YIELD AND WATER USE EFFICIENCY (WUE) OF *MEDICAGO SATIVA* AS INFLUENCED BY VESICULAR ARBUSCULAR MYCORRHIZAE (VAM)

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The influence of VAM on yield and water use efficiency (WUE) of *Medicago sativa* was studied under two water regimes (100% field capacity and 50% field capacity). The shoot dry weight and root dry weight significantly increased at 100% field capacity as compared to 50% field capacity. There was a proportion of increase in shoot and root weight of the plant at dual mycorrhizal inoculation. The water use efficiency significantly increased by the inoculation with mycorrhizae under both the water regimes. Water use efficiency recorded increased at the dual inoculation but maximum water use efficiency recorded with *Glomus etunicatum* + *Glomus intraradices* was 294 g at 100% field capacity and 198 g at 50% field capacity. The maximum shoot and root dry weight also increased to 12.57, 10.22 g for shoot and 3.68, 2.97 g for root at 100 and 50% field capacity, respectively.
Keywords: Yield, water use efficiency, *Medicago sativa,* VAM

INTRODUCTION

Productivity of Rangeland of Pakistan is about 10-15% of the potential due to inadequate and erratic rainfall, poor soil conditions, over grazing etc. (Quraishi *et al.,* 1993). Problems regarding water use efficiency have become serious because water is either scarce or of poor quality in extensive area of Pakistan. At present, it is realized that one should not only try to achieve the highest yield per unit area but should also aim at use efficient water as well. Vesicular arbuscular mycorrhizal (VAM) fungi can adopt to a wide range of soil water regimes and can be found in extreme habitats (Mosse *et al.,* 1980). In arid regions the low level of soil moisture can be improved by increasing the absorbing area for water uptake through ramifying hyphae into the soil.

Vesicular arbuscular mycorrhizae (VAM) occur widely under various environmental conditions and are found in association with a number of leguminous crops (Islam and Ayanaba, 1981). Inoculation enhanced the growth 7-8 times, as compare to non-inoculation system for flat pod, crown vetch and lotus (Lambert *et al.,* 1980). The beneficial effects of mycorrhizae on alfalfa production are associated with a better nutrient balance (Hamel *et al.,* 1992).

Arbuscular mycorrhizal infection increased the above ground biomass and seed production suggesting that AM fungi may influence the establishment of *Kummerosia striata* in nutrient poor, disturbed habitats. The evaluation of four hundred and sixty five soybeans (*Glycine max* (L.) Merr.) Varieties, from different parts of the world for their ability to grow in Phosphorus deficient soils and to determine the effect of VAM fungi showed that VAM fungi, differed in their effects on plant growth. It suggested the importance of evaluating the compatibility of VAM fungus and plant host (Abdelgadir, 1998).

Vesicular arbuscular mycorrhizae enhance water uptake and transport in plants and allow plant to withstand high temperature (Call and Meckell, 1982). VA mycorrhizae can cause drought resistance in many plants under stress conditions therefore the plants infected with VA mycorrhizae are less likely to wilt under drought affected conditions (Lindermann and Hendrix, 1982).

In this paper the influence of mycorrhizal association on WUE levels in *Medicago sativa* is reported.

MATERIALS AND METHODS

Inoculation of *Gigaspora rosea, Glomus intraradices* + *Gigaspora rosea, Glomus etunicatum* + *Glomus intraradices* and one control were used to conduct the experiment in order to study the effect of mycorrhizae inoculation on water use efficiency.
Sterilized and analyzed soil with the following composition was used in 16 cm diameter earthen pots, moisture 32%, total organic Carbon 0.6%, total nitrogen 16 mg Kg^{-1}, phosphorus 5.3 mg kg^{-1}, potassium 140 mg kg^{-1} and pH 7.4.
The seeds of *Medicago sativa* were obtained from the Fodder Section, National Agricultural Research Centre, Islamabad. Both experiments were arranged out door air under natural field conditions using Completely Randomized Design.

First experiment

Medicago sativa fodder seeds and three VAM fungi species and one control were used with three replications. Twelve pots were filled with autoclaved soil. Inoculation with VAM was done by layering method (Jackson, 1972). Pots were kept in open air under natural field conditions with 100 % field capacity (F.C), four plants were grown in each pot. Plants were harvested just after seed formation.

Second experiment

Twelve pots of *Medicago sativa* were again grown with 50% field capacity (F.C) moisture level and were compared with the first experiment which was grown with 100% FC. moisture level.

Determining amount of daily watering per pot for maintaining 100 and 50% FC:

Separate experiments were conducted to find out weights of water present in 1 kg soil at 100 and 50% field capacity levels. In this connection, 1 kg oven dry soil was saturated with water and was weighed; the difference of water at 100% FC was calculated. Half of this was taken as weight of water at 50% F.C. The weight of water thus determined was 250 and 125 g per kg oven dry soil for 100 and 50% field capacities, respectively.
The weight of potted plant having 100% FC. was determined as follows:
Weight of pot + Weight of soil + Weight of water

8 kg 8 kg 2 kg = 18 kg

Weight of potted plant having 50% FC. was determined as follows:
Weight of pot + Weight of soil + Weight of water

8 kg 8 kg 1 kg = 17 kg

Total weight of 18 and 17 kg were maintained daily by adding appropriate quantity of water ranging from 700 to 1000 ml for obtaining 100 and 50% FC., respectively. In this experiment plants were harvested just after seed formation. Each part of the harvested plant / pot was separately oven dried and weighed.
The data regarding different plant characters under study were subjected to analysis of variance technique to determine significance of mean and among the treatments by Method of Steel and Torrie (1980) and comparisons of treatment means accomplished by least significant difference (L.S.D.) test at 0.05 level of significance.

RESULTS AND DISCUSSION

The influence of mycorrhizal fungi on *Medicago sativa* at two different water regimes (100 and 50% field capacity) was studied. The influence of mycorrhizae on water use efficiency, shoot dry weight and root dry weight of mycorrhizal inoculated plants is given in Tables 1, 2 and 3, respectively. Table 1 indicated that

Table 1. Water use efficiency (WUE) of mycorrhizae inoculated and uninoculated *Medicago sativa* under two water regimes.

Treatment	WUE under 100% FC	WUE under 50% FC
Control	340 a	246 e
Gigaspora rosea	320 b	222 f
Glomus intraradices + Gigaspora rosea	309 c	208 g
Glomus etunicatum + Glomus intraradices	294 d	198 h

Any two means not sharing a letter differ significantly at 0.05 probability level.

water use efficiency increased by inoculation with mycorrhizal fungi under both the water regimes. The water use efficiency without mycorrhizae was 340 g at 100% field capacity and increased to 320, 309 and 294 g by inoculation with *Gigaspora rosea, Glomus intraradices* + *Gigaspora rosea* and *Glomus etunicatum* + *Glomus intraradices*, respectively. As far as 50% field capacity is concerned, the WUE of *Medicago sativa* without mycorrhizae was 246 g that increased to 222, 208 and 198 g in plants inoculated by the same above single and dual mycorrhizae inoculations with the same ratio.

The shoot dry weight (9.12, 9.81, 10.61 and 12.57 g) significantly increased by the increasing water use efficiency at 100% field capacity and shoot weight 7.47, 7.85, 8.56 and 10.22 g increased by increasing the water use efficiency at 50% field capacity, respectively in Table 2.

The root dry weight was 2.67, 2.88, 3.11 and 3.68 g at 100% field capacity and 2.17, 2.23, 2.49 and 2.97g root dry weight was at 50% field capacity by the increasing water use efficiency at 100 and 50% field capacity, respectively with same inoculations but the maximum water use efficiency, shoot weight and root weight was achieved with the dual inoculation than single inoculation, respectively under both water regimes (Table 3).

Duddridge *et al.* (1980) reported that anatomy of ectomycorrhizae differed from that of VA (endomycorrhizae) in their most specific feature being the fungal sheath which completely covers the absorbing roots, most of the flux of water between the soil and the plant has to pass through the fungus. Such a difference in structure is likely to induce difference in drought resistance mechanisms. VAM fungi are known to increase P uptake in the host plant which in turn is known to stimulate nitrogen uptake. (Subba Rao *et al.,* 1986).

Similar findings were reported by Hardie and Leyton (1981) who reported that VA mycorrhizal fungi of the plants increased absorbing area for water uptake through ramifying hyphae into the soil. Several other authors have also reported the soil moisture levels and mycorrhizal association in many plants have correlation.

Table 2. Shoot dry weight (g) of mycorrhizae inoculated and uninoculated *Medicago sativa* with increasing WUE under two water regimes

Treatment	Shoot dry wt under 100% FC	Shoot dry wt under 50% FC
Control	9.12 d	7.47 f
Gigaspora rosea	9.81 c	7.85 f
Glomus intraradices + Gigaspora rosea	10.61 b	8.56 e
Glomus etunicatum + Glomus intraradices	12.57 a	10.22 bc

Any two means not sharing a letter differ significantly at 0.05 probability level.
LSD (0.05) for Shoot wt = 0.5335

Table 3. Root dry weight (g) of mycorrhizae inoculated and uninoculated *Medicago sativa* with increasing WUE under two water regimes

Treatment	Root dry wt under 100% FC	Root dry wt under 50% FC
Control	2.67 d	2.17 f
Gigaspora rosea	2.88 c	2.23 f
Glomus intraradices + Gigaspora rosea	3.11 b	2.49 e
Glomus etunicatum + Glomus intraradices	3.68 a	2.97 bc

Any two means not sharing a letter differ significantly at 0.05 probability level.

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