دانش بیماری‌شناسی گیاهی (شاپای ا: ۶۲۹۰-۲۵۸۸، شاپای چ: ۹۲۷۰-۲۲۵۱)
سال یازدهم، جلد ۲، بهار و تابستان ۱۴۰۱
Plant Pathology Science (eISSN:2588-6290, pISSN:2251-9270)
Vol. 11(2), 2022

Research Article

Correlation between arbuscular mycorrhiza in wheat and physicochemical characteristics of soil

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Received: 07.22.2022 Accepted:10.12.2022

Talaei F, Sadravi M, Adhami E (2022) Correlation between arbuscular mycorrhiza in wheat and physicochemical characteristics of soil. Plant Pathology Science 11(2):32-41. Doi: 10.2982/PPS.11.2.32

Abstract

Introduction: Arbuscular mycorrhizal fungi (AMF) in symbiosis with plant roots help to absorb more phosphorus, and increase the growth and development of plants. The aim of this study was to determine the correlation between population and diversity of AMF, and physicochemical characteristics of soil in wheat fields of Kohgiluyeh and Boyer-Ahmad province in southwestern Iran. **Materials and Methods:** Thirty wheat fields in this province, were visited near harvest time, and their rhizosphere and aerial organs were sampled. AMF spores were isolated by sieving the rhizosphere suspension in water and centrifuging in Sucrose solution. The spore population of these fungi was count. The percentage of root length colonization by these fungi was calculated in every sample. The morphological characteristics of the isolated spores were studied and the collected information was compared with the descriptions of AMF and the fungi present in each sample were identified. Texture, soil dispersion, soil and plant phosphorus content were determined and the correlation coefficient between AMF population and diversity with physical and chemical characteristics of soil and wheat plant were calculated. **Results:** Fifteen arbuscular mycorrhizal fungi belonging to nine genera: *Acaulospora*, *Archaeospora*, *Entrophospora*, *Gigaspora*, *Claroideumglomus*, *Funeliformis*, *Rhizoglomus*, *Septoglomus* and *Scutellospora* were identified. The diversity of these fungi in the samples was (2-)2.9(-5) and *F. mosseae* was dominant species with 90% relative frequency. The population of these fungi had a negative correlation with soil pH, but with soil soluble phosphorus and plant phosphorus content had a positive correlation. The diversity of these fungi had a positive correlation with soil soluble phosphorus. There was a positive correlation between the amount of sand in the soil and the root length colonization. **Conclusion:** AMF have a greater population and diversity in soils with light texture, less moisture along with low amounts of soluble phosphorus and organic matter. The positive correlation between the population of these fungi and plant phosphorus indicates their usefulness for the plant.

Keywords: *Funeliformis*, Phosphorus, *Rhizoglomus* , *Septoglomus*

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مقاله پژوهشی

همبستگی بین میکوریزای آربوسکولی در گندم و ویژگی‌های فیزیکی و شیمیایی خاک

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دریافت: ۱۴۰۱/۰۴/۳۱ پذیرش: ۱۴۰۱/۰۷/۲۰

طلایی ف، صدروی م، ادهمی ا (۱۴۰۱) همبستگی بین میکوریزای آربوسکولی در گندم و ویژگی‌های فیزیکی‌وشیمیایی خاک. دانش بیماری‌شناسی گیاهی ۱۱(۲): ۳۲-۴۱.
.Doi: 10.2982/PPS.11.2.32

چکیده

مقدمه: قارچ‌های میکوریز آربوسکولی(AMF) در همزیستی با ریشه گیاهان به جذب بیشتر فسفر و افزایش رشد و نمو گیاهان کمک می‌کنند. هدف از این پژوهش تعیین همبستگی جمعیت و تنوع قارچهای میکوریزآربوسکولی با ویژگی‌های فیزیکی وشیمیایی خاک، در مزرعه های گندم استان کهگیلویه و بویراحمد در جنوب غربی ایران، بود. **مواد و روشها:** سی مزرعه گندم این استان در نزدیکی زمان برداشت محصول بازدید شدند و از ریزوسفر و اندام‌های هوایی آن‌ها نمونه‌برداری شد. هاگهای AMF به روش الک سوسپانسیون ریزوسفر در آب و سانتریفیوژ کردن در محلول سوکرز جداسازی شدند. جمعیت هاگ این قارچها شمارش شدند. درصد کلنیزاسیون طول ریشه توسط این قارچها در هر نمونه محاسبه شد. خصوصیات ریخت‌شناسی هاگهای جداسازی شده مطالعه شدند و اطلاعات جمع‌آوری شده، با توصیفهای AMF مقایسه و قارچهای حاضر در هر نمونه شناسایی شدند. بافت، pH خاک ، فسفر خاک و موجود در گیاه تعیین شدند و ضریب همبستگی بین جمعیت و تنوع AMF با این خصوصیات فیزیکی و شیمیایی خاک و گیاه محاسبه شدند. **یافته‌ها:** پانزده قارچ میکوریز آربوسکولی، متلعق به ۹ جنس : *Acaulospora* ، *Archaeospora*، *Entrophospora*، *Gigaspora*، *Rhizoglomus* ، *Claroideumglomus* ، *Funeliformis* ، *Septoglomus* و *Scutellospora* شناسایی شدند. تنوع این قارچها در نمونه‌ها(۵-) ۲/۹ (-۲) و *F. mosseae* با فراوانی ۹۰ درصد گونه غالب بود. جمعیت این قارچها با pH خاک همبستگی منفی ولی با فسفر محلول خاک و فسفر گیاه همبستگی مثبت داشت. تنوع این قارچها نیز با فسفر محلول خاک همبستگی مثبت داشت. بین میزان شن در خاک و درصد کلنیزاسیون ریشه‌ها همبستگی مثبت وجود داشت. **نتیجه‌گیری:** قارچهای میکوریز آربوسکولی در خاکهای با بافت سبک، pH کمتر همراه با مقادیر کم فسفر محلول و ماده آلی جمعیت و تنوع بیشتری دارند. همبستگی مثبت جمعیت این قارچها با فسفر گیاه حاکی از سودمندی آنها برای گیاه است.

واژگان کلیدی: فسفر، *Funeliformis*، *Rhizoglomus* ، *Septoglomus*

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Introduction مقدمه

Mycorrhiza is a symbiotic relationship between some soil fungi and the roots of higher plants. The most common type of this symbiosis is endomycorrhiza or arbuscular mycorrhiza (AM). Arbuscular mycorrhizal fungi (AMF; Phylum:*Glomeromycota* C.Walker & A. Schüßler), settled on earth more than 400 million years ago, are symbiotic with 83% of dicotyledons, 79% of monocotyledons, and all gymnosperms (Remy et al. 1994, Quilambo 2003). AMF increase the absorption area of the plant's roots with their extra radical hyphae and thus enable the plant to absorb nutrients from an area far from the access of roots. Also they produce a shrub-like organelle called an arbuscule inside the cells of endodermis, which is the place of water and nutrient elements (especially phosphorus) exchange with plant carbohydrates. They increase growth and development, product quantity and quality, the number of hormones controlling plant growth, photosynthesis, carbohydrates, lipids, and proteins, and the symbiotic plant's resistance to soil-borne pathogens. The ability of AMF to increase the supply of phosphorus, which usually exists in agricultural soils as a chelate, is by dissolving soil phosphorus and transferring it to the root of the symbiotic plant (Sadravi 2022).

Cereals, including wheat, are known as one of the best hosts of AMF, so dozens of species of these fungi were reported from wheat in the world (Gerdman and Trape 1974, Walker and Rhodes 1981, Sadravi et al. 1999, 2000, 2001, Sadravi 2002, 2004, Talukdar and Germida 1993, Blaszkowski 1993). Wheat plants colonized with AMF have higher quality in terms of high concentration of elements, such as phosphorus and zinc, compared to non-symbiotic plants, and higher yield potential (Al-Karaki et al. 2004). AMF increased the growth, development, and optimal production of the wheat crop, and the dry weight and the amount of phosphorus in the roots and stems of wheat plants colonized with AMF were more than non-mycorrhizal plants. Mycorrhizal wheat plants increase in the number of spikes, grains, and 1000-grain weight compared to non-mycorrhizal plants. AM affects the grain size, quantity, and nutritional composition of the grain. Wheat plants with AM have significantly more spikes, grains, and 1000-grain weight than non-mycorrhizal plants (Mohammad et al. 2004).

The relationship between soil texture, pH, phosphorus, organic matter, and AM were studied (Sieverding 1989, Ravnskov et al. 2006, Carrenho et al. 2007, Amijee et al. 1989, Vieira et al. 2020, Fall et al. 2022, Alguacil et al. 2016). Using the potential of these fungi to increase plant growth requires identifying the species composition of these fungi in agricultural soils. Therefore, in Kohgilouye and Boyer-Ahmed Province, southwestern Iran, one of the most important areas of wheat cultivation, this research was carried out to identify the AMF of wheat and to ascertain the correlation between the physicochemical characteristics of soil with population and diversity of these fungi.

Materials and Methods مواد و روش‌ها

Sampling, and identification of arbuscular mycorrhiza in wheat

Thirty wheat fields in Kohgiluyeh and Boyer-Ahmad Province were visited from June to July when the grains were ripe, and healthy plants were selected from at least four points of each field, and the rhizosphere mass from a depth of 30 cm, and their aerial parts were collected. After noting the criteria, each sample was packaged in paper envelopes and transported to the laboratory. The rhizosphere masses collected from each field were mixed together and exposed to airflow in order to reduce humidity and drying, in the laboratory. Pot trap cultures with corn and 100 g of the rhizosphere of each sample were kept in the greenhouse for three months to obtain a sufficient population of healthy spores of the species present in each sample (Gaur and Adholeya 2000). AMF spores were isolated from field samples and pot trap cultures by sieving and decanting method followed by centrifugation in 50% sucrose solution (Gerdemann and Nicolson 1963, Jenkins 1964). The morphological characteristics of the spores of each AMF species were studied in polyvinyl alcohol-lactic acid-glycerol (PVLG), and a mixture 1:1 of PVLG and Melzer's reagent (Morton et al. 1993). The collected information was compared with the descriptions of AMF species. The root tissue of each sample was stained by Phillips and Hayman (1970) method, and their root length colonization was determined by the intersecting lines method (McGonigle et al. 1990).

Determining correlation coefficient between physical and chemical characteristics of soil and arbuscular mycorrhiza

Soil samples texture, soluble phosphorus, organic matter, pH, and total plant phosphorus were determined (Pal 2019). The Pearson correlation coefficient of these characteristics, with the population and diversity (Species richness) of AMF, and the root length colonization in the samples were calculated using SPPS20 software.

Results and Discussion یافته‌ها و بحث

Identified Arbuscular Mycorrhizal Fungi

AMF were present in all samples, and 15 species were identified by studying their morphological characteristics (Table 1).

The diversity of these fungi in the samples was (-2) 2.9 (-5) and *F. mosseae* and *F. caledonius* had the most frequency in the samples with 90% and 53.3%, respectively. Figure 1 shows the spore of some of these fungi.

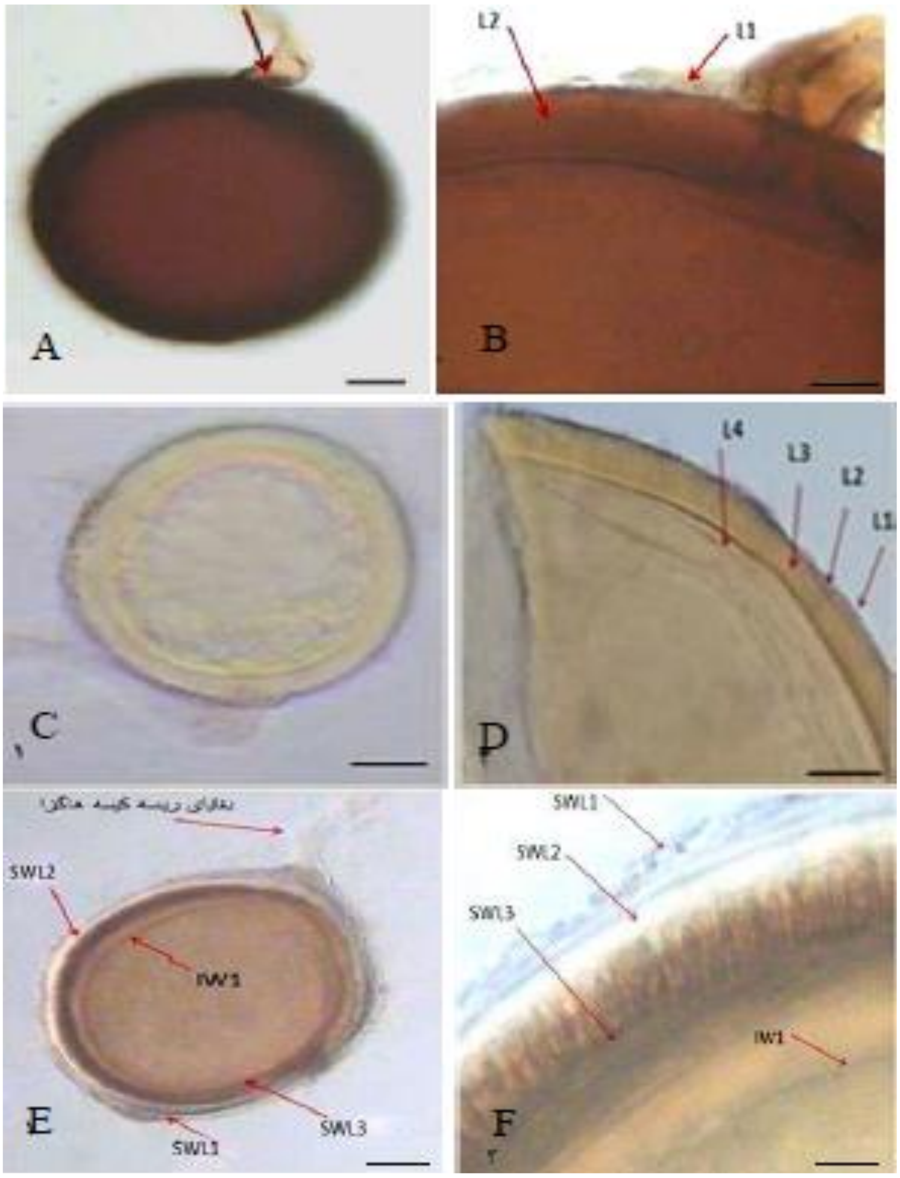
Other AMF reported from the wheat rhizosphere include: *Acaulospora denticulata* Sieverd. & S. Toro, *Paraglomus albidum* (C. Walker & L.H. Rhodes)Oehl, G.A. Silva & Sieverd. , *Funneliformis caledonium* (T.H. Nicolson & Gerd.) C. Walker & A. Schüßler, *Funneliformis coronatu*s (Giovann.)C. Walker & A. Schüßler, *Glomus dominikii* Błaszk. , *Glomus etunicatum* W.N. Becker & Gerd., *Glomus gibbosum* Blaszk., *G. macrocarpum* Tul. & C. Tul., *G. monosporum* Gerd. & Trappe, *Funneliformis multiforus* (Tadych & Błaszk.) Oehl, G.A. Silva & Sieverd. , *Glomus rubiforme* (Gerd. & Trappe) R.T. Almeida & N.C. Schenck, *Glomus sinuosum* (Gerd. and B. K. Bakshi) R.T. Almeida & N.C. Schenck, *G.*

versiforme (P. Karsten) S.M. Berch, *Gigaspora decipiens* I.R. Hall & L.K. Abbott, and *Scutellospora dipurpurascens* J.B.Morton & Koske (Gerdman and Trape 1974, Walker and Rhodes 1981, Sadravi et al. 1999, 2000, 2001, Sadravi 2002,2004, Talukdar and Germida 1993, Blaszkowski 1993).

جدول ۱. قارچ‌های میکوریز آربوسکولی گندم در استان کهگیلویه و بویر احمد ایران.

Table 1. Arbuscular mycorrhizal fungi of wheat in Kohgiluyeh and Boyer-Ahmad Province of Iran.

Fungus	Frequency in Samples (%)
1. *Archaeospora trappei* (R.N. Ames & Linderman) J.B. Morton & D. Redecker	3.3
2. *Acaulospora bireticulata* F. M. Rothwell and Trappe	2.6
3. *Entrophospora infrequens* (I.R. Hall) R.N. Ames & R.W. Schneid.	3.3
4. *Gigaspora gigantea* (T.H. Nicolson & Gerd.) Gerd. & Trappe	3.3
5. *Funneliformis caledonius* (T.H. Nicolson & Gerd.) C. Walker & A. Schüßler	53.3
6. *Claroideoglomus claroideum* (N.C. Schenck & G.S. Sm.) C. Walker & A. Schüßler	20
7. *Rhizoglomus clarum* (T.H. Nicolson & N.C. Schenck) Sieverd., G.A. Silva & Oehl	30
8. *Septoglomus constrictum* (Trappe) Sieverd., G.A. Silva & Oehl	13.3
9. *Septoglomus deserticola* (Trappe, Bloss & J.A. Menge) G.A. Silva, Oehl & Sieverd.	3.3
10. *Rhizoglomus fasciculatum* (Thaxt.) Sieverd., G.A. Silva & Oehl	16.6
11. *Funneliformis geosporum* (T.H. Nicolson & Gerd.) C. Walker & A. Schüßler	23.3
12. *Rhizoglomus intraradices* (N.C. Schenck & G.S. Sm.) Sieverd.	3.3
13. *Claroideoglomus lamellosum* (Dalpé, Koske & Tews) C. Walker & A. Schüßler	11.1
14. *Funneliformis mosseae* (T.H. Nicolson & Gerd.) C. Walker & A. Schüßler	90
15. *Scutellospora calospora* (T.H. Nicolson & Gerd.) C. Walker & F.E. Sanders	3.3



شکل ۱. سه قارچ میکوریز آربوسکولی گندم در استان کهگیلویه و بویراحمد ایران:

A,B. *Septoglomus constrictum*، C,D. *Claroideoglomus claroideum*، E,F. *Entrophospora infrequens*. (خط مقیاس= ۵ میکرومتر)

Figure 1. Three arbuscular mycorrhizal fungi of wheat in Kohgilouye and Boyer-Ahmad province of Iran: A,B. *Septoglomus constrictum*, C,D. *Claroideoglomus claroideum*, E,F. *Entrophospora infrequens*. (Bars= 5 µm)

The correlation between AM and physicochemical characteristics of Soil

The AMF population was 235-360 spores per 100 g of the rhizosphere in the samples. The root length colonization rates 40-60 percent. AMF species richness, according to study on samples taken from the field and pot trap cultures of each sample was (2-) 2.9 (-5). Soil texture varied from silt-loam to clay, soil soluble phosphorus content from 7.78 to 54.49 ppm, organic matter from 0.57% to 5.1%, pH from 7 to 7.9, plant

جدول ۲. ضریب همبستگی جمعیت و تنوع قارچهای میکوریز آربوسکولی و طول کلنیزه شده ریشه گندم با خصوصیات فیزیکی‌وشیمیایی خاک.

Table 2. Correlation coefficient of population and diversity (species richness) of arbuscular mycorrhizal fungi and root length colonization of wheat with physicochemical characteristics of soil.

Factors	Correlation Coefficient						
	Soil sand	Soil clay	Soil silt	Soil organic material	Soil pH	Soil phosphorus	Plant phosphorus
AMF spores population/100gr rhizosphere	0.19	-0.25	-0.11	0.22	-0.15	0.16	0.60
AMF species richness	0.11	0.08	0.02	-0.20	0.06	0.01	0.28
Root length colonization	0.09	-0.10	-0.20	0.25	-0.14	0.20	0.30

phosphorus from 905.76 to 2307.90 mg/kg of plant dry weight. Table 2 presents the correlation coefficient among these factors.

These correlation coefficients show that the growth and sporulation of AMF and the root length colonization in light soils are better than in soils with heavy and fine textures. Sandy soils were shown to increase mycorrhizal symbiosis, while clay soils decrease it. Heavy soils with clay texture have a high cation exchange capacity, and for this reason, in these types of soils, the concentration of nutrients is higher than in light soils, reducing the development of mycorrhizal symbiosis (Carrenho et al. 2007). AMF from the order *Gigasporales* was more abundant in soils with low clay content, and their species richness was influenced by the soil's pH, carbon and clay content. (Vieira et al. 2020).

Soil organic matter may have different effects on AMF species. The soils examined in this study had low amounts of organic matter, for this reason, it showed a positive correlation with the spore population of AMF and the root length colonization and a negative correlation with the species diversity of these fungi. This issue shows that organic matter in the soil improves the AM but limits the diversity of AMF species. Studies showed that adding organic matter to the soil sometimes can decrease the population of AMF (Ravnskov et al. 2006), and in some cases increase them (Albertsen et al. 2006, Gaur and Adholeya 2002).

Soil pH is one of the crucial and determining characteristics related to AM and can affect the performance and benefits of AMF on plant growth. The results show that soil pH has a negative correlation with the population of AMF and the degree of root length colonization and a positive correlation with the diversity of AMF species. The response of AMF to soil pH mainly depends on the fungus species. Mycorrhizal fungi react to soil pH highly variably. Some AMF species easily form mycorrhiza in low-pH soils, while other species form mycorrhiza in high-pH soils (Sieverding 1989, Alguacil et al. 2016) .

The amount of soil-soluble phosphorus in the samples examined in this study was not enough to negatively affect mycorrhiza symbiosis. AM traits were strongly linked with the quantity of soil-soluble phosphorus, indicating that even a minor increase in soil-soluble phosphorus would promote AM. Amiji et al. (1989) also have reported that only when the amount of soluble phosphorus in the soil exceeds 140 mg/kg, the amount of mycorrhizal colonization of roots decrease.

The positive correlation of plant phosphorus levels with the population and species richness of AMF indicates the usefulness of these fungi for the symbiotic plant. AMF can help plants to absorb more phosphorus (Fall et al. 2022).

Conclusion نتیجه‌گیری

This study showed that AMF is present in all wheat fields of Kohgiluyeh and Boyer Ahmad Province. These fungi are the species of 9 genera, *Acaulospora*, *Archaeospora*, *Entrophospora*, *Gigaspora*, *Claroideumglomus*, *Funeliformis*, *Rhizoglomus*, *Septoglomus*, and *Scutellospora* and their diversity in the samples (-2) 2.9 (-5) and *F. mosseae* with frequency 90% of species are dominant. The population of these fungi was negatively correlated with soil pH but positively correlated with soil-soluble phosphorus and plant phosphorus. The diversity of these fungi had a positive correlation with soil-soluble phosphorus. A positive correlation is observed between the amount of sand in the soil and the percentage of the colonization of roots. Therefore, these fungi in the soils with a light texture have a lower pH along with soluble phosphorus and organic matter with low amounts of population and more diversity. The positive correlation of the population of these fungi with plant phosphorus indicates their usefulness for the plant.

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