

Study of vesicular arbuscular mycorrhizal (VAM) fungi symbiosis with maize root and its effect on yield components, yield and protein content of maize in water deficit condition

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ABSTRACT: In order to study the effect of vesicular arbuscular mycorrhizal (VAM) fungi coexistence and water deficit on maize, a field experiment in split plot as complete randomized block design with three replications was conducted in 2011 in Goharkouh region, Iran. VAM treatments were composed of V_0 : Without consumption of, V_1 : Consumption of 80 kg/ha VAM, V_2 : Consumption of 100 kg/ha VAM, V_3 : Consumption of 120 kg/ha VAM and V_4 : Consumption of 140 kg/ha VAM, as main-plots, and water stress treatments composed of S_0 : Without stress (optimum irrigation), and water stress at two stages of growth S_1 : 20 days after appearing male flowers and S_2 : 20 days after appearing female flowers as sub-plots. In this experiment, factors of the number of seed per fruit, biological yield, seed yield, harvest index and protein content were measured. The results showed that the most amount of the number of seed per fruit, biological yield, seed yield and harvest index obtained from S_0V_4 treatment. For factor of protein content, the highest amount was achieved from S_2V_1 treatment.

Keywords: Maize, Yield, Stress, Mycorrhizal fungi.

INTRODUCTION

Soil contamination due to the disposal of chemical fertilizer and urban wastes generated by human activities has become a major environmental concern. Controlled and uncontrolled disposal of wastes to agricultural soils are responsible for the migration of contaminants into non-contaminated sites (Ghosh and Singh, 2005). Soil contamination by chemical fertilizer and heavy metals may pose a threat to human health, if the metals enter the food chain (Berti and Jacobs, 1996). So, use of biofertilizers such as Mycorrhizal fungi is a suitable substitution for chemical fertilizers in agriculture ecosystem.

Vesicular-arbuscular mycorrhizas (VAM) are widespread in field crops and many investigations have demonstrated that plant growth may be increased by them (Jeffries, 1987). In short season crops a significant effect of VAM on plant growth must depend on early infection (Tinker, 1975); this in turn is related to inoculum density, which can be increased either through inoculation or through judicious manipulation of agronomic practices (Sieverding, 1986).

Mycorrhizal fungi function as an interface between plants and the soil (Bethlenfalvay, 1992), and without these associations grow poorly because of a reduced capacity to acquire the soil resources needed for growth (Perry et al., 1987).

Arbuscular mycorrhizal fungi (AMF) are symbiotic soil fungi that colonize roots of about 80% of vascular plants. The mycorrhizal symbiosis enhances the growth and survival of numerous plant species (Smith and Read, 1997). The establishment of the highly complex mycorrhizal association requires a continuous exchange of signals between the host roots and AMF, which affects the whole metabolism of the host (Smith and Read, 1997).

Studies have shown that use of VAM in agriculture ecosystem led to increase of crops yield. Vamerali et al, (2003) reported that in maize was seen biomass increase when maize seeds were inoculated with VAM before planting.

They concluded that better transfer of water and nutrients, also increase of plant photosynthesis led to biomass yield increase. Sajedi and Madani, (2006) reported that consumption of mycorrhizal increased yield components of maize both in condition of optimum irrigation and in condition of water deficit than treatment of without mycorrhizal consumption. Hajilou et al, (2010) showed that mycorrhizal consumption has significant effect in probability level of 5% on the number of seed per fruit.

The aim of this study was to investigate mycorrhiza effects on developmental processes of maize plants in water deficit condition.

MATERIALS AND METHODS

In order to study of effect of vesicular arbuscular mycorrhizal (VAM) fungi coexistence and water deficit on maize, a field experimental was conducted in 2011 in Goharkouh region, Iran. The site lies at longitude 57°45' E, and latitude 37°26' N and the altitude of the area is 1067 m above sea level. It has a semi-arid climate, with cold winters and dry and warm summers. The precipitation average of region has been reported about 250 mm.yr⁻¹. The soil characteristics of experimentation place is clay-loam in texture, pH = 7.4 and EC = 2.1 ds.m⁻¹ (The soil properties prior to the experiment is shown in Table 1).

Table 1. chemical characteristics of soil

pH	EC (ds/m)	Total N (%)	(%)	P (ppm)	K (ppm)	Ca (meq/lit)
7.4	2.1	0.023		1.29	242	12.1

This experiment was conducted with use of split plot as complete randomized block design with three replications. VAM treatments were composed of V₀: Without consumption of, V₁: Consumption of 80 kg/ha VAM, V₂: Consumption of 100 kg/ha VAM, V₃: Consumption of 120 kg/ha VAM and V₄: Consumption of 140 kg/ha VAM, as main-plots, and water stress treatments composed of S₀: Without stress (optimum irrigation), and water stress at two stages of growth S₁: 20 days after appearing male flowers and S₂: 20 days after appearing female flowers as sub-plots.

Each block was including 15 plots. The size of each plot was 3m×4m, and there was in each plot, 4 rows with a distance of 75 cm, and the length of 4 m. The distance between plots was selected 150 cm, and the distance between blocks was selected 3 m. After plotting and before the planting, 150 kg/ha sulfate of potassium was given to experimental plots. And also 250 kg/ha nitrogen fertilizer from urea source was added to plots. The consumption of nitrogen fertilizer was done in three equal parts and three stages (Planting, 10 leafy and flowering). The other operations of cultivation (wedding, irrigation, control of pests and diseases) was done as it required. Seeds before planting were inoculated with VAM fungi. Maize seeds, Single Cross 704 cultivar, were planted at 10 may 2011. In this research, factors of the number of seed per fruit, biological yield, seed yield, harvest index and protein content were measured.

For determining of the biological yield, primarily the weight of fresh forage was measured in samples, then it transferred to Oven (within a period of 48 hours and in temperature of 70°C), and finally biological yield of maize measured and it was reported as kg/ha.

Harvest index was calculated by equation 1:

$$HI = \frac{\text{Seed yield}}{\text{Biological yield}} \times 100 \quad (1)$$

For measuring seed protein was used from Kejedal method.

At the final, data were analyzed using SAS software; mean comparison was done using Duncan Multiple Comparison at 5% probability level.

RESULTS AND DISCUSSION

The number of seed per fruit

The analysis of variance showed that interaction effect of water stress and mycorrhizal consumption was significant on the number of seed per fruit (P<5%) (Table 2). The most and the lowest the number of seed per fruit obtained from S₀V₄ and S₁V₀ respectively (Figure 1). Sajedi and Madani, (2006) reported that consumption of mycorrhizal increased yield components of maize both in condition of optimum irrigation and in condition of water

deficit than treatment of without mycorrhizal consumption. Hajilou et al, (2010) showed that mycorrhizal consumption has significant effect in probability level of 5% on the number of seed per fruit.

Table 2. Analysis of variance on factors measured

SOV	df	The number of seed per fruit	biological yield	seed yield	harvest index	protein content
		Mean Square				
VAM	4	22240.2*	362539403.0*	5802258.8*	93.9*	0.079 n.s
Error _a	8	3459.1	575139705.0	720320.5	8.5	0.171
Water stress	2	4609.7n.s	103752926.0*	3629840.0*	125.9*	0.029 n.s
Water stressx VAM	8	2435.76 *	141341643.0 *	582628.8 *	33.7 *	0.458*
Error	20	4374.6	140146206.0	647307.7	17.9	0.195
C.V (%)	-	15.2	28.2	29.1	27.5	3.1

ns, * and **, Non-significant, significant at 5% and 1% probability levels, respectively

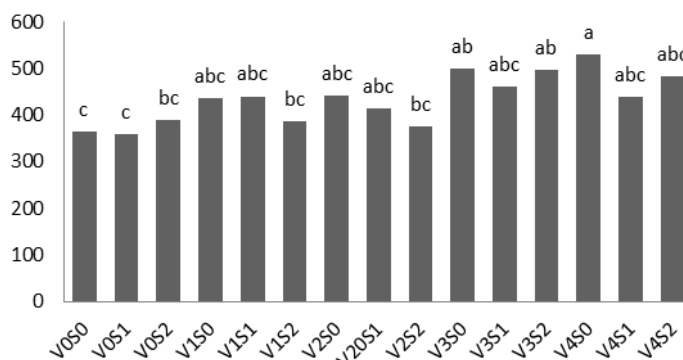


Figure 1. Interaction effect of VAM and water stress on the number of seed per fruit

Biological and seed yield

The analysis of variance showed that interaction effect of water stress and mycorrhizal consumption was significant on the number of seed per fruit (P<5%) (Table 2).

The most biological and seed yield obtained from V4S0 with yield mean of 41060 kg/ha and 4233 kg/ha respectively (Figure 2 and 3). Vamerali et al, (2003) reported that in maize was seen biomass increase when maize seeds were inoculated with VAM before planting. They concluded that better transfer of water and nutrients, also increase of plant photosynthesis led to biomass yield increase. Sajedi and Madani, (2006) reported that consumption of mycorrhizal increased maize yield both in condition of optimum irrigation and in condition of water deficit than treatment of without mycorrhizal consumption. Elwan, (2001) stated that yield decrease in water deficit condition is because of abnormal development of embryo and seed. Also Elwan, (2001) reported that maize seed inoculation can increase maize yield by reason of mycorrhizal positive effects on root growth increase, nutrients uptake increase by root, nitrogen fixation activity increase and phytohormone productions increase.

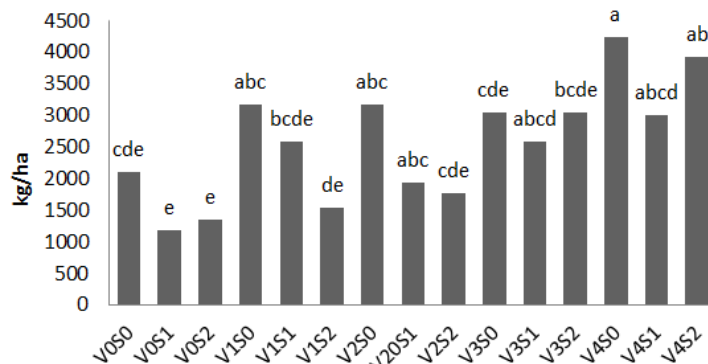


Figure 2. Interaction effect of VAM and water stress on seed yield

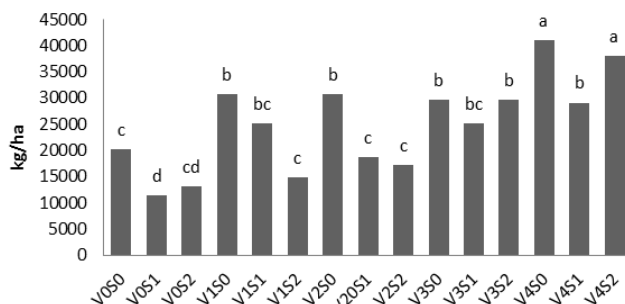


Figure 3. Interaction effect of VAM and water stress on biological yield

Harvest index

The analysis of variance showed that interaction effect of water stress and mycorrhizal consumption was significant on harvest index ($P < 5\%$) (Table 2).

The most and the lowest harvest index obtained from S_0V_4 (22.01) and S_1V_0 (7.22) respectively (Figure 4). Karami, (2011) reported mycorrhizal consumption and optimum irrigation increased sunflower yield than stress treatment and without mycorrhizal consumption. Sajedi and Madani, (2006) reported that consumption of mycorrhizal increased harvest index than treatment of without mycorrhizal consumption. Mehraban, (2009) reported similar results with this research.

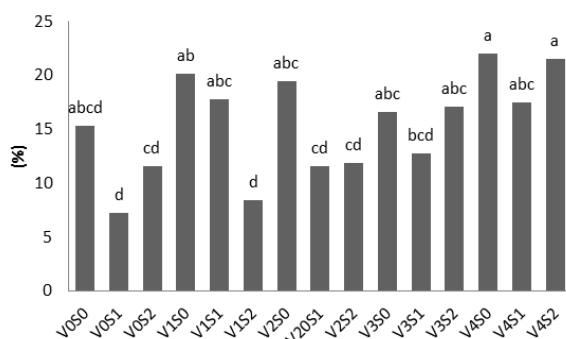


Figure 4. Interaction effect of VAM and water stress on harvest index

Protein content

The analysis of variance showed that interaction effect of water stress and mycorrhizal consumption was significant on protein content ($P < 5\%$) (Table 2).

The most and the lowest protein content obtained from treatments of S_1V_4 (13.70 kg/ha) and S_1V_0 (12.57 kg/ha) respectively (Figure 5).

Karami, (2011) reported mycorrhizal consumption and water stress increased sunflower protein content than optimum irrigation treatment and without mycorrhizal consumption. Sajedi et al, (2011) this same results obtained for maize. Khourgami et al, (2010) concluded that with decrease of amount of irrigation water than optimum irrigation, seed protein content of maize increased significantly.

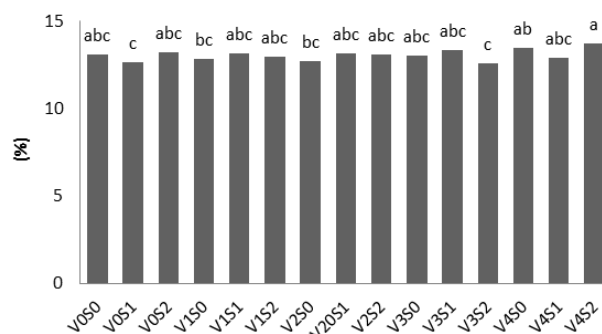


Figure 5. Interaction effect of VAM and water stress on protein content

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