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THE IMPACT OF VESICULAR ARBUSCULAR FUNGI ON THE YIELD, FREE PROLINE CONCENTRATION AND RELATIVE WATER CONTENT OF WHEAT AND BARLEY IN IRAN'S DRY LAND CONDITIONS

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In dry stress conditions in the leaves of wheat and barley the concentration of proline increases and the amount of relative water content decreases in the tissues of the plant. The vesicular arbuscular fungi of the strains of *Glomus mossea, Glomus intraradices, Glomus etunicatum, Glomus caledonium*, as well as a mixture of them actively favor the formation of symbiosis with wheat and barley, which leads to an increase of the ability of plants in water uptake from rhizosphere and a decrease in accumulation of proline in the leaves compared to the control.

In variants treated with fungi a significant increase in the yield of the grains has been stated.

Dry land – vesicular arbuscular fungi – symbiosis – proline – relative water content – wheat – barley

Չորային պայմաններում ցորենի և գարու տերևներում նկատվում է պրոլինի քանակության ավելացում և բույսերի հյուսվածքներում ջրի հարաբերական պարունակության նվազում: Վեզիկուլյար արբուսկուլյար սնկերի *Glomus mossea, Glomus intraradices, Glomus etunicatum, Glomus caledonium* տեսակները և նրանց խառնուրդը ակտիվորեն նպաստում են բույսերի հետ սիմբիոզի առաջացմանը, որի արդյունքում ցորենի և գարու արմատների կողմից ավելանում է ջրի կլանումը ռիզոսֆերայից և նվազում պրոլինի կուտակումը տերևներում ստուգիչ բույսերի համեմատ: Սնկերի կիրառման տարբերակներում նկատելիորեն ավելանում է նաև հատիկի բերքը:

Չորային հող - վեզիկուլյար արբուսկուլյար սնկեր - սիմբիոզ - պրոլին - ջրի հարաբերական պարունակություն - ցորեն - գարի

В засушливых условиях в листьях пшеницы и ячменя наблюдается повышение концентрации пролина и уменьшение относительного содержания воды в тканях растений. Везикулярно-арбускулярные грибы видов *Glomus mossea, Glomus intraradices, Glomus etunicatum, Glomus caledonium*, а также их смесь, активно благоприятствуют формированию симбиоза с растениями пшеницы и ячменя, в результате чего повышается способность поглощения воды корнями из ризосферы и снижение аккумуляции пролина в листьях по сравнению с контрольными растениями.

В вариантах с применением грибов отмечалось также значительное повышение урожайности зерна.

Засушливая почва – везикулярно-арбускулярные грибы - симбиоз – пролин - относительное содержание воды – пшеница – ячмень

Dryness is one of the most critical stressful environmental factors, which affects agricultural production in arid and semi-arid regions and results in a decline in production [4, 5, 10, 12]. With average annual precipitation of 250 ml, Iran is among regions which experience dry stress in most of its dry land areas during the growing season [13].

Vesicular arbusculars are categorized as fungi which form symbiosis with different types of crops. They belong to the Zygomycetes order. In this symbiosis, as the fungus takes its required carbon in, it leads to more water and nutrient uptake by the plant and improves its growth [7]. In addition, multiple advantages have been reported, such as higher growth of the plant, higher yield, and greater resistance against biotic and abiotic stress [19].

According to their dependence on the above-mentioned fungi, plants differ from each other. Generally, the dependence of crops on these fungi range from very high to very low. The impact that fungi had on the wheat grown under moisture stress in a 75 day period shows that the dry mass and the amount of the output of the wheat inoculated by fungi had been two times as much as in the control plant [3]. Also, it is reported that the hydraulic conductivity of the root in mycorrhizal plants had been higher than that of the similar non-mycorrhizal plants [1]. Many eco-physiological studies put stress on the fact that mycorrhizal symbiosis brings about a decline in the amount of water [16]. Dry stress is in fact a decrease in hydraulic potential of the soil. Under such conditions the plant reduces its osmotic potential through concentration of osmotic components, including prolin amino acid [11].

The accumulation of proline in the tissues of plants which have been dehydrated was first reported in 1954 [15]. The increase in the concentration of this amino acid is connected with the disturbance of metabolic processes in the plant [8]. Other investigations suggest that proline plays a dominant role in osmotic processes in wheat tissues under dry stress [15]. Also, dry stress leads to a decrease in the relative water content (RWC) and a decline in the uptake of dioxide carbon and consequently, to the reduction in the yield of the plant.

Materials and methods. In this research, we have tried to examine the impact of the symbiosis between different strains of vesicular arbuscular fungi on the yield of Triticalea and barley under dry stress (dry land). The investigation was implemented in Kuhdasht County, Lorestan Province, at an elevation of 1200 m above sea level. Precipitation mean of the region in a ten years period was less than 390 millimeter.

Table 1. Results of physicochemical analyses of the examined soil

Cu	Mn	Zn	Fe	K	P	Texture	Sand	Silt	Clay	CaCO3	N	FC	EC(ds/m)	pH
mg/kg							%							
0.79	4.2	0.97	3.1	228	6.2	light loam	29	48	23	53.5	0.062	28	0.9	7.6

Table 1 contains the physicochemical characteristics of the soil in the region. According to international classifications, the used soil belongs to the semi-desert type of soils.

Precipitation in the region confirms that crops suffer moisture stress at the end of April (grain-filling period). During this period the efficiency of different strains of vesicular arbuscular fungi (strains Glomus mossea, Glomus intraradices, Glomus etunicatum, Glomus caledonium, the mixture of the mentioned strains) was studied on Triticalea and barley. The results have been compared with the control (without application of fungus).

After the emergence of the flag leaf, two flag leaves were picked from the experimental plot to measure the concentration of proline amino acid [2]. The relative water content (RWC) was measured by the following equation [10].

$$RWC=(Wf-Wd)\cdot 100/Wt-Wd$$

In this equation, Wf is the weight of fresh leaf, Wd is the weight of the dried leaf (dried in an oven at 70°C for 48 hours), Wt is the weight of the leaf after turgidity when it is left in distilled water for 48 hours. We measured the above-mentioned parameters to examine whether or not the colonization and improved water uptake would lead to a decrease in concentration of proline in the leaf and to an increase in relative water content. Also, Grind line Intersect Method was applied to evaluate the amount of colonization of Triticalea and barley with each strain of the fungi [6]. All the data obtained from the experiments have undergone mathematical statistical analysis [17, 18].

Results and Discussion. The obtained results suggested that the colonization of Triticalea and barley had a very significant effect on the free proline of the leaf, the relative water content, and the yield. The amount of proline increases in the leaves and other parts of the plant under dry stress. In variants treated with fungi the rate of colonization is 5% higher than in natural conditions (tab. 2). Among fungal treatments, Glomus mossea variant had the highest percentage of colonization and Glomus caledonium variant had the lowest colonization in the Triticalea's root, but there was no significant difference between the fungal treatments in the barley roots. The concentration of free prolin in the leaves in different treatments shows that the concentration of this component in the plants under treatment by the fungi was lower than that of the control so that at the level of 5% probability they are significantly different. The concentration of free proline in the leaves of both plants showed no significant difference among all the variants. Also, there was no significant difference between the fungal treatments. Also after the comparison of the relative water content in different treatments we came to the conclusion that the plants under fungal treatment had more moisture in their tissues compared with that of the control. Among fungal treatments Glomus caledonium treatment had the highest and the mixture of four strains had the lowest percentage of relative water content. The plants under fungal treatment had the higher yield than that of the control, so that at the level of 5% probability they were significantly different. Among fungal treatments, Glomus mossea treatment had the highest and Glomus etunicatum treatment the lowest yield.

Table 2. Comparison of average symbiotic effects of vesicular arbuscular strains on colonization, concentration of free proline, relative water content and the yield of Triticalea and barley

Crop	Treatment	Yield (kg/h)	RWC (%)	Proline (mg/gr leaf)	Colonization (%)
Triticalea	Control (without fungi)	1923 b	69.5 b	46.99 a	16 b
	Glomus mossea	2551 a	76.69 a	42.87 ab	28.50 a
	Glomus intraradices	2464 a	76.18 a	42.91 ab	28 a
	Glomus etunicatum	2404 a	75.47 a	43.03 ab	28.25 a
	Glomus caledonium	2504 a	77.53 a	41.63 c	27.25 a
	mixture of four strains	2485 a	74.27 a	43.52 b	28 a
Barley	Control (without fungi)	2093 a	68.44b	45.62 a	14.25 b
	Glomus mossea	2501 a	78.36 a	44.05 a	24 a
	Glomus intraradices	2363 a	76.24 a	43.30 a	22 a
	Glomus etunicatum	2357 a	76.03 a	44.11 a	22a
	Glomus caledonium	2466 a	79.60 a	42.30 a	24.25 a
	mixture of four strains	2408 a	76.16 a	43.81 a	24.25 a

Means, in each column, followed by similar letter(s) are not significantly different at the 5% probability level using Duncan's Multiple Range[17].

When plants are exposed to environmental stress such as dryness, salinity, heat and so on, they combat them by storing osmotic adjustments. Osmotic adjustments mostly include amino acids, carbohydrates, some inorganic ions, hormones and proteins.

Prolin is an amino acid which is active in the osmotic adjustment phenomenon, playing a major role in developing and maintaining osmotic pressure.

The increase in the concentration of proline amino acid helps the plant with osmotic adjustment. During dry stress, prolin concentrates in all the organs of the healthy plant. However, the amino acid concentrates most widely and extensively in leaves. In the process of osmotic adjustment, turgidity and the processes dependent on it continue under water shortage conditions. Therefore, osmotic adjustment helps the growth and cellular development in the plant under water stress [15].

In an experiment conducted to compare osmotic adjustment in different genotypes of wheat and barley it was determined that the varieties with high osmotic stability in their tissues show more stability in their yield under different stressful conditions including dryness. Dry stress results in decomposition and a decrease in concentration of protein in mature leaves and, as a result, amino acids, such as proline, begin to increase [20]. The rise in the concentration of prolin under stressful conditions may demonstrate its probable role in osmotic adjustment. Also, researchers show that dry stress leads to a decline in hydraulic potential of the plant and relative water content [14].

In this study, the control treatment has the highest level of prolin in its tissues due to the dry stress dominating the region. On the other hand, fungal treatments have experienced less stress and less concentration of prolin in their tissues due to the role of the mentioned fungi in the improved uptake of the moisture present in the porous space of soil; so that the control treatment, compared with other treatments, has more proline in its tissues.

But it seems that the existence of symbiosis and formation of colonization between the plant and fungi lead to the more effective uptake of moisture from the soil and it makes its presence felt when the amount of RWC increases. On the other hand, the effective colonization creates more effective conditions for water uptake by the plant in grain-filling period.

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