African Journal of Agricultural Research Vol. 6(24), pp. 5481-5489, 26 October, 2011
Available online at http://www.academicjournals.org/AJAR
DOI: 10.5897/AJAR11.101

Full Length Research Paper

Effects of mycorrhizal symbiosis and different levels of phosphorus on yield, macro and micro elements of *Zea mays* L. under water stress condition

D. Ghorbanian[1]*, S. Harutyunyan[1], D. Mazaheri[2] and F. Rejali[3]

[1]State Agrarian University of Armenian, Armenia.
[2]University of Tehran, Iran.
[3]Soil and Water Research Institute of Iran, Iran.

Accepted 28 September, 2011

Nowadays, Mycorrhizal fungi are widely used due to their symbiosis relation with roots of so many plants. These fungi, by supplying some of plant nutritional and water requirements, have a key role in all ecosystems. In this research the effects of mycorrhizal fungi and different levels of phosphorous chemical fertilizers on yield and nutrient uptake under three levels of irrigation were studied. This experiment was performed in fully randomized blocks and as a split factorial design with four replications in which different irrigation levels (A1, A2, A3) (60.120.180 mm) were placed in the main plots while different phosphor levels including P1=0 kg/ha, P2=60 kg/ha and P3=120 kg/ha of pure phosphorus were placed in the subplots. Half of these subplots inoculated by mycorrhizal fungi and the others regarded as uninoculated ones in inoculated sub plots, at seed sowing, 6 g of Mycorrhizal inoculums were placed 3 cm under the each seed. The results indicated that the effects of Mycorrhizal inoculation were statistically significant and positive on measured characteristics. Among triple interactions irrigation/chemical phosphorus/mycorrhizal inoculation had significant effects ($P<0.05$, 5045 kg/ha) on grain yield and ($P<0.01$) on Phosphorus concentration. Highest grain yield and other yield component were in A1P2G2 treatment. Results showed that in moderate water stress, by using proper amount of chemical phosphorus and mycorrhizal inoculation can compensate decrease in grain yield. Other treatments had significant difference with A2P2G2 which means by increasing water stress, increasing or decreasing amount of chemical phosphorus and without mycorrhizal inoculation grain yield of corn will decrease significantly. However, such mycorrhizal ability can help us to decrease amount of phosphorus chemical fertilizes in corn growth. Moreover, under water stress, mycorrhizal inoculation improved most of measured indexes. Therefore this kind of biofertilizer can have an important key role in agriculture of arid and semiarid climates.

Key words: Mycorrhizal symbiosis, phosphorus, water stress, corn.

INTRODUCTION

Water is much necessary for plant growth and production because of its important functioning in plant including solubilization and hence uptake of nutrients and their movement in the plant, plant transpiration, and creating the necessary pressure for the growth and development of plant cells Hence, under drought stress plant activities such as photosynthesis , activities of nitrate reducing and hydrolyzing enzymes (like amylase) decrease, which eventually reduce plant growth and production (Munns, 2002). Plant morphological and biochemical responses to drought stress vary with stress intensity. Corn cellular development decreases under moderate to medium drought stress, which eventually reduces plant growth (Laffitte and Edmeades, 1995). Lam (2004) showed that corn can be planted using minimum level of irrigation water. Nonetheless, under such conditions corn yield and some of its qualitative characters may be adversely affected.

Many researchers have indicated that arbuscular

*Corresponding author. E-mail: diyako_ghorbaniyan@yahoo.com.

mycorrhizal (AM) fungi are capable of alleviating the unfavorable effects of drought on plant growth (Auge, 2001; Miransari et al., 2010). Symbiotic relationship between AM fungi and a variety of plants produces colonies on the exterior part of root system resulting in the enhanced uptake of water and nutrients by the plant roots. Such characters improve plant performance under drought stress, which is believed to be in part related to the increased absorption of water and some nutrients such as zinc (Zn) and copper (Cu) improved plant variables may include leaf height, leaf water turgidity, stomatal activities, and root growth and development (Ghazi and Zak, 2003). AM fungi perform as the enhancer of plant-water relationship through increasing stomatal resistance by adjusting plant hormonal balance. Moreover, this chain of improvements enhances plants phosphorous (P) nutrition introduced by AM fungi activities under growth conditions (Elwan, 2001). Mycorrhizal fungi have a long history in having symbiosis relation with most plants families and they are existing in most ecosystems. Most plants (about 95% of vascular plants) include at least one type of Mycorrhizal (Salehrastin, 1998). Some Mycorrhiza types develop inside the root and also produce two specific organs named Vesicule and Arbuscule. That is why they are called Vesicular Arbuscular Mycorrhiza, briefly called VAM. Vesicule usually plays a storage role for the fungus and the organ's Arbuscul plays an exchanging role between the fungus and the plants. Hence, in the new references, it is called Arbuscular Mycorrizal fungi's (AM) (Salehrastin, 1998). Nowadays a special attention is paid to the potential role of these fungi in agricultural production due to their ability to increase water and nutrient uptake of agricultural plants (Sardi, 1992). One of the most important effects of Mycorrhizal fungi is increasing the yield of agricultural plants especially in soils of low fertility. Such an increase may be due to the increase in the absorption of the roots as a result of the wide extension of fungus mycelium in the soil around the root system that allows the agricultural plant to have access to higher volume of soil (Hayman 1983). Application of *Glomus mosseae* improved the growth of aerial part for 30% and applying *Glomus caledonium* for alfalfa improved the yield of this plant compared to non inoculated plant. Ortas(1996) stated that Mycorrhiza fungus accelerated plant growth and affected the transfer of biomass in the root and in the stem and because of higher absorption of nutritional elements, the dried weight of aerial plant parts increased in white trifolium in mycorrhiza bushes, the effect of application of 150 mg phosphor in each kilogram of soil proved statistically significant as to developing the hypha, the weight of the dried aerial organs, and density of phosphor in the aerial organs, compared to those bushes that received 50 mg phosphor (Lin et al., 1991). Phosphorous is one of main elements needs for plants. This element in flowering, root extending and grain yield have necessary roles. One of the benefit methods for efficiency if use the phosphorous is apply of AM fungi. Mycorrhizal fungi by symbiosis with plants roots and extending hyphae's into soils be cases absorption better phosphorous (Cox and Tinker, 1976). In corn and sorghum, leaf surface, weight of dried aerial organs, net surface of leaves, pressure potential of the wooden vessel, and water and soil potentials proved to be the same in phosphorus and mycorrhizal treatments (Osonubi, 1994). Tarafdar et al. (1994) showed that the increase in the percentage of mycorrhiza applied to the corn root had significant effect on the absorption of phosphor, zinc, and copper, while it has no significant effect on the absorption of Fe. George et al. (1994) declared that root mycorrhizal symbiosis percentage had a negative correlation with the amount of phosphorus exist in the soil. Shiranirad (1998) found out that mycorrhizal symbiosis had the statistically significant effect on phosphorus absorption when the amount of phosphorus in soil is low.

MATERIALS AND METHODS

This experiment was carried out within 2 years 2008 and 2009 in the agricultural farm of Islamic Azad University / Takestan Branch in Ghazvin Province. The latitude of the region is northern 36.6 and eastern 49.39 of Iran Country and the altitude is 1325 m. According to kopen,s classification, the climate of this region is CSBS that is moderate climate with hot and dry summers. The mean rainfall is 250 mm and means temperature during the last five years has been 14 in the days. Rainfall is mainly during fall and winter. This experiment was performed in fully randomized blocks and as a split factorial design with four replications. The factors studied included: different amounts of irrigation including A1, A2, A3 of the main plots for 60, 120 and 180 mm evaporation respectively from the class A vapor basin, and different levels of pure phosphorus supplied from triple super phosphate source applied to different levels of P1, P2, P3, for 0, 60 and 120 kg/ha respectively. Azotes, phosphorus and potassium used from the source of urea 46%, super phosphate triple 46% and sulfate potassium 50%. Mycorrhiza fungi were combination of different species including *Glomus mossea, Glomus intraradices, Glomus etunicatum* with nearly equal spore population. mycorrhizal inoculums applied levels of non inoculation (g1) and inoculation (g2) respectively, referring to without inoculation and inoculation. To prepare the plots, as it was customary in the region, the land was ploughed once and two discs were devised in the land in a vertical position. After clarification of the plan of the main and sub plots, various amounts of Phosphor fertilizer in addition to other macro and micro elements were weighed according to soil test (Table 1) and were mixed with the soil (Fe, Mn_4O and Zn, Cu_2Okg/ha). Each subplot included five rows, and 8 m length each. The distance between each two rows was 70 cm. The corn seeds were planted at a distance of 20 cm on each row. Each plot included 6 subplots. To prevent water of different plots from being mixed, each main plot was made at distance from one another and in between by two water canals. Data of planting was on 4th May, 2008 and 2009. The hybrid used was Jeta planted with a density of 71000 Plants per ha and the irrigation was performed steadily in the form of furrow and it continued until a date when the height of the bushes reached to 20 cm above the ground. Next the irrigation was performed based on the degree of vapor in the basin and according to the treatments. At the end of corn growth period, the seed yield and other attributes were assessed by randomly selected one square meter of

Table 1. Soil physical and chemical analysis.

Mn (mg/kg)	Cu (mg/kg)	Zn (mg/kg)	Fe (mg/kg)	Ec (ds/m)	pH	O.C (%)	K (mg/kg)	P (mg/kg)	N (%)	Sand (%)	Silt (%)	Clay (%)	Texture
0.78	0.78	2.42	2.5	1.7	7.5	1.52	408	8	0.05	46	40	14	Loam

Table 2. Analysis of variance characters.

S.O.	DF	Grain yield	Ca (%)	N (%)	P concentration (g/kg)	K (%)	Cu (%)	Zn (%)	Fe (%)
Replication	3	360659.370	0.000	0.10	0.000	0.003	0.158	0.629	27.327
Year (A)	1	696112.111$^{n.s}$	0.007*	0.014*	0.001$^{n.s}$	0.000$^{n.s}$	5.844*	0.514$^{n.s}$	13.020 $^{n.s}$
Error	3	257088.407	0.000	0.000	0.000	0.004	0.361	0.916	6.962
Irrigation (B)	2	39434744.11**	0.105**	0.044**	0.020**	0.089**	55.662**	96.240**	3012.099**
AB	2	290668.111$^{n.s}$	0.003*	0.003$^{n.s}$	0.002*	0.004$^{n.s}$	0.877*	3.290**	10.891 $^{n.s}$
Error	12	105945	0.001	0.002	0.000	0.001**	0.174	0.373	5.289
Phosphorus (C)	2	2305518.861**	0.059**	0.018**	0.010**	0.111**	14.230**	15.386**	781.651 **
AC	2	438134.194**	0.001	0.009*	0.001	0.014**	0.172$^{n.s}$	0.434$^{n.s}$	18.889 $^{n.s}$
BC	4	462971.194**	0.011**	0.002$^{n.s}$	0.005**	0.013**	2.860**	0.594$^{n.s}$	75.968 **
ABC	4	116005.194$^{n.s}$	0.001$^{n.s}$	0.005$^{n.s}$	0.001$^{n.s}$	0.002$^{n.s}$	0.189$^{n.s}$	1.315**	5.003 $^{n.s}$
Mycorrhiza (D)	1	5201440.444**	0.00$^{n.s}$	0.006$^{n.s}$	0.014**	0.010*	16.667**	1.480*	13.020 n$^{.s}$
AD	1	207328.444$^{n.s}$	0.00$^{n.s}$	0.007$^{n.s}$	0.000	0.00$^{n.s}$	2.536**	3.240**	59.162 *
BD	2	1880094.778**	0.00$^{n.s}$	0.001$^{n.s}$	0.010**	0.004$^{n.s}$	1.604**	0.094$^{n.s}$	15.908 $^{n.s}$
ABD	2	35467.444$^{n.s}$	0.00$^{n.s}$	0.001$^{n.s}$	0.000	0.002$^{n.s}$	0.079$^{n.s}$	0.564$^{n.s}$	9.066 $^{n.s}$
CD	2	391947.528**	0.00$^{n.s}$	0.001$^{n.s}$	0.005**	0.0$^{n.s}$	1.427**	1.060*	1.664 $^{n.s}$
ACD	2	21248.861$^{n.s}$	0.00$^{n.s}$	0.001$^{n.s}$	0.000	0.002^{ns}	1.081*	0.100^{n}	2.710 $^{n.s}$
BCD	4	212368.111*	0.00$^{n.s}$	0.003$^{n.s}$	0.003**	0.003$^{n.s}$	0.290$^{n.s}$	0.349$^{n.s}$	7.676 $^{n.s}$
ABCD	4	105421.611$^{n.s}$	0.001	0.003$^{n.s}$	0.00$^{n.s}$	0.00$^{n.s}$	0.097$^{n.s}$	0.653*	2.008 $^{n.s}$
Error	90	64705.296	0.001	0.002	0.000	0.002	0.236	0.251	9.913
Coefficient of variation CV (%)		6.71	7.95	5.80	10.68	5.08	4.42	2.77	3.79

n.s*and **: Non significant at the 5% and 1% level of probability respectively.

each sub plot. Soil texture was determined using the hydrometric method (Gee and Bauder, 1986). pH of a saturated paste (Rhoades, 1982), organic carbon (wet oxidation method, Nelson and Sommers, 1982), total nitrogen (Kjeldahl method, Nelson and Sommers, 1973), available phosphorus (sodium bicarbonate extraction method, Olsen, 1954), and potassium (flame photometer method, emission spectrophotometry, Knudsen et al., 1982), iron and manganese (Dithyenetriaminepentaacetic acid (DTPA) method, Baker and Amachar, 1982, using atomic absorption spectrometer, Model Perkin Elmer 3110) were also determined. The statistical analysis was performed through Mstatc and Excel Software.

RESULTS

According to the analysis of variance (Table 2), irrigation treatments had significantly effects (P<0.01) on all studied parameters. Highest grain yield (4429 kg/ha) was in sufficient irrigation (A1) treatment and highest Nitrogen (0.813%) and Potassium percentage (0.820) were in moderate water stress (A2) treatments which had not significant difference with A1 treatment. Interaction effects of irrigation/inoculation had significant

Table 3. Mean comparison of interaction effects of characters.

Treatment	Grainyield(kg/ha)	Ca(%)	N(%)	(P)Density(g/kg)	K(%)	Cu(%)	Zn(%)	Fe(%)
Irrigation: A1	4429^{a}	0.429^{a}	0.813^{a}	0.219^{a}	0.820^{a}	12.100^{a}	19.523^{a}	91.006^{a}
A2	4195^{b}	0.401^{b}	0.790^{a}	0.197^{b}	0.820^{a}	10.919^{b}	18.052^{b}	82.792^{b}
A3	2755^{c}	0.338^{c}	0.752^{b}	0.178^{c}	0.746^{b}	9.950^{c}	16.652^{c}	75.167^{c}
Phosphorus P1	3619^{b}	0.430^{a}	0.789^{a}	0.182^{c}	0.826^{a}	11.465^{a}	18.669^{a}	87.125^{a}
P2	4039^{a}	0.375^{b}	0.802a	0.211^{a}	0.820^{a}	11.108^{b}	18.060^{b}	82.777^{b}
P3	3722^{b}	0.364^{b}	0.764^{b}	0.201^{b}	0.740^{b}	10.396^{c}	17.537^{c}	79.063^{c}
Irrigation Mycorriza+A1g1	4246^{b}	0.429^{a}	0.802^{a}	0.192^{c}	0.817^{a}	12.631^{a}	19.371^{b}	90.063^{a}
A1g2	4613^{a}	0.430^{a}	0.823^{a}	0.245^{a}	0.824^{a}	11.569^{b}	19.675^{a}	91.950^{a}
A2g1	3804^{c}	0.399^{a}	0.782^{a}	0.193^{c}	0.802^{a}	11.242^{b}	17.971^{c}	82.958^{a}
A2g2	4586^{a}	0.404^{a}	0.798^{a}	0.201^{b}	0.839^{a}	10.596^{c}	18.133^{c}	82.625^{a}
A3g1	2760^{d}	0.339^{a}	0.752^{a}	0.179^{d}	0.742^{a}	10.117^{d}	16.621^{d}	75.042^{a}
A3g2	2751^{d}	0.337^{a}	0.752^{a}	0.178^{e}	0.749^{a}	9.783^{d}	16.762^{d}	75.292^{a}
Irrigation+Phosphorus A1p1	4167^{cd}	0.502^{a}	0.822^{a}	0.187^{e}	0.882^{a}	12.884^{a}	20.100^{a}	95.250^{a}
A1p2	4684^{a}	0.400^{c}	0.831^{a}	0.253^{a}	0.829^{bc}	12.429^{b}	19.450^{a}	89.706^{b}
A1p3	4437^{b}	0.386^{c}	0.785^{a}	0.215^{b}	0.749^{e}	10.987^{cd}	19.019^{a}	88.063^{bc}
A2p1	3956^{d}	0.435^{b}	0.786^{a}	0.182^{f}	0.843^{ab}	11.425^{c}	18.850^{a}	86.125^{c}
A2p2	4368^{bc}	0.391^{c}	0.801^{a}	0.200^{d}	0.835^{bc}	10.844^{de}	17.956^{a}	81.625^{d}
A2p3	4260^{bc}	0.377^{cd}	0.782^{a}	0.209^{c}	0.783^{de}	10.488^{ef}	17.350^{a}	80.625^{d}
A3p1	2733^{f}	0.352^{de}	0.760^{a}	0.177^{i}	0.752^{e}	10.087^{fg}	17.056^{a}	80.000^{d}
A3p2	3065^{e}	0.333^{e}	0.774^{a}	0.179^{g}	0.797^{cd}	10.050^{fg}	16.775^{a}	77.000^{e}
A3p3	2468^{g}	0.329^{e}	0.724^{a}	0.178^{h}	0.687^{f}	9.712^{g}	16.244^{a}	68.500^{f}
Phosphorus+Mycorriza P1g1	3500^{d}	0.428^{a}	0.779^{a}	0.181^{f}	0.187^{a}	11.987^{a}	18.396^{a}	86.854^{a}
P1g2	3737^{bc}	0.431^{a}	0.779^{a}	0.184^{e}	0.835^{a}	10.943^{c}	18.942^{a}	87.396^{a}
P2g1	3747^{bc}	0.375^{a}	0.798^{a}	0.190^{d}	0.812^{a}	11.427^{b}	18.042^{a}	82.646^{a}
P2g2	4331^{a}	0.375^{a}	0.806^{a}	0.231^{a}	0.828^{a}	10.788^{c}	18.079^{a}	82.908^{a}
P3g1	3562^{cd}	0.364^{a}	0.759^{a}	0.194^{c}	0.732^{a}	10.575^{cd}	17.525^{a}	78.563^{a}
P3g2	3882^{b}	0.365^{a}	0.768^{a}	0.208^{b}	0.748^{a}	10.217^{d}	17.550^{a}	79.563^{a}
Irrihation+Phosphorus+Mycorriza A1p1g1	4038^{ef}	0.502^{a}	0.819^{a}	0.185^{gh}	0.892^{a}	13.650^{a}	19.600^{a}	93.653^{a}
A1p1g2	4297^{cde}	0.501^{a}	0.826^{a}	0.189^{f}	0.872^{a}	12.118^{a}	20.600^{a}	96.938^{a}
A1p2g1	4312^{cde}	0.399^{a}	0.804^{a}	0.206^{d}	0.831^{a}	13.044^{a}	19.400^{a}	89.188^{a}

Table 3. Contd.

A1p2g2	5056^{a}	0.401^{a}	0.857^{a}	0.300^{a}	0.827^{a}	11.815^{a}	19.500^{a}	90.225^{a}
A1p3g1	4387^{cd}	0.386^{a}	0.783^{a}	0.186^{g}	0.728^{a}	11.200^{a}	19.113^{a}	87.438^{a}
A1p3g2	4487^{c}	0.386^{a}	0.788^{a}	0.245^{b}	0.771^{a}	10.775^{a}	18.925^{a}	88.688^{a}
A2p1g1	3724^{g}	0.428^{a}	0.767^{a}	0.180^{j}	0.818^{a}	11.950^{a}	18.688^{a}	87.125^{a}
A2p1g2	4187^{de}	0.443^{a}	0.805^{a}	0.184^{i}	0.868^{a}	10.900^{a}	19.013^{a}	85.125^{a}
A2p2g1	3918^{fg}	0.394^{a}	0.808^{a}	0.184^{hi}	0.815^{a}	11.025^{a}	17.975^{a}	81.625^{a}
A2p2g2	4818^{ab}	0.388^{a}	0.794^{a}	0.216^{c}	0.854^{a}	10.663^{a}	17.938^{a}	81.625^{a}
A2P3g1	3768^{g}	0.374^{a}	0.770^{a}	0.215^{c}	0.772^{a}	10.750^{a}	17.250^{a}	80.125^{a}
A2P3g2	4752^{b}	0.380^{a}	0.794^{a}	0.202^{e}	0.794^{a}	10.22^{a}	17.450^{a}	81.125^{a}
A3p1g1	2737^{i}	0.355^{a}	0.752^{a}	0.176^{l}	0.741^{a}	10.362^{a}	16.900^{a}	79.875^{a}
A3p1g2	2728^{i}	0.349^{a}	0.767^{a}	0.178^{k}	0.764^{a}	9.813^{a}	17.212^{a}	80.125^{a}
A3 p2g1	3012^{h}	0.331^{a}	0.781^{a}	0.181^{j}	0.791^{a}	10.212^{a}	16.750^{a}	77.125^{a}
A3 p2g2	3118^{h}	0.335^{a}	0.767^{a}	0.178^{k}	0.803^{a}	9.888^{a}	16.800^{a}	76.875^{a}
A3P3g1	2531^{ij}	0.330^{a}	0.724^{a}	0.180^{j}	0.696^{a}	9.775^{a}	16.212^{a}	68.125^{a}
A3P3g2	2406^{j}	0.328^{a}	0.723^{a}	0.177^{kl}	0.678^{a}	9.650^{a}	16.275^{a}	68.875^{a}
Year								
Y1	3724^{a}	0.383^{b}	0.775^{a}	0.195^{a}	0.795^{a}	10.788^{b}	18.029^{a}	83.289^{a}
Y2	3863^{a}	0.396^{a}	0.795^{a}	0.200^{a}	0.796^{a}	11.191^{a}	18.149^{a}	82.688^{a}
Y1A1	4449^{a}	0.415^{b}	0.802^{a}	0.223^{a}	0.810^{a}	11.831^{b}	19.396^{a}	90.783^{a}
Y1A2	4091^{a}	0.403^{b}	0.772^{a}	0.189^{d}	0.822^{a}	10.629^{d}	17.771^{c}	83.500^{a}
Y1A3	2631^{a}	0.329^{c}	0.751^{a}	0.176^{f}	0.754^{a}	9.904^{e}	16.921^{d}	75.583^{a}
Y2A1	4410^{a}	0.444^{a}	0.823^{a}	0.214^{b}	0.831^{a}	12.369^{a}	19.650^{a}	91.229^{a}
Y2A2	4298^{a}	0.399^{b}	0.808^{a}	0.205^{c}	0.819^{a}	11.208^{c}	18.333^{b}	82.083^{a}
Y2A3	2880^{a}	0.347^{c}	0.754^{a}	0.180^{e}	0.737^{a}	9.996^{e}	16.463^{d}	74.750^{a}
Y1P1	3484^{d}	0.425^{a}	0.781^{a}	0.181^{a}	0.845^{a}	11.204^{a}	18.708^{a}	88.000^{a}
Y1P2	3925^{b}	0.370^{a}	0.805^{a}	0.213^{a}	0.813^{ab}	10.906^{a}	17.992^{a}	82.408^{a}
Y1P3	3762^{bc}	0.353^{a}	0.739^{a}	0.194^{a}	0.728^{c}	10.254^{a}	17.387^{a}	79.458^{a}
Y2P1	3753^{bc}	0.435^{a}	0.798^{a}	0.183^{a}	0.807^{b}	11.727^{a}	18.629^{a}	86.250^{a}
Y2P2	4154^{a}	0.379^{a}	0.799^{a}	0.208^{a}	0.828^{ab}	11.309^{a}	18.129^{a}	83.146^{a}
Y2P3	3682^{c}	0.376^{a}	0.788^{a}	0.208^{a}	0.752^{c}	10.537^{a}	17.688^{a}	78.667^{a}
Y1g1	3496^{a}	0.383^{a}	0.762^{a}	0.188^{a}	0.786^{a}	11.261^{ab}	17.778^{b}	82.347^{b}
Y1g2	3952^{a}	0.383^{a}	0.788^{a}	0.204^{a}	0.804^{a}	10.315^{c}	18.281^{a}	84.231^{a}
Y2g1	3711^{a}	0.395^{a}	0.796^{a}	0.189^{a}	0.788^{a}	11.399^{a}	18.197^{a}	83.028^{ab}
Y2g2	4015^{a}	0.398^{a}	0.794^{a}	0.211^{a}	0.803^{a}	10.984^{b}	18.100^{a}	82.347^{b}
Y1A1P1	4098^{a}	0.479^{a}	0.824^{a}	0.189^{a}	0.880^{a}	12.550^{a}	20.187^{a}	95.125^{a}
Y1A1P2	4662^{a}	0.391^{a}	0.844^{a}	0.271^{a}	0.815^{a}	12.119^{a}	19.525^{abc}	89.350^{a}

Table 3. Contd.

Y1A1P3	4587^{a}	0.375^{a}	0.739^{a}	0.210^{a}	0.734^{a}	10.825^{a}	18.475^{d}	87.875^{a}
Y1A2P1	3862^{a}	0.449^{a}	0.769^{a}	0.181^{a}	0.878^{a}	11.038^{a}	18.513^{d}	87.875^{a}
Y1A2P2	4250^{a}	0.391^{a}	0.792^{a}	0.192^{a}	0.821^{a}	10.500^{a}	17.725^{ef}	81.000^{a}
Y1A2P3	4162^{a}	0.370^{a}	0.754^{a}	0.193^{a}	0.767^{a}	10.350^{a}	17.075^{fgh}	81.625^{a}
Y1A3P1	2493^{a}	0.346^{a}	0.749^{a}	0.174^{a}	0.777^{a}	10.025^{a}	17.425^{fg}	81.000^{a}
Y1A3P2	2862^{a}	0.329^{a}	0.779^{a}	0.177^{a}	0.803^{a}	10.100^{a}	16.725^{gh}	76.875^{a}
Y1A3P3	2537^{a}	0.313^{a}	0.724^{a}	0.178^{a}	0.683^{a}	9.587^{a}	16.612^{h}	68.875^{a}
Y2A1P1	4237^{a}	0.524^{a}	0.820^{a}	0.185^{a}	0.885^{a}	13.217^{a}	20.013^{ab}	95.375^{a}
Y2A1P2	4706^{a}	0.409^{a}	0.817^{a}	0.235^{a}	0.843^{a}	12.740^{a}	19.375^{bc}	90.063^{a}
Y2A1P3	4287^{a}	0.397^{a}	0.832^{a}	0.221^{a}	0.765^{a}	11.150^{a}	19.563^{abc}	88.250^{a}
Y2A2P1	4049^{a}	0.422^{a}	0.803^{a}	0.183^{a}	0.808^{a}	11.813^{a}	19.188^{c}	84.375^{a}
Y2A2P2	4487^{a}	0.390^{a}	0.81^{a}	0.208^{a}	0.849^{a}	11.188^{a}	18.188^{de}	82.250^{a}
Y2A2P3	4358^{a}	0.384^{a}	0.81^{a}	0.224^{a}	0.800^{a}	10.625^{a}	17.625^{ef}	79.625^{a}
Y2A3P1	2972^{a}	0.358^{a}	0.77^{a}	0.180^{a}	0.728^{a}	10.150^{a}	16.688^{h}	79.000^{a}
Y2A3P2	3268^{a}	0.337^{a}	0.769^{a}	0.182^{a}	0.792^{a}	10.000^{a}	16.825^{gh}	77.125^{a}
Y2A3P3	2400^{a}	0.345^{a}	0.723^{a}	0.179^{a}	0.691^{a}	9.837^{a}	15.875^{i}	68.125^{a}
Y1A1g1	4259^{a}	0.417^{a}	0.788^{a}	0.198^{a}	0.812^{a}	12.542^{a}	19.025^{a}	89.625^{a}
Y1A1g2	4639^{a}	0.413^{a}	0.816^{a}	0.249^{a}	0.807^{a}	11.121^{a}	19.767^{a}	91.942^{a}
Y1A2g1	3645^{a}	0.403^{a}	0.754^{a}	0.189^{a}	0.798^{a}	11.058^{a}	17.483^{a}	82.583^{a}
Y1A2g2	4537^{a}	0.404^{a}	0.789^{a}	0.189^{a}	0.846^{a}	10.200^{a}	18.058^{a}	84.417^{a}
Y1A3g1	2583^{a}	0.328^{a}	0.742^{a}	0.176^{a}	0.748^{a}	10.183^{a}	16.825^{a}	74.833^{a}
Y1A3g2	2679^{a}	0.331^{a}	0.759^{a}	0.176^{a}	0.760^{a}	9.625^{a}	17.017^{a}	76.333^{a}
Y2A1g1	4233^{a}	0.441^{a}	0.816^{a}	0.187^{a}	0.821^{a}	12.721^{a}	19.717^{a}	90.500^{a}
Y2A1g2	4587^{a}	0.446^{a}	0.83^{a}	0.240^{a}	0.840^{a}	12.018^{a}	19.583^{a}	91.958^{a}
Y2A2g1	3962^{a}	0.394^{a}	0.809^{a}	0.198^{a}	0.806^{a}	11.425^{a}	18.458^{a}	83.333^{a}
Y2A2g2	4635^{a}	0.403^{a}	0.806^{a}	0.213^{a}	0.832^{a}	10.992^{a}	18.208^{a}	80.833^{a}
Y2A3g1	2937^{a}	0.350^{a}	0.762^{a}	0.182^{a}	0.737^{a}	10.050^{a}	16.417^{a}	75.250^{a}
Y2A3g2	2823^{a}	0.344^{a}	0.745^{a}	0.179^{a}	0.737^{a}	9.942^{a}	16.508^{a}	74.250^{a}
Y1P1g1	3350^{a}	0.426^{a}	0.76^{a}	0.180^{a}	0.829^{a}	12.017^{a}	18.325^{a}	87.292^{a}
Y1P1g2	3618^{a}	0.423^{a}	0.801^{a}	0.183^{a}	0.861^{a}	10.392^{a}	19.092^{a}	88.708^{a}
Y1P2g1	3591^{a}	0.371^{a}	0.793^{a}	0.194^{a}	0.806^{a}	11.34^{abc}	17.833^{a}	81.375^{a}
Y1P2g2	4258^{a}	0.370^{a}	0.817^{a}	0.232^{a}	0.820^{a}	10.471^{de}	18.150^{a}	83.442^{a}
Y1P3g1	3545^{a}	0.350^{a}	0.731^{a}	0.189^{a}	0.724^{a}	10.425^{de}	17.175^{a}	78.375^{a}
Y1P3g2	3979^{a}	0.355^{a}	0.747^{a}	0.198^{a}	0.731^{a}	10.083^{e}	17.600^{a}	80.542^{a}
Y2P1g1	3649^{a}	0.430^{a}	0.798^{a}	0.181^{a}	0.805^{a}	11.958^{a}	18.467^{a}	86.417^{a}
Y2P1g2	3856^{a}	0.439^{a}	0.798^{a}	0.184^{a}	0.809^{a}	11.495^{ab}	18.792^{a}	86.083^{a}
Y2P2g1	3904^{a}	0.378^{a}	0.802^{a}	0.186^{a}	0.819^{a}	11.512^{ab}	18.250^{a}	83.917^{a}

Table 3. Contd.

Y2P2g2	4404[a]	0.380[a]	0.795[a]	0.231[a]	0.837[a]	11.106[bcd]	18.008[a]	82.375[a]
Y2P3g1	3579[a]	0.377[a]	0.787[a]	0.198[a]	0.739[a]	10.725[cde]	17.875[a]	78.750[a]
Y2P3g2	3785[a]	0.374[a]	0.789[a]	0.217[a]	0.764[a]	10.350[e]	17.500[a]	78.583[a]
Y1A1P1g1	3952[a]	0.488[a]	0.82[a]	0.188[a]	0.889[a]	13.625[a]	19.550[bcd]	93.375[a]
Y1A1P1g2	4244[a]	0.470[a]	0.829[a]	0.190[a]	0.870[a]	11.475[a]	20.825[a]	96.875[a]
Y1A1P2g1	4300[a]	0.390[a]	0.797[a]	0.222[a]	0.820[a]	12.975[a]	19.425[bcd]	88.625[a]
Y1A1P2g2	5025[a]	0.392[a]	0.89[a]	0.320[a]	0.810[a]	11.263[a]	19.625[bcd]	90.075[a]
Y1A1P3g1	4525[a]	0.372[a]	0.747[a]	0.184[a]	0.728[a]	11.025[a]	18.100[fghi]	86.875[a]
Y1A1P3g2	4650[a]	0.377[a]	0.73[a]	0.236[a]	0.740[a]	10.625[a]	18.850[def]	88.875[a]
Y1A2P1g1	3625[a]	0.450[a]	0.729[a]	0.180[a]	0.839[a]	11.875[a]	18.250[efghi]	87.750[a]
Y1A2P1g2	4100[a]	0.477[a]	0.808[a]	0.183[a]	0.918[a]	10.200[a]	18.775[defg]	88.000[a]
Y1A2P2g1	3650[a]	0.392[a]	0.805[a]	0.184[a]	0.801[a]	10.675[a]	17.325[ijkl]	79.500[a]
Y1A2P2g2	4850[a]	0.391[a]	0.780[a]	0.199[a]	0.840[a]	10.325[a]	18.125[fghi]	82.500[a]
Y1A2P3g1	3662[a]	0.367[a]	0.729[a]	202[a]	0.754[a]	10.625[a]	18.875[jklm]	80.500[a]
Y1A2P3g2	4662[a]	0.372[a]	0.779[a]	0.183[a]	0.779[a]	10.075[a]	17.275[ijkl]	82.750[a]
Y1A3P1g1	2475[a]	0.340[a]	0.732[a]	0.171[a]	0.758[a]	10.550[a]	17.175[ijkl]	80.750[a]
Y1A3P1g2	2512[a]	0.352[a]	0.766[a]	0.176[a]	0.795[a]	9.500[a]	17.675[hijk]	81.250[a]
Y1A3P2g1	2825[a]	0.332[a]	0.778[a]	0.177[a]	0.796[a]	10.375[a]	16.750[jklm]	76.000[a]
Y1A3P2g2	2900[a]	0.325[a]	0.78[a]	0.177[a]	0.809[a]	9.825[a]	16.700[jklm]	77.750[a]
Y1A3P3g1	2450[a]	0.311[a]	0.716[a]	0.180[a]	0.691[a]	9.625[a]	16.550[lm]	67.750[a]
Y1A3P3g2	2625[a]	0.314[a]	0.733[a]	0.175[a]	0.675[a]	9.550[a]	16.675[hijk]	70.000[a]
Y2A1P1g1	4125[a]	0.516[a]	0.818[a]	0.183[a]	0.894[a]	13.675[a]	19.650[bcd]	93.750[a]
Y2A1P1g2	4350[a]	0.533[a]	0.823[a]	0.188[a]	0.875[a]	12.760[a]	20.375[ab]	97.000[a]
Y2A1P2g1	4325[a]	0.408[a]	0.811[a]	0.189[a]	0.841[a]	13.112[a]	19.375[bcd]	89.750[a]
Y2A1P2g2	5087[a]	0.410[a]	0.823[a]	0.280[a]	0.845[a]	12.368[a]	19.375[bcd]	90.375[a]
Y2A1P3g1	4250[a]	0.400[a]	0.818[a]	0.189[a]	0.728[a]	11.375[a]	20.125[abc]	88.000[a]
Y2A1P3g2	4325[a]	0.394[a]	0.845[a]	0.253[a]	0.802[a]	10.925[a]	19.000[def]	88.500[a]
Y2A2P1g1	3824[a]	0.405[a]	0.804[a]	0.181[a]	0.798[a]	12.025[a]	19.125[cdef]	86.500[a]
Y2A2P1g2	4275[a]	0.439[a]	0.803[a]	0.185[a]	0.818[a]	11.600[a]	19.250[cde]	82.250[a]
Y2A2P2g1	4187[a]	0.397[a]	0.812[a]	0.185[a]	0.830[a]	11.375[a]	18.625[defgh]	83.750[a]
Y2A2P2g2	4787[a]	0.384[a]	0.809[a]	0.232[a]	0.868[a]	11.000[a]	17.750[ghij]	80.750[a]
Y2A2P3g1	3875[a]	0.381[a]	0.811[a]	0.277[a]	0.790[a]	10.875[a]	17.625[hijkl]	79.750[a]
Y2A2P3g2	4842[a]	0.387[a]	0.808[a]	0.221[a]	0.809[a]	10.375[a]	17.625[hijkl]	79.500[a]
Y2A3P1g1	3000[a]	0.370[a]	0.772[a]	0.181[a]	0.723[a]	10.175[a]	16.625[klm]	79.000[a]
Y2A3P1g2	2945[a]	0.345[a]	0.768[a]	0.180[a]	0.733[a]	10.125[a]	16.750[jklm]	79.000[a]
Y2A3P2g1	3200[a]	0.330[a]	0.784[a]	0.185[a]	0.786[a]	10.050[a]	16.750[jklm]	78.250[a]
Y2A3P2g2	3337[a]	0.344[a]	0.754[a]	0.179[a]	0.798[a]	9.950[a]	16.900[jklm]	76.000[a]

Table 3. Contd.

Y2A3P3g1	2612[a]	0.349[a]	0.732[a]	0.180[a]	0.700[a]	9.925[a]	15.875[m]	68.500[a]
Y2A3P3g2	2187[a]	0.341[a]	0.714[a]	0.178[a]	0.682[a]	9.750[a]	15.875[m]	67.750[a]

Mean in each column having at least a common letter are not significantly different. *Irrigation for plots was 600 m^3; A1:60 mm evaporation; A2:120 mm evaporation; A3:180 mm evaporation **p1: Apply 0, p2:60 kg/ha p2o5, p3:120 kg/ha***g1:0, g2:6 g under seed Mycorriza u****Y: year, R: repetition.

effects (P<0.01) on grain yield (4613 kg/ha) and Phosphorus concentration (0.245g/kg), Copper percentage (12.631%). Interaction effect of irrigation/chemical phosphorus also had significant effects (P<0.01) on grain yield (4684 kg/ha) and other yield component except in Calcium (0.502), Fe (95.25), P concentration (0.253 g/kg),Cu (12.88) and K (0.882) percentage. Highest yield was in sufficient irrigation with 60 kg/ha pure phosphorus (A1P2) in water stress conditions using of chemical phosphorus could not compensate, decrease in grain yield. Interaction effects of chemical phosphorus/ mycorrhizal inoculation had significant effect (P<0.01) on grain yield (4331) in P2G2 (60 kg/ha pure phosphorus moderate level phosphorus with inoculation mycorrhizal, Phosphorus concentration (0.231, p2g2), Copper percentage (11.98) first level of phosphorus without mycorrand Zinc percentage (P<0.05) and without any meaningful effection other characters. Among triple interactions irrigation/chemical phosphorus/ mycorrhizal inoculation had significant effects (P<0.05, 5045 kg/ha) on grain yield and (P<0.01) on Phosphorus concentration (0.185 g/kg). Highest grain yield and other yield component were in sufficient level irrigation, moderate level phosphorus with inoculation mycorrhizal (A1P2G2) treatment. Results showed that in moderate water stress, by using proper amount of chemical phosphorus and mycorrhizal inoculation can compensate decrease in grain yield. Other treatments had significant difference with A2P2G2 which means by increasing water stress, increasing or decreasing amount of chemical phosphorus and without mycorrhizal inoculation grain yield of corn will decrease significantly.

DISCUSSION

The results of this experiment showed that in moderate and not in sever water stress using proper amount of phosphorus and mycorrhizal inoculation can increase grain yield and wet forage yield of corn. This results is according to Shiranirad (1998), Miransari (2008) and Nadian (1996). Mycorrhizal fungi by extending root absorbing area through their mycelium network and changing unavailable Phosphorus to available form and translate to root system cause increase in plant height, yield and yield components especially under water stress condition (Rejali et al., 2008; Hayman, 1983; George et al., 1994). Other scientists also showed that under drought stress mycorrhizal fungi by extending their hypha in soil can absorb more water and mineral nutrient such as phosphorus and zinc, copper and iron and in this way can increase yield quality and quantity. In this way can help host plant to resist more against drought stress (Salehrastin, 1998; Tarafdar et al., 1994; Alkaraki and Raddad, 1997). AM fungi develop an extensive network of hypha when in symbiosis with the host plant. This can significantly enhance the absorbing capacity of the host plant roots. It has also been indicated that AM fungi may behave more effectively with increased stress leval (Miransari et al., 2007, 2010), which is somehow in accordance with the results of this experiment. AM fungi can substantially enhance the uptake of different nutrients under different conditions, because of their extensive network of hypha and production of different enzymes such as phosphatase, enhancing the solubility of nutrients including P and the less mobile microelements (Marschner and Dell, 1994; Miransari et al., 2009). AM fungi are able to enhance plant uptake, which can contribute to the production of energy in the plant. In addition P can improve plant growth under stress by enhancing water and nutrient uptake (Miransari et al., 2007, 2009a,b). When conditions are unfavorable to plant growth, for example under high level of drought stress, the host plant may not be able to develop a symbiosis with AM fungi, as the plant prefer to spend its energy to alleviate the stress rather than developing a symbiosis with AM fungi (Miransari et al., 2007, 2008). This is somehow similar to some of the effects of AM fungi on plant growth under stress as AM fungi with its great abilities are able to enhance plant growth under stress and in the presence of pathogens (Song, 2005). Under drought stress, AM fungi are able to decrease abscisic acid concentration and increase IAA and gibberellins concentrations (Liu et al., 2000) and hence alleviate the stress. Therefore in shortage of available water sources, using mycorrhizal inoculums and using less chemical fertilizer and water supply may be a proper method to produce more food with less expenditure in developing countries with low soil fertility and climates under arid and semiarid (Table 3).

REFERENCES

Al-Karaki GN, Al-Raddad A (1997). Effects of arbuscular mycorrhizal fungi and drought stress on groth and nutrient uptake of two wheat genotypes differing in drought resistence. Mycorrhiza, 7: 83-88.

Auge RM (2001). Water relations, drought and vesicular-arbuscular mycorrhiza symbiosis. Mycorrhiza, 11: 3-42.

Elwan LM (2001). Effect of soil water regimes and inoculation with mycorrhizae on growth and nutrients content of maize plants. J. Agric. Res., 28: 163-172.

Gee GW, Bauder JW (1986). Particle-size analysis. In: Klute A (ed) Methods of soil Analysis, Part 1. 2 ed.,Agronomy Monograps, vol. 9. ASA and SSSA. Madison, pp. 383-411.

George E, Romheld V, Marschner H (1994).contribution of mycorrhiza al fungi to micronutrient ptake by plant. In biochemistry of metal micro nutrient in the rhizosphere, pp. 93-109.

Ghazi AK, Zak BM (2003). Field response of wheat to arbuscular mycorrhizal fungi and drought stress. Mycorrhiza, 14: 263-269.

Hopkins WG, Huner NP (2004). Introduction to plant physiology (3rd ed).John Wiely & Sons. Inc, New York, 560 pp.

Hayman DS (1983).the physiology of VA-endo Mycorrhiza symbiosis. Can. J. Bot., 61: 944-963.

Laffhtte HR, Edmeades GO (1995) Stress tolerance in tropical maize is linked to constitutive change in ear growth characteristics. Crop Sci., 3: 820-826.

Lam F (2004) Corn production as related to sprinkler irrigation capacity.16th annual central plains irrigation conferenceéKearney, Nebraska, Feb 17-18.

Liu R, Li M, Meng X (2000) Effects of AM fungi on endogenous hormones in corn and cotton plants. Mycosystem, 19: 91-96

Lin W, Okon Y, Hardy RWF (1991). Enhanced mineral uptake by zea mays and sorghum bicolor roots inoculated with azospirillum brasilense. Appl. Environ. Microbial., 45: 1775-1779

Marchner H, Dell B (1994). Nutrient uptake in mycorrhizal symbiosis. Plant Soil, 159: 89-102

Miransari M, Bahrami HA, Rejali F, Malakuti MJ, Torabi H (2007). Using arbuscular mycorrhiza to reduce the stressful effects of soil compaction on corn (*Zea mays* l.) growth. Soil Biol. Biochem., 40: 1197-1206.

Miransari M, Bahrami HA, Rejali F, Malakouti MJ (2009). Using arbuscular mycorrhiza toreduce the stressful effects of soil compaction on wheat (*Triticum aestivum* L.)Growth .Soil Biol.Biochem., 40: 1197-1206.

Miransari M (2010). Contribution of arbuscular mycorrhizal symbiosis to plant growth under different types of soil stresses. Review article. Plant Biol., 12: 563-569.

Munns R (2002). Comparative physiology of salt and water stress. Plant Cell Environ., 25: 239-250.

Nadian H, Smith SE, Alson AM, Murray RS, Sibert BD (2006).Effects of soil compaction on phosphorus uptake and growth of Trifolium subterraneum.colonized by four species of vesicular-arbuscular mycorrhizal fungi. New Phytol., 140: 155-165.

Nelson DW, Sommers LE (1973). Detemination of total nitrogen in plant material. Agron. J., 65: 109-112.

Nelson DW, Sommers LE (1982). Total carbon, organic carbon. And organic matter. In:page AL, Miller RH, Keenney DR (eds) Methods of soil analysis, part 2, 2nd edn. Am. Soc. Agron., Madison, pp. 539-573

Olsen RS (1954). Estimation of available phosphorus in soils by extraction with sodium bicarbonate. US Department of Agriculture, pp. 939.

Osonubi O (1994). Comparative effects of Vesicular arbusclar mycorrhiza inoculation and phosphorus fertilization on growth and phosphorus uptake of maize (*Zea mays*. L.) and sorghum (gorghum bi color. L.) plants under drought _stressed (conditions. bio1.ferti1.soi1.18(1): 55-59.

Ortas JM, Waters AG (1996). Aggregate hierarch in soils. Aust. J. Soils Res., 29: 815-828.

Rejali FA, Alizadeh M, Malakuti J, Salehrastin N (2008). Efficiency Mycorrhizal relationship on growth, quality and mineral uptake absorbation in drought stess on weat. Soil Water Sci., 21(2): 241-256.

Saleh RN (1998). Manur biology. Soil Biol., 12: 1-36.

Sardi P, Saracchi M, Quaroni S, Petrolini B, Borgonovi G, Meril S (1992). Isolation of endophytic streptomyces strains from surface sterilized roots. Appl. Environ. Microb., 58: 2691-2693.

Shiranirad AH (1998). Study ecophisiology symbiosis mycorrhiza in wheat and soybean.ph.D theses. Tehran Azad Eslami University.

Song H (2005). Effects of VAM on host plant in condition of drought stress and its mechanisms. Electron. J. Biol., 3: 44-48.

Tarafdar JC, Marschner H (1994) b. Phosphatase activity in the rhizosphere and hyposphere of VA- Mycorrhizal wheat supplied with inorganic and organic phosphorus. Soil Biol. Biochem., 26: 385-395.