Plant Nutrition 3(1):37-50.

Larkin RP, Fravel DR (1998) Efficacy of various fungal and bacterial biocontrol organisms for control of Fusarium wilt of tomato. Plant Disease 82:1022-1028.

McGovern R J (2015) Management of tomato diseases caused by *Fusarium oxysporum*. Crop Protection 73:78-92.

Rahimizadeh M, Sadravi M (2020) Biocontrol of Fusarium wilt of tomato by Nano-extract of *Trichoderma harzianum*. Indian Journal of Agricultural Sciences 90(6):1058-1062.

Rajeshkumar S, Nisha M C, Chidambaram Prabu P, Selvaraj T (2009) Interaction between *Glomus geosporum*, *Azotobacter chroococcum*, and *Bacillus coagulans* and their influence on growth and nutrition of *Melia azedarach* L. Turkish Journal of Biology 33(2): 109-114.

Sadravi M (2002) Five Glomus species of arbuscular mycorrhizal fungi from Iran. Journal of Agricultural Sciences and Natural Resources 9:15-30. (In Persian with English abstract)

Sadravi M (2003) Mycorrhizal fungi of soybean, sunflower, and sesame in Golestan Province of Iran. Proceedings of First National Oilseeds Congress. Gorgan, Iran, p:6.

Sadravi M (2004) Seven fungi new for Iran. Journal of Agricultural Sciences and Natural Resources 11(3):71-78. (In Persian with English abstract)

Sadravi M (2005) Role of mycorrhizal fungi in increasing growth, yield, and resistance in pulse crops. Proceedings of First Pulse Crops Congress of Iran. Mashhad, Iran, p:132.

Sadravi M (2006a) Arbuscular mycorrhizal fungi of wheat in northeast Iran. Abstract Book of 8th International Mycological Congress. Cairnes, Queensland, Australia p: 86.

Sadravi M (2006b) Comparison population and species richness of arbuscular mycorrhizal fungi between six field crops. Proceedings of 17th Plant Protection Congress of Iran. Tehran University, Karaj, Iran p:180.

Sadravi M (2006c) Effect of crops rotation on the population of mycorrhizal fungi of wheat. Journal of Agricultural Sciences and Natural Resources 13: 90-98. (In Persian with English abstract)

Sadravi M (2006d) Establishment of four arbuscular mycorrhizal fungi in tomato's root on minimal M medium. Proceedings of 17th Plant Protection Congress of Iran. Tehran University, Karaj, Iran p:200.

Sadravi M (2007) Arbuscular mycorrhizal fungi of wheat fields in the Golestan Province. Rostaniha 7: 129-140. (In Persian with English abstract)

Sadravi M (2012) Role of arbuscular mycorrhizal fungi in plants diseases management. Plant Pathology Science 1(1): 1-13. (In Persian with English abstract)

Sadravi M, Mohamadi-Goltapeh E, Blaszkowski J, Minasian V, Alizadeh A (2000) Seven cereal vesicular–arbuscular mycorrhizal fungi of Iran. Proceedings of 14th Plant Protection Congress of Iran, Karaj p:27.

Sadravi M, Gharacheh N (2015) Arbuscular mycorrhizal fungi of pulse crops in southwest Iran. Proceedings of Asian Mycological Congress, 7-10 October 2015, Goa University, Goa, India, p:172.

Sadravi M, Mohamadi-Goltapeh E, Blaszkowski J, Minasian V, Alizadeh A (1999) Four vesicular-arbuscular mycorrhizal fungi of Iran. Seed and Plant 15: 9-24. (In Persian with English abstract)

Sadravi M, Moshiri-Rezvany R (2019) Biodiversity of arbuscular mycorrhizal fungi of seven ornamental plants in northeast Iran. Proceedings of 4th Iranian Mycological Congress, Sari, Iran, p:10.

Sadravi M, Seifi E (2002) Mycorrhizal fungi of Olive trees in Golestan province. Proceedings of Second Golestan Province Research Projects Congress, Gorgan, Iran p:60.

Srinivas C, Nirmala Devi D, Narasimha Murthy K, Dhananjaya Mohan C, Lakshmeesha T R, Singh B P, Kalagatur N K, Niranjana S R, Hashem A, Alqarawi A A, Tabassum B, Abd_Allah E F, Chandra Nayaka S, Srivastava R K (2019) *Fusarium oxysporum* f. sp. *lycopersici* causal agent of vascular wilt disease of tomato: Biology to diversity– A review. Saudi Journal of Biological Sciences 26(7): 1315-1324.

Srivastava R, Khalidb A, Singh US, Sharma A K (2010) Evaluation of arbuscular mycorrhizal fungus, fluorescent Pseudomonas and *Trichoderma harzianum* formulation against *Fusarium oxysporum* f. sp. *lycopersici* for the management of tomato wilt. Biological Control 53(1):24-31.

Ugwuoke KI, Eze SC (2010) The Effect of Mycorrhiza (*Glomus geosporum*), *Rhizobium* and *Meloidogyne incognita* on growth and development of cowpea (*Vigna unguiculata* L. Walp). Research Journal of Agriculture and Biological Sciences 6(6): 937-941.