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

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Abstract

The influence of VAM on yield and water use efficiency (WUE) of *Cenchrus ciliaris* was studied at 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 proportionate 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 increased with the dual inoculation but maximum water use efficiency with *Glomus etunicatum* + *Glomus intraradices* was 915 g at 100% field capacity and 633 g at 50% field capacity. The maximum shoot and root dry weight also increased to 11.43, 9.21 g for shoot and 5.71, 4.61 g for root at 100 and 50% field capacity, respectively.

Introduction

Vast lands of Pakistan are mostly range resources. Out of a total of 80.7 m ha, 65% area of Pakistan is under rangelands. More than half of the forage requirements of livestock is obtained from rangelands. 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 increasingly important 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 water use efficiency as well.

Azcon-Aguilar *et al.,* (2003) found that there were more AM fungal propagules in the rhizospheres of all the shrub species studied compared with adjacent fallow soils, suggesting that AM propagules can be considered as a functional component of the resource islands developing around plant roots. Caravaca *et al.,* (2005) stated that reconstitution of the potential of soil mycorrhizal inoculum is a key step in revegetation programs for semi arid envrionments. They also found that the mixture of native AM fungi produced the highest levels of mycorrhizal propagules in soil from the center of the canopy of *P. lentiscus* and *R. lycioides*.

Wilson *et al.,* (2001) also studied the effects of arbuscular mycorrhizal symbiosis on growth rate and flowering of three forb species. The results indicate that the effects of mycorrhizae on community structure are a result of interspecific differences in the balance between direct positive effects of the symbiosis on host plant performance and indirect negative effects mediated through altered competitive interactions. Among various factors that contribute to enhance water use efficiency and phosphorus use efficiency, arbuscular mycorrhizal fungi are of vital importance. The arbuscular mycorrhizal (AM) colonize plant roots and through the symbiotic association assist the plant to absorb more water and phosphorus.

Vesicular arbuscular mycorrhizal fungi can adapt to a wide range of soil water regimes and can be found in extreme habitats (Mosse *et al.,* 1981). In arid regimes the low level of soil moisture can be improved by increasing the absorbing area for water uptake through ramifying hyphae into the soil. Several authors have reported the soil moisture levels and mycorrhizal associations in many plants (Hardie & Leyton, 1981; Nelsen & Safir, 1982; Allen & Boosalis, 1983; Ponder, 1983). In this paper, the influence of mycorrhizal association on WUE levels in *Cenchrus ciliaris* 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 following experiment in order to study the effect of mycorrhizae inoculation on water use efficiency. Autoclaved soil with the following composition (Table 1) was used in 16cm dismeter earthen pots.

The seeds of *Cenchrus ciliaris* were obtained from the Fodder Section, National Agricultural Research Centre, Islamabad. All experiments were arranged in open air under natural field conditions using Completely Randomized Design. *Cenchrus ciliaris* grass seeds and three VAM 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. Twelve pots of *Cenchrus ciliaris* were again grown with 50% field capacity (F.C) moisture level and were compared with the first experiment which was grown with 100% field capacity moisture level.

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 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% F.C, 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% F.C, 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 weight of water ranging from 700 to 1000 ml for obtaining 100 and 50% F.C, respectively. In this experiment plants were harvested just after seed formation. Each part of the harvested plant / pot was separately oven dried and weighed.

Table 1. Chemical characteristics of soil used in the experiments.

pH	7.4
Moisture	32%
Total organic carbon	0.6%
Total nitrogen	16 mg kg^{-1}
Phosphorus	5.3 mg kg^{-1}
Potassium	140 mg kg^{-1}

Table 2. Water use efficiency (WUE) of mycorrhizae inoculated and un-inoculated *Cenchrus ciliaris* under two water regimes.

Treatment	100% Field capacity	50% Field capacity
Control	1050a	760e
Gigaspora rosea	990b	704f
Glomus intraradices + Gigaspora rosea	961 c	677 g
Glomus etunicatum + Glomus intraradices	915d	633 h

Any two names not sharing a letter differ significantly at 0.05 probability level.
LSD (0.05) for WUE =10.19

Table 3. Shoot dry weight (g) of mycorrhizae inoculated and uninoculated *Cenchrus ciliaris* under two water regimes.

Treatment	100% Field capacity	50% Field capacity
Control	8.10 e	6.64 h
Gigaspora rosea	8.82 d	7.05 g
Glomus intraradices + Gigaspora rosea	9.90b	7.97 f
Glomus etunicatum + Glomus intraradices	11.43a	9.21 e

Any two names not sharing a letter differ significantly at 0.05 probability level.
LSD (0.05) for shoot weight =0.1238

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 Steel & Torrie (1980) and comparisons of treatment means were accomplished by least significant difference (L.S.D.) test at 0.05 level of significance.

Results and Discussion

The influence of mycorrhizae on *Cenchrus ciliaris* 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 plant is given in Table 1, 2 and 3, respectively. Table 2 and Fig. 1 indicated that water use efficiency increased by inoculation with mycorrhizae under both the water regimes. The water use efficiency without mycorrhizae was 1050 g of water at 100% field capacity and increased to 990, 961 and 915 g of water required by the plants 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 *Cenchrus ciliaris* without mycorrhizae was 760 g of water that increased to 704, 677 and 633 g of water required by the plants inoculated by the single and dual mycorrhizae inoculation. Boyd *et al*., (1986) reported that information on the role of ectomycorrhizal associations in plant water relations was scarce. Water use efficiency was higher and less variable in L1 than in Tt. The data suggested that the improvement in the *L. laccaria* infected seed as compared to the *T. terresttris* seed is mediated by a nutritional P effect. VAM infected plants are less susceptible to wilting and transplant shock in low level of soil moisture (Levy & Krikvn, 1980). In the water stress condition, VAM infected plant has the ability to absorb the nutrients with the development of external mycelium. Allen & Boosalis (1983) found reduction in the resistance to water transport in stressed mycorhizal wheat plant at high P nutritional regime. This reduced resistance in mycorrhizal plants could have resulted from improved water uptake, increased photosynthesis or elevated cytokinin levels which stimulate stomatal opening. Querejeta *at al.,* (2003) also found that WUE during drought was significantly enhanced by inoculation with *Glomus intraradices* in *Olea europaea* ssp *sylvestris*, but not in *Rhamnus lycioides*.

The shoot dry weight (8.10, 8.82, 9.90 and 11.43 g) significantly increased by the increasing water use efficiency at 100% field capacity and shoot weight 6.64 7.05, 7.97 and 9.21 g increased by the increasing water use efficiency at 50% field capacity, respectively (Table 3 and Fig. 2). Similar results were observed by Eerens *et al.,* (1998) who reported that although Endophyte-free plants had significantly higher shoot and total weight, higher water use efficiency but were more wilted than endophyte-infected plants. However, mycorrhizal plants may also have a greater tolerance for continued drought. Our results suggest the increase in the dry weight of mycorrhizal plant to daily watered conditions. 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).

The root dry weight was 4.08, 4.31, 4.95 and 5.71 g at 100% field capacity and 3.32, 3.34, 3.96 and 4.61 g at 50% field capacity under control, single and dual inoculations, respectively. Maximum water use efficiency, shoot weight and root weight increased with the dual inoculation than single inoculation, respectively under both water regimes (Table 4 and Fig. 3). The present studies conform with the result of Kothari *et al.,* (1990). They examined VA mycorrhizal effects on plant water relations in case of maize. There were no differences in shoot dry weight between VA mycorrhizal and non-mycorrhizal or control plants maintained under sterile conditions (sterile control). Over the 6 week growth period, mycorrhizal plants transpired more water than non-mycorrhizal or sterile control plants and had a higher rate of water uptake per until root length. Similar results were also obtained by Call & Mckell (1982) who reported that VA mycorrhizal enhance water uptake and transport in plants and allow plants to withstand high temperature. 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 differences in drought resistance mechanisms.

Table 4. Root dry weight (g) of mycorrhizae inoculated and uninoculated *Cenchrus cilaris* under two water regimes.

Treatment	**100% Field capacity**	**50% Field capacity**
Control	4.08 e	3.32 f
Gigaspora rosea	4.31 d	3.34 f
Glomus intraradices + Gigaspora rosea	4.95 b	3.96 e
Glomus etunicatum + Glomus intraradices	5.71 a	4.61 c

Any two names not sharing a letter differ significantly at 0.05 probability level.
LSD (0.05) for root weight =0.1238

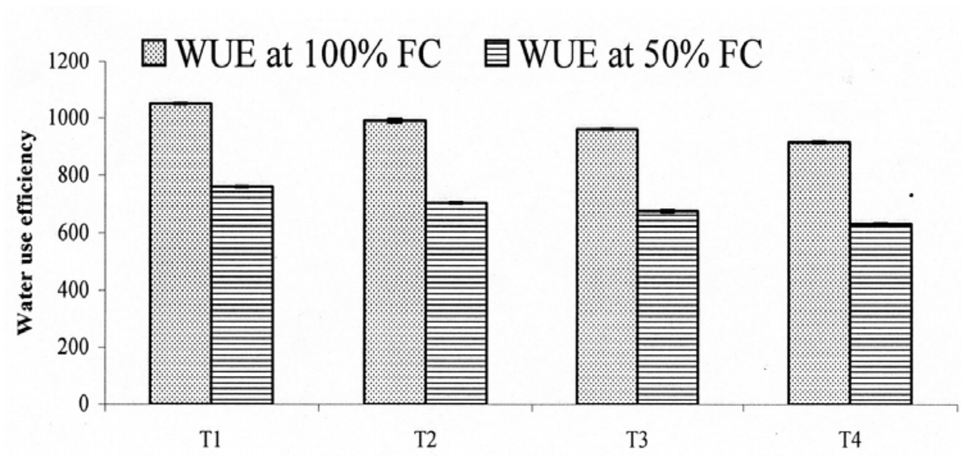

Fig. 1. Water use efficiency (WUE) of mycorrhizae inoculated and uninoculated *Cenchrus ciliaris* under two regimes.

T_1 = Control, T_2 = *Gigaspora rosea*, T_3 = *G. intraradices* + *Gigaspora rosea*, T_4 = *G. etunicatum* + *G. intraradices*

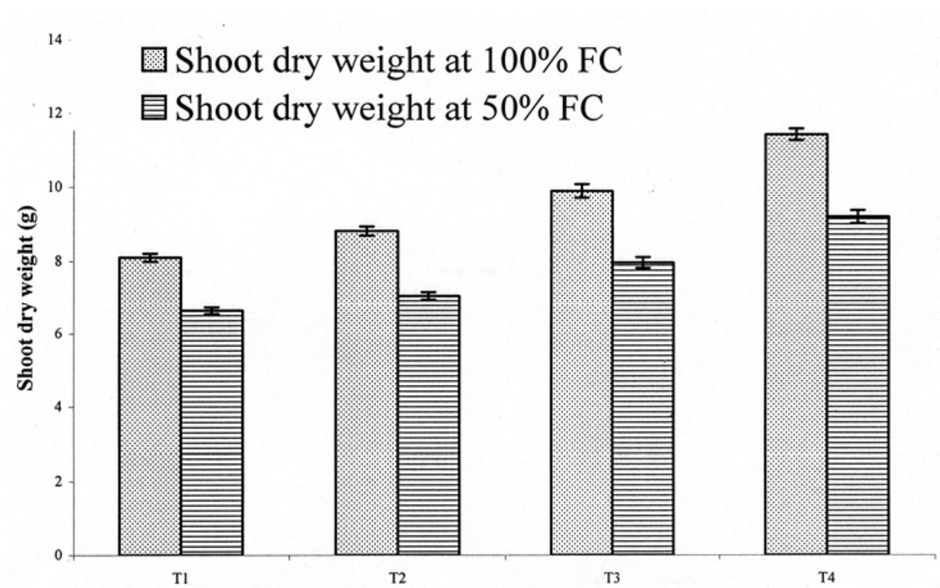

Fig. 2. Shoot dry weight (g) of mycorrhizae inoculated and uninoculated *Cenchrus ciliaris* under two water regimes.

T_1 = Control, T_2 = *Gigaspora rosea*, T_3 = *G. intraradices* + *Gigaspora rosea*, T_4 = *G. etunicatum* + *G. intraradices*

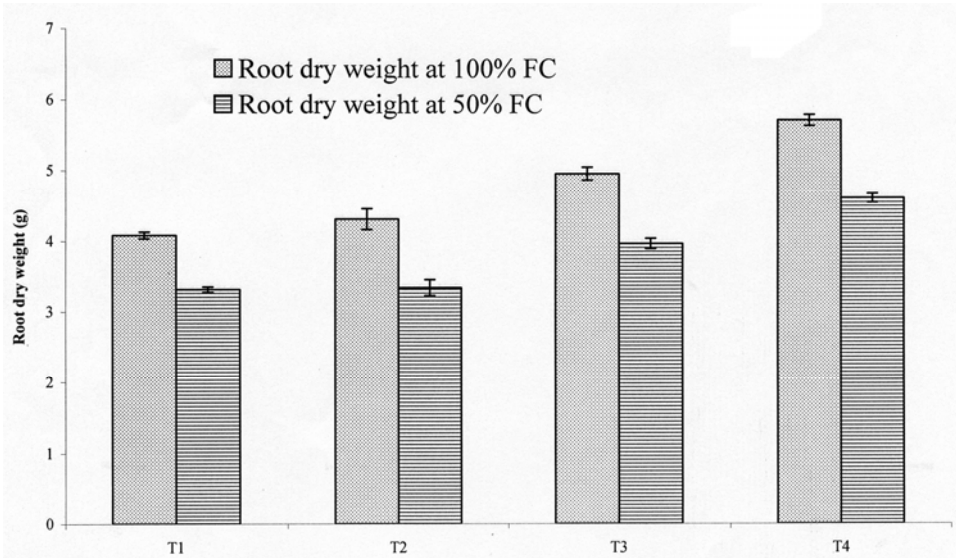

Fig. 3. Root dry weight (g) of mycorrhizae inoculated and uninoculated *Cenchrus ciliaris* under two water regimes.

T_1 = Control, T_2 = *Gigaspora rosea*, T_3 = *G. intraradices* + *Gigaspora rosea*, T_4 = *G. etunicatum* + *G. intraradices*

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