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Yield and Water Use Efficiency (WUE) of *Avena sativa* as Influenced by Vesicular Arbuscular Mycorrhizae (VAM)

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Abstract: The influence of VAM on yield and water use efficiency (WUE) of *Avena sativa* 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 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 increased at the dual inoculation but maximum water use efficiency with *Glomus etunicatum* + *Glomus intraradices* was 925 g at 100% field capacity and 639 g at 50% field capacity. The maximum shoot and root dry weight also increased to 38.45, 31.25 g for shoot and 19.13, 15.47 g for root at 100 and 50% field capacity, respectively.

Key words: Yield, water use efficiency, *Avena sativa,* VAM

Introduction

Productivity of Range land 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 areas 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 efficient use of water as well.

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 regions 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 and Leyton, 1981; Nelsen and Safir, 1982; Allen and Boosalis, 1983; Ponder, 1983). In this paper, the influence of mycorrhizal association on WUE levels in *Avena sativa* is reported.

- Variation in water use efficiencies of inoculated and uninoculated plants at 100% field capacity.
- Variation in water use efficiencies of inoculated and uninoculated plants at 50% field capacity.

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 and analyzed soil with the following composition was used in 16 cm diameter earthen pots, Moisture 32%, total organic Carbon 0.6%, total nitrogen (mg kg^{-1}) 16, phosphorus (mg kg^{-1}) 5.3, potassium (mg kg^{-1}) 140 and pH 7.4.

The seeds of *Avena sativa* 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.

First experiment: *Avena sativa* fodder 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.

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

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 and Torrie (1980) and comparisons of treatment means accomplished by least significant difference (LSD) test at 0.05 level of significance.

Results and Discussion

The influence of mycorrhizae on *Avena 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 plant is given in Table 1, 2 and 3, respectively. Table 1 indicated that water use efficiency increased by inoculation with mycorrhizae under both the water regimes. The water use efficiency without mycorrhizae was 1060 g at 100% field capacity and increased to 1000, 971 and 925 g by inoculation with *Gigaspora rosea, Glomus intraradices+Gigaspora* and *Glomus etunicatum +Glomus intraradices,* respectively. As far as 50% field capacity is concerned, the WUE of *Avena sativa* without mycorrhizae was 768 g, that increased to 711, 684 and 639 g in plants inoculated by the same above single and dual mycorrhizae inoculation with the same ratio similar results were obtained. 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 and Krikvn, 1980). In the water stress condition, VAM infected plant has the ability to absorb the nutrients with the development of external mycelium. Allen and 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.

The shoot dry weight (27.38, 29.50, 33.35 and 38.45 g) significantly increased by the increasing water use efficiency at 100% field capacity and shoot weight 24.45, 23.60, 27.17 and 31.25 g increased by the increasing water use efficiency at 50% field capacity, respectively in Table 2. Similar results were observed by Eerens *et al.* (1998) reported that although Endophyte-free plants had significantly higher shoot and total weight, higher water use efficiency but were more wilted than end ophyte-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 in 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 13.61, 14.75, 16.84 and 19.13 g at 100% field capacity and 11.06, 11.43, 13.74 and 15.47 g root dry weight was at 50% field capacity by the increasing water use efficiency at 100 and 50% field capacity, respectively with same inoculation but the maximum water use efficiency, shoot weight and root weight increased with the dual inoculation than single inoculation, respectively under both water regimes (Table 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 unit root length. Similar results were also obtained by Call and Mckell (1982) who reported that VA mycorrhizal enhance water

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

Treatment		100%	50%
T_1	Control	1060a	768e
T_2	*Gigaspora rosea*	1000b	711f
T_3	*Glomus intraradices* + *Gigaspora*	971c	684g
T_4	*Glomus etunicatum* + *Glomus intraradices*	925d	639h

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

Treatment		100%	50%
T_1	Control	27.38e	24.45g
T_2	*Gigaspora rosea*	29.50d	23.60f
T_3	*Glomus intraradices* + *Gigaspora*	33.35b	27.17e
T_4	*Glomus etunicatum* + *Glomus intraradices*	38.45a	31.25c

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

Treatment		100%	50%
T_1	Control	13.61e	11.06g
T_2	*Gigaspora rosea*	14.75d	11.43f
T_3	*Glomus intraradices* + *Gigaspora*	16.84b	13.74e
T_4	*Glomus etunicatum* + *Glomus intraradices*	19.13a	15.47c

uptake and transport in plants and allow plants to with stand 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.

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