REVISTA SCIENTIA AGRARIA
Versão On-line ISSN 1983-2443
Versão Impressa ISSN 1519-1125
SA vol. 19 n°. 2 Curitiba abr/jun. 2018 p. 30-36

GROWTH ANALYSIS OF Glycine max UNDER DIFFERENT IRRIGATION REGIMES AND THREE SPECIES OF ARBUSCULAR MYCORRHIZA

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Artigo enviado em 14/01/2017, aceito em 28/04/2018 e publicado em 17/07/2018.

Abstract – To evaluate the optimal irrigation system to increase soybean yield, introducing a beneficial species of symbiotic mycorrhizal fungus, and assessment of interaction effect of irrigation×mycorrhiza on the growth of soybean (Glycine max L.), a split plot experiment was conducted based on randomized complete block design with three replications at Urmia University in 2015. Treatments were irrigation systems (drip: D, constant partial root- zone drying irrigation: CPRD, rainy: R, furrow: F and alternate partial root- zone drying irrigation: APRD) and mycorrhizal fungi species (Glomus mosseae, G. intraradices, G. hoi and non-inoculated treatment as control). The binomial regressions for Total Dry Matter (TDM), Leaf Area Index (LAI), Leaf Weight (LW) showed the accumulated increase of biomass production up to 1111 GDDs (96 DAS). The furrow irrigation produced the largest amounts of LAI followed down by LAI in APRD and CPRD irrigation systems, respectively. The same binomial regressions for LAI were observed in mycorrhizal treatment, too. Stem dry weight with the linear increasing for drip irrigation and binomial function for other 4 irrigation systems, show the highest level in drip irrigation. The respective usefulness of stem dry weight was for plants inoculated with G. intraradices, G. mosseae and G. hoi. All irrigation systems and mycorrhizal treatments indicated the linear rises for pod weight along with growing season. We observed a diminishing returns for Relative Growth Rate (RGR) in all irrigation systems and mycorrhizal treatments (G. mosseae, G. intraradices, G. hoi and non-mycorrhizal as control). But, a latest increase in RGR at the end season was occurred. There was a sharp decline for Crop Growth Rate (CGR) at the end of growing season for all irrigation systems. The same cubic function was obtained for all mycorrhizal treatments, with the respective magnitude for non mycorrhizal control than mycorrhizal plants.

Keywords – *Glycine max*; mycorrhiza; RGR; Total Dry Matter.

INTRODUCTION

The soybean (*Glycine max* L., Fabaceae family) plant is an important oilseed (high protein content of 40%, 32% carbohydrate, 20% oil, 5% minerals and 3% fiber) crop native to South-East Asia that provides fatty acids and proteins for human beings (LUO et al., 2005). The use of soybean products in the feed and food industry has increased steadily. The world soybean production is about 278 million tons obtained from 111 million hectares. Out of this production, less than 10% is directly used for human consumption (FAO, 2013). Five of soybean's fatty acids, palmitic (C16:0), stearic (C18:0), oleic (C18:1), linoleic (C18:2), and linolenic (C18:3), are considered essential fatty acids (FARNO, 2005). However, 19 of amino acids, included cysteine, aspartate, glutamate, serine, histidine, glycine, threonine, methionine, alanine, arginine, tyrosine, tryptophan, valine, Phenylalanine, isoleucine, leucine, lysine, hydroxyproline, proline (CARRERA et al., 2011).

Plant growth consists of the production and distribution of carbon among the different plant organs as a result of the interaction between the plant and environment. Thus, a growth analysis is an inexpensive and accurate method to evaluate plant growth (SMITH and READ, 2008). This analysis allows for the inference of the contribution by different physiological processes of growth to plant performance and is the first step in the interpretation and analysis of primary production (PEDO et al., 2013).

It is widely accepted that the symbiotic arbuscular mycorrhizal fungi (AMF) play a key role in sustainable production systems (LUMINI et al., 2011). In exchange for the plant-assimilated carbon, the fungal partner benefits the host plant by facilitating plant access to mineral nutrients and water also influence plant productivity and community structure (VAN DER HEIJDEN et al., 2008). In addition to these direct effects, the AMF community composition and diversity may under different management and environmental conditions (AUMONDE et al., 2013). The extension of AM fungal mycelia in the soil has been found to be an important determinant in the role of AM symbiosis in plant performance under water-deficit stress (AUGE et al., 2003; AUGE et al., 2007) as well as well irrigated plants (HABIBZADEH et al., 2013). Auge (2001), reported that the mycorrhizal soybean plants produced less drought-induced pod abortion than non-mycorrhizal plants, because of increasing photosynthesis, photosynthetic storage and export at the same time. Earlier, Habibzadeh et al. (2015), showed that the mycorrhizal symbiosis clearly increased the seed yield, leaf phosphorus, root length, root volume and root dry weight in mycorrhizal mung bean plants compared to the non-mycorrhizal plants in all the tested (excess water to stressed condition) irrigation regimes.

Since irrigation fixed costs are incurred even when irrigation is not applied, only a very small yield increase will pay the variable costs for irrigation. Anew method of irrigation proposed by Kang (1998) is the alternate irrigation system by which water is supplied to alternate sides of the plants root system. This method induces root signal concentration such as production of Abscisic Acid (ABA) in the xylem to trigger drought responses such as reduced stomatal opening that reduces transpiration rate, but photosynthesis to a lesser extent (SEPASKHAH and AHMADI, 2010). Rose (1988) indicated that moisture stress occurred early in pod filling resulted in a low protein and high oil percentage. Increases in irrigation interval throughout the whole growing season maintained protein contents constant while increased oil content. Comparison of conventional 0.76 m irrigation (every furrow) and wide 1.52 m irrigation (alternate furrow) showed that the yields were similar in the two furrow irrigation treatments although less water (46% less gross and 29% less net) was applied to the alternate than to the every-furrow irrigation treatment. Total water use efficiency (TWUE) was 6.12 and 5.52 kg ha^{-1} mm^{-1} for the alternate and every-furrow irrigation, respectively (GRATEROL et al., 1993).

Pulse drip irrigation technology is applied all over the world because it has positive effects on increasing yield, improving quality, saving water, and reducing from clogging emitters, etc. Pulsing irrigation refer to the practice of irrigating for a short period then waiting for another short period, and repeating this on-off cycle until the entire irrigation water is applied (ABDELGHANY, 2009**)**.

An efficient sprinkler system is the result of good system design, proper irrigation scheduling, careful operation, and timely maintenance. Good sprinkle irrigation requires an understanding of soil-water-plant relationships and that irrigation timing and amount depends on soil water holding capacity, weather and crop growth progress (WANG et al., 2002).

A well designed drip irrigation system benefits the environment by conserving water and fertilizer. A properly installed drip system can save as much as 80% of the water normally used in other types of irrigation systems. Water is applied either on the surface, next to the plant, or subsurface, near the root zone (HANSON and MAY, 2004).

Although many studies involving soybean as a main crop have been conducted, references on the analysis of growth of mycorrhizal (symbiosis with Arbuscular Mycorrhizal Fungi; AMF species) soybean at different irrigation systems are scarce. Therefore, the objectives of this study were (1) to determine the possible effect of irrigation systems on soybean growth (2) to evaluate effect of three species of mycorrhizal fungi on the growth analysis of soybean and (3) their interactions.

MATERIAL AND METHODS

To evaluate effect of irrigation systems on the growth of soybean (*Glycine max* L. *cv.* Williams) in mycorrhizal symbiosis, a split-plot experiment was conducted based on Randomized Complete Block Design (RCBD) with three replications at Urmia University (37º 39' N and 44 º 58' E, altitude 1365 m, West Azarbayjan Province, Urmia, Iran) in 2015. Treatments were irrigation systems (drip: D, constant partial root- zone drying irrigation: CPRD, rainy: R, furrow: F and alternate partial root- zone drying irrigation: APRD) and mycorrhizal symbiosis (*Glomus mosseae, G. intraradices, G. hoi* and non-mycorrhizal as control). The substrate consisted of soil obtained from two layers 0-30 and 30-60 cm deep of a clay texture. See soil physical and chemical characteristics in Table 1.

TABLE 1- The soil characteristics of experimental site

Depth of Sampling (cm)	pH	EC	O.C	O.M	$CaCO_3$	Clay	Silt	Sand	Texture	K	P	FC
		dSm^{-1}	%							Mg kg^{-1}		%
0-30	7.65	1.4	0.52	0.9	8	50	33	17	Clay	238	22.8	0.22
30-60	7.73	1.4	0.48	0.8	12	51	32	17	Clay	88	15.9	0.22

FC: Field Capacity, O. C: Organic Carbon, O. M: Organic Matter

REVISTA SCIENTIA AGRARIA
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SA vol. 19 n°. 2 Curitiba abr/jun. 2018 p. 30-36

Soybean seeds were sown on 26 April 2015 by hand in the soil at a depth of 4 cm in Plants of 2-by-3 m size, with plant spacing of 50 by 8 cm. Plants were monitored carefully in growth duration and weeds were controlled by hand. Growth analysis was fitted by six samples during growth season.

Leaf area index (LAI) was measured by PAR/LAI Ceptometer (LP-80) in 324, 549, 889, 1111, 1440 and 1703 GDDs coincided with 41, 59, 80, 96, 118 and 142 Days After Sowing (DAS) as well as the total dry matter (aerial parts) was also measured in these points. Total dry matter (TDM) included the weight of all aerial parts (Leaf, stem and seed). Plant samples were dried in an 70°C oven to constant weight.

The following equations were used to calculate the different growth indices (RODERICK, 1990):

$$LAI = \frac{L}{P} \quad (1)$$

$$CGR = \frac{1}{P} \cdot \frac{dw}{dt} \quad (2)$$

$$RGR = \frac{1}{W} \cdot \frac{dw}{dt} \quad (3)$$

Where LAI is the Leaf Area Index; CGR is the Crop Growth Rate; RGR is the Relative Growth Rate; W is the initial dry weight production in t $days^{-1}$; P is the ground area and Lis the initial leaf area.

Statistical analysis (regression) was performed using SAS 9.1.3 and MS Office Excel 2010 softwares.

RESULTS AND DISCUSSION

The binomial regressions for TDM show the accumulated increase of biomass production. But, these risings were different for irrigation systems especially at the end of growing season. So, the noticeable differences were shown after 889 GDDs (80 DAS) in dry matter accumulation. In this matter, drip irrigation accumulated the highest TDM follow down by furrow and rainy irrigation (Figure 1A).The same trends were observed for TDM in mycorrhizal treatments, so the binomial functions were fitted and exhibited large differences at the end of growing season (1111 GDDs; 96 DAS). The mycorrhizal plants (*G. intraradices*) produced the maximum increase of TDM compared to control as more as *G. hoi* and *G. mosseae* (Figure 1B).

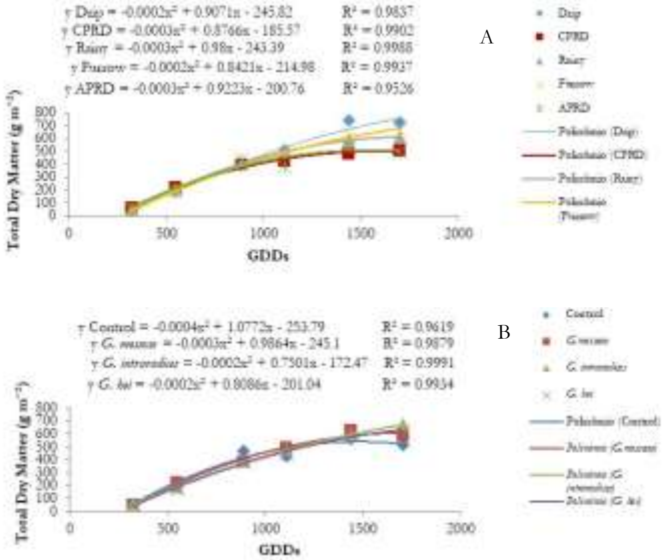

FIGURE 1- Dry matter accumulation of soybean (*Glycine max* L. cv. Williams) during growing season for different irrigation systems (A) and mycorrhizal inoculation (B).

The binomial regression for Leaf Area Index showed slow increasing up to 1111 GDDs (96 DAS) following down to end of plant growth 1703 GDDs (142 DAS). At all, the furrow irrigation produced the largest amounts of LAI. There were descending order of LAI in APRD and CPRD respectively in CPRD treatment (Figure 2A). The same binomial regressions for LAI were observed in mycorrhizal treatment, too. So, decreasing LAI were occurred for all non-mycorrhizal and mycorrhizal (*G.intraradices, G. mosseae, G. hoi*) treatments at the end season, after earlier increasing (Figure 2B).

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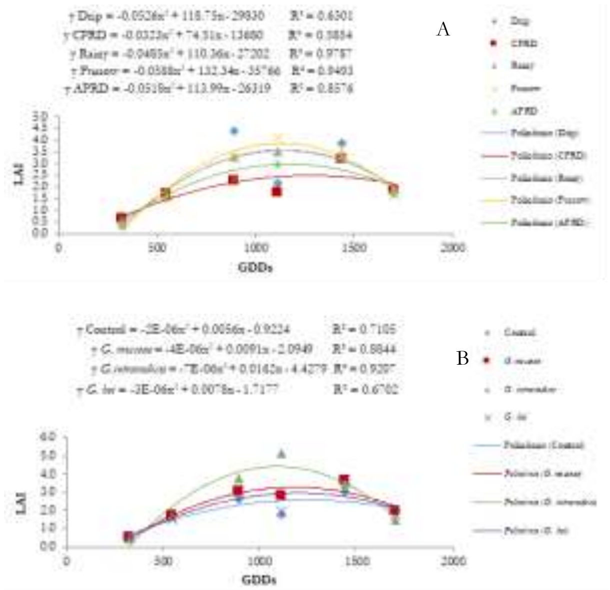
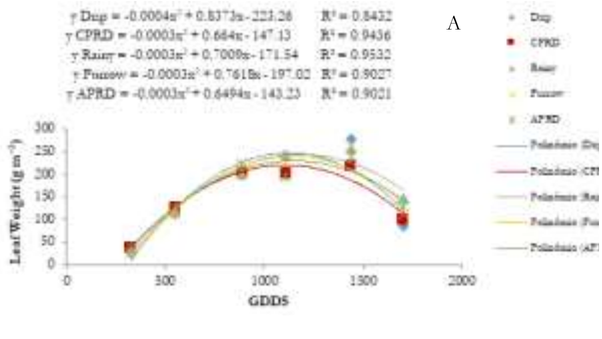


FIGURE 2- Leaf Area Index accumulation of soybean (*Glycine max* L. cv. Williams) during growing season for different irrigation systems (A) and mycorrhizal inoculation (B).

The binomial regression for leaf weight show irrigation systems and mycorrhizal treatments led to increasing LW, that it was started from 324 GDDs (41 DAS) to 1111 GDDs (96 DAS), but it was continued by downtown at the end of growing season (Figure 3). The results indicated the superiority of rainy irrigation having the highest LW, of course after the 96 DAS. The maximum reduction was observed in CPRD (Figure 3A). All of mycorrhizal plants exhibited the increasing leaf weight trend with end season downfall as same as non mycorrhizal treatments (Figure 3B).



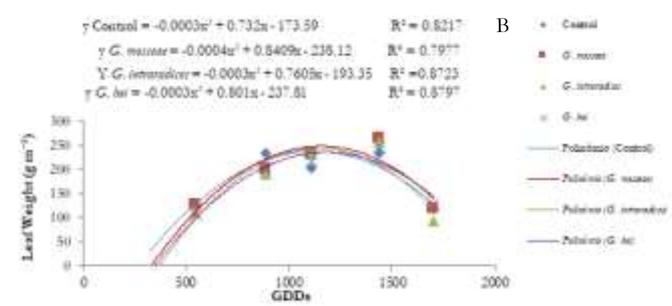


FIGURE 3- Leaf weight Index accumulation of soybean (*Glycine max* L. cv. Williams) during growing season for different irrigation systems (A) and mycorrhizal inoculation (B).

Stem dry weight with the linear increasing for drip irrigation and binomial function for other 4 irrigation systems, show the highest level in drip irrigation. But binomial functions were observed for others (furrow, rainy, CPRD and APRD in decreasing series) with a little reduction at the end of growing season, so the highest values was occurred in 1703 GDDs (142 DAS) (Figure 4A). Mycorrhizal benefits were observed after 96 DAS, so there was any different between non mycorrhizal control and mycorrhizal plants in term of stem dry weight till 1111 GDDs (96 DAS). The respective usefulness of stem dry weight was for plants inoculated with *G. intraradices*, *G. mosseae* and *G. hoi* (Figure 4B).

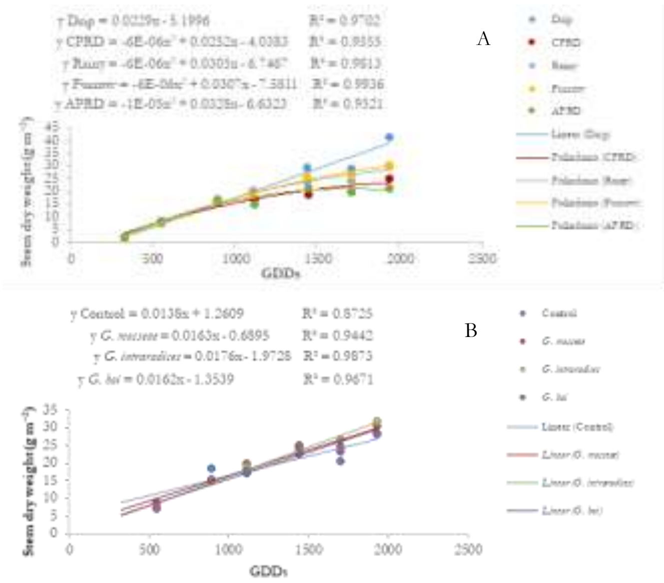


FIGURE 4- Stem dry weight accumulation of soybean (*Glycine max* L. cv. Williams) during growing season for different irrigation systems (A) and mycorrhizal inoculation (B).

The linear increasing of pod dry weight, as an important component of biomass, show the

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SA vol. 19 n°. 2 Curitiba abr/jun. 2018 p. 30-36

accumulated trend for biomass production. All irrigation systems (Figure 5A) and mycorrhizal treatments (Figure 5B) indicated the linear variation of pod weight along with growing season. Also it was observed, the drip irrigation had the highest pod dry weight for all growth stages, following by furrow irrigation, CPRD, rainy and APRD with a little difference respectively were observed (Figure 5A). According to the linear increasing of pod dry weight which is related to mycorrhizal, the highest function was caused by *G. intraradices* and the lowest was related to control. There were the below respects for greater pod dry weight; *G. intraradices* > *G. mosseae* = *G. hoi* (Figure 5B).

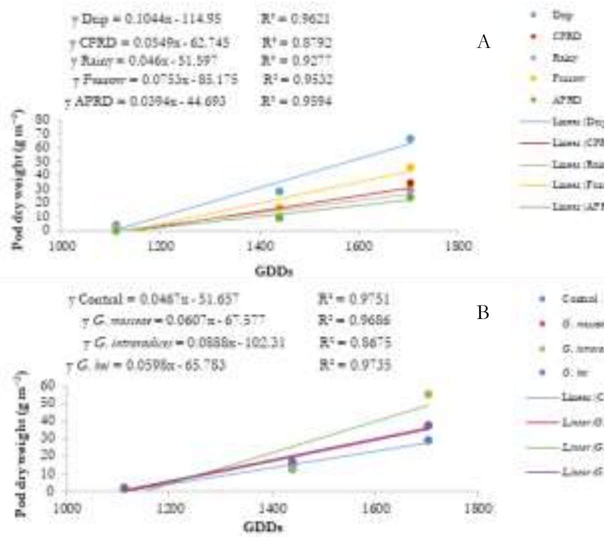

FIGURE 5- Pod dry weight accumulation of soybean (*Glycine max* L. cv. Williams) during growing season for different irrigation systems (A) and mycorrhizal inoculation (B).

We observed a diminishing returns for RGR in all irrigation systems (drip, constant partial root-zone drying irrigation, rainy, furrow and alternate partial root- zone drying irrigation) and mycorrhizal treatments (*Glomus mosseae, G. intraradices, G. hoi* and non-mycorrhizal as control). But, a latest increase in RGR at the end season were occurred due to leaf defoliation in soybean (SETIYONO et al., 2010). The APRD system had always minimum RGR for all growing season, and there was respectively increasing order for furrow, rainy, drip and CPRD irrigation systems (Figure 6A). However, the below decreasing order was obtained for mycorrhizal treatments; control with higher level of RGR > *G. mosseae* > *G. intraradices* = *G. hoi* (Figure 6B).

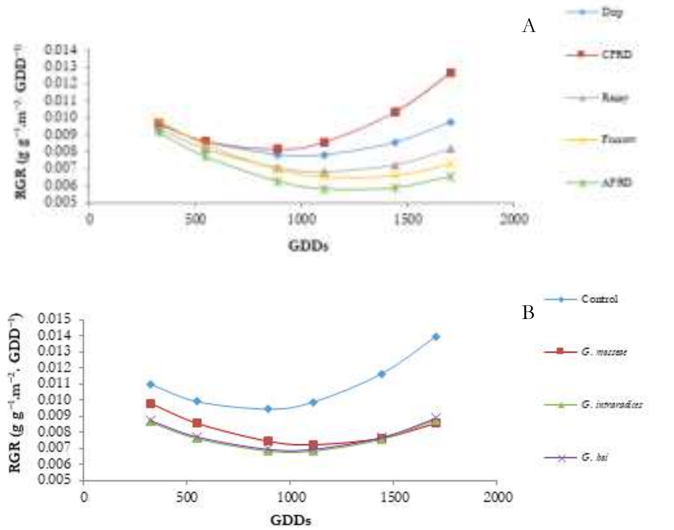

FIGURE 6- RGR accumulation of soybean (*Glycine max* L. cv. Williams) during growing season for different irrigation systems (A) and mycorrhizal inoculation (B).

Crop growth rate having a constant values up to 1111 GDDs (96 DAS), after that we found a sharp increase for CPRD, drip, and a slightly rise for rainy, furrow and APRD to 1440 GDDs (118 DAS). But, there was a sharp decline at the end of growing season for all irrigation systems (Figure 7A). The same cubic function were obtained for all mycorrhizal treatments, with the respective magnitude for non mycorrhizal control than mycorrhizal plants (Figure 7B).

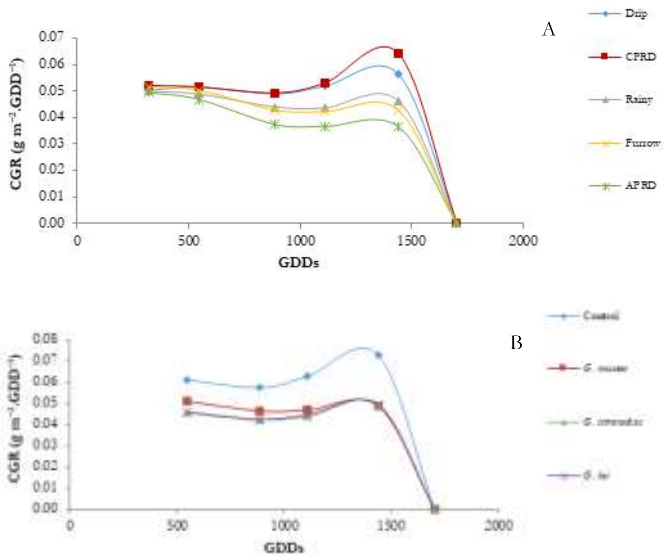

FIGURE 7- CGR accumulation of soybean (*Glycine max* L. *cv.* Williams) during growing season for different irrigation systems (A) and mycorrhizal inoculation (B).

CONCLUSIONS

The results of De Santa Olalla et al. (1994) showed that irrigation increased dry matter production, which was associated with increased LAI, LAD and CGR. They were reported that NAR and RGR were not significantly affected by irrigation. Soybean yield increased with the volume of water supply, mainly due to the greater number of grains m^{-2}. Variation in grain yield was related to the growth parameters of dry matter accumulation, LAI, LAD and CGR. Oil concentration in the seed increased with seasonal amount of water, while protein concentration decreased. Both oil and protein yield increased as irrigation increased, although with a diminishing return. But the other report showed the small differences between irrigated and non-irrigated soybean plants (PEDERSEN and LAUER, 2004).

For row crops, the drip emitters are often placed at the center of row beds, below which most salt loading or leaching would probably occur. In sprinkler irrigation, water is applied over the entire soil surface (SHANNON, 1997). Another conventional method of applying water is by furrow irrigation. However, it may not be very suitable for crop production, especially for saline drainage water reuse because it may generate large quantities of runoff tail water. An option with furrow irrigation is to recirculate the tail water for irrigation of salt tolerant crops. However, lateral water movement due to capillary effect may also generate sufficient leaching in the plant root zone below the field row beds. Surface evaporation would tend to re-concentrate the salt near the soil surface on the field row beds (WANG et al., 2002).

Arbuscular mycorrhizal fungi can improve plant growth by taking up relatively immobile nutrients such as phosphate (BAREA and JEFFRIES, 1995). Enhanced growth of mycorrhizal plants grown in stressed environments has been related partly to mycorrhiza-mediated enhancement of host plant nutrition (KAYA et al., 2003). Also, it seems that the presence of higher amounts of antioxidant production in AM plants could be related to plant growth. In this experiment, the effect of AM on dry matter was more pronounced in aerial biomass than root biomass that may be because of arbuscular mycorrhizal colonization caused a proportionally greater allocation of carbohydrates to the shoot than root tissues (SHOKRI and MAADI, 2009).

REFERENCES

ABDELGHANY, A. R. E. Study the performance of pulse drip irrigation in organic agriculture for potato crop in sandy soils. Ph.D. thesis. Cairo University. EGYPT, 2009.

AUGE, R. M. Water relations, drought and vesicular-arbuscular mycorrhizal symbiosis. *Mycorrhiza*. v. 11, n. 1, p. 3–42, 2001.

AUGE, R. M.; MOORE, J. L.; STUTZ, J. C.; SYLVIA, D. M.; AL-AGELY, A. K.; SAXTON, A. M. Relating foliar dehydration tolerance of mycorrhizal *Phaseolus vulgaris* to soil and root colonization by hyphae. *Journal of Plant Physiology*. v. 160, n. 10, p. 1147–1156, 2003.

AUGE, R. M.; TOLER, H. D.; MOORE, J. L.; CHO, K.; SAXTON, A. M. Comparing contributions of soil versus root colonization to variations in stomatal behavior and soil drying in mycorrhizal *Sorghum bicolor* and *Cucurbita pepo*. *Journal of Plant Physiology*. v. 164, n. 10, p. 1289–1299, 2007.

AUMONDE, T. Z.; PEDO, T.; MARTINAZZO, E. G.; MORAES, D. M.; VILLELA, F. A.; LOPES, N. F. Growth analysis and partitioning of assimilates in marynightshade plants submitted to shading levels. *Planta Daninha*. v. 31, n. 1, p. 99-108, 2013.

BAREA, J. M.; JEFFRIES, P. Arbuscular mycorrhizas in sustainable soil plant systems. In: VARMA, H., HOCK, B. (Eds.): Mycorrhiza. Berlin, Springer, 1995. p. 521–560.

CARRERA, C. S.; REYNOSO, C. M.; FUNES, G. J.; MARTINEZ, M. J.; DARDANELLI, J.; RESNIK, S. L. Amino acid composition of soybean seeds as affected by climatic variables. *Pesquisa Agropecuaria Brasileira*. v. 46, n. 12, p. 1579-1587, 2011.

DE SANTA OLALLA, M.; DE JUAN VALERO, J. A.; FABEIRO CORTES, C. Growth and yield analysis of soybean (*Glycine max* (L.) Merr.) under different irrigation schedules in Castilla-La Mancha, Spain. *European Journal of Agronomy*. v. 3, n. 3, p. 187-196, 1994.

FAO. 2013. FAOSTAT. Available in www.fao.org/faostat/en/.

FARNO, L. A. Oil and fatty acid profiles of soybeans. Ph.D. thesis. Oklahoma State University, USA, 2005.

GRATEROL, Y. E.; EISENHAUER, D. E.; ELMORE, R. W. Alternate-furrow irrigation for soybean production. *Agricultural Water Management*. v. 24, n. 2, p. 133-145, 1993.

HABIBZADEH, Y.; JALILIAN, J.; ZARDASHTI, M. R.; PIRZAD, A.; EINI, O. Some morpho-physiological characteristics of Mung Bean mycorrhizal plant under different irrigation regimes in field condition. *Journal of Plant Nutrition*. v. 38, n. 11, p. 1754-1767, 2015.

HABIBZADEH, Y.; PIRZAD, A.; ZARDASHTI, M.

R.; JALILIAN, J.; EINI, O. Effects of Arbuscular Mycorrhizal Fungi on Seed and Protein Yield under Water-Deficit Stress in Mungbean. *Agronomy Journal***.** v. 105, n. 1, p. 79-84, 2013.

HANSON, B.; MAY, D. Effect of subsurface drip irrigation on proceeding tomato yield, water table depth, soil salinity, and profitability. *Agricultural Water Management*. v. 48, p. 1-17, 2004.

KANG, S.; LIANG, Z.; HU, W.; ZHANG, J. Water use efficiency of controlled alternate irrigation on root-divided maize plants. *Agricultural Water Management***.** v. 38, p. 69-76, 1998.

KAYA, C.; HIGGS KIRNAK, D. H.; TAS, I. Mycorrhizal colonization improves fruit yield and water use efficiency in watermelon (*Citrullus lanatus* Thunb.) grown under well-watered and water stressed conditions. *Plant and Soil*. v. 253, n. 2, p. 287–292, 2003.

LUMINI, E.; VALLINO, M.; ALGUACIL, M. M.; ROMANI, M.; BIANCIOTTO, V. Different farming and water regimes in Italian rice fields affect arbuscular mycorrhizal fungal soil communities. *Ecological Applications*. v. 21, n. 5, p. 1696–1707, 2011.

LUO, Q.; YU, B.; LIU, Y. Differential sensitivity to chloride and sodium ions in seedlings of *Glycine max* and *G. soja* under NaCl stress. *Journal of Plant Physiology*. v. 162, n. 9, p. 1003–1012, 2005.

PEDERSEN, P.; LAUER, J. G. Soybean growth and development in various management systems and planting dates. *Crop Science*. v. 44, p. 508-515, 2004.

PEDO, T.; AUMONDE, T. Z.; LOPES, N. F.; VILLELA, F. A.; MAUCH, C. R. Comparative analysis of growth between genotypes of pepper grown in greenhouse. *Bioscience Journal*. v. 29, n. 1, p. 125-131, 2013.

RODERICK, H. *Basic growth analysis*. Unwin Hyman Ltd., London: 1990.

ROSE, I. A. Effects of moisture stress on the oil and protein components of soybean seeds. *Australian Journal of Agricultural Research*. v. 39, n. 2, p. 163-170, 1988.

SEPASKHAH, A. R.; AHMADI, S. H. A review on partial root-zone drying irrigation. *International Journal of Plant Production*. v. 4, n. 4, p. 241-258, 2010.

SETIYONO, T. D.; CASSMAN, K. G.; SPECHT, J. E.; DOBERMANN, A.; WEISS, A.; YANG, H.; CONLEY, S. P.; ROBINSON, A. P.; PEDERSEN, P.; DE BRUIN, J. L. Simulation of soybean growth and yield in near-optimal growth conditions. *Field Crops Research*. v. 119, p. 161-174, 2010.

SHANNON, M. C. Adaptation of plants to salinity. *Advances in Agronomy*. v. 60, p. 75–120, 1997.

SHOKRI, S.; MAADI, B. Effects of arbuscular mycorrhizal fungus on the mineral nutrition and yield of *Trifolium alexandrinum* plants under salinity stress. *Journal of Agronomy*. v. 8, n. 2, p. 79-83, 2009.

SMITH, S. E.; READ, D. *Mycorrhizal symbiosis*. Academic Press, Cambridge, United Kingdom: 2008.

VAN DER HEIJDEN, M. G.; BARDGETT, R. D.; VAN STRAALEN, N. M. The unseen majority: soil microbes as drivers of plant diversity and productivity in terrestrial ecosystems. *Ecology Letters*. v. 11, n. 3, p. 296–310, 2008.

WANG, D.; SHANNON, M. C.; GRIEVE, C. M.; SHOUSE, P. J.; SUAREZ, D. L. Ion partitioning among soil and plant components under drip, furrow, and sprinkler irrigation regimes: Field and modeling assessments. *Journal of Environmental Quality*. v. 31, p. 1684-1693, 2002.