

## **Effect of two species of arbuscular mycorrhizal fungi on growth, assimilation and leaf water relations in maize (*Zea mays*)**

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### **Summary**

In a greenhouse experiment, the effect of arbuscular mycorrhizal (AM) fungi on some effect of drought stress and recovery from it was investigated in maize (*Zea mays* L.). Plants were grown with and without the fungi *Glomus mosseae* and *Glomus intraradices* in sandy loam soil. After 3 months, water was withheld from all plants for 5 days. During the unwatered period and after rewatering, leaf water potential, CO<sub>2</sub> assimilation rate and transpiration of plants were measured. During the unwatered period, leaf water potential, CO<sub>2</sub> assimilation rate and transpiration in mycorrhizal plants were in most cases greater than in the non-mycorrhizal plants, particularly in plants infected by *G. mosseae*. Mycorrhizal plants were able to postpone the onset of wilting.

During recovery from drought, leaf water potential and CO<sub>2</sub> assimilation rate of mycorrhizal plants were mostly higher than those of non-mycorrhizal plants, particularly in those that were infected by *G. mosseae*. Leaf areas and specific leaf area of mycorrhizal plants were generally greater than in non-mycorrhizal plants.

**Keywords:** Mycorrhizae, water stress, *Zea mays* L, maize, assimilation, leaf water potential

### **Introduction**

Arbuscular mycorrhizal (AM) colonisation can dramatically increase absorption of mineral nutrients, particularly immobile nutrients from the soil by host plants. These symbioses are also known to alter plant water relations (Safir *et al* 1971). However after 30 years of investigations and many publications on the water relations of mycorrhizal plants, there is still debate about AM effect on the water relations and mechanisms involved. Most reports are of positive effects for instance AM colonisation can have beneficial effects on the water relations and related physiological characters of the host plant by improving hydraulic conductivity (Hardie,

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1981;Cooper, 1984); enhancing leaf water potential (Subramanian *et al* 1997) and increasing water uptake rate per unit root length and per unit time (Kothari *et al.*, 1990). Many studies have shown that colonisation by mycorrhizal fungi enhances drought resistance in a variety of host plant species (Koide 1993) and increases transpiration rate and decreases stomatal resistance (Bethlenfalavay *et al.*1988);

Dixon *et al* have reported on *Leucaena leucocephala* L. seedlings which maintained slightly higher leaf water potential, leaf stomatal conductance and photosynthesis relative to the non-mycorrhizal plants at the peak of the drought treatment and after rewatering, (Dixon *et al.*, 1994). However Augé in 2000 reviewed listed 8 reports of negative effects, e.g. AM inoculation increased stomatal conductance and transpiration in *Ziziphus mauritiana* plants (Mathur&Vyas1995).

The aim of this work was to investigate the effects of different species of AM fungus on the water relations, photosynthesis, and some growth parameters of maize during drought and recovery from drought. This project constitutes an initial stage of investigations on the effects of AM fungi on drought stress in intercropped maize and bean (*Phaseolus vulgaris* L.).

## Materials and Methods

The experiment was performed as a randomised complete block design (3×3 with three replicates and conducted in a controlled environment chamber (25 /20°C day/night, 15 h day 140  $\mu\text{mol m}^{-2} \text{s}^{-1}$ ). The host plant was maize (*Zea mays* L).

Three inoculation treatments (inoculated with *Glomus mosseae*, inoculated with *G. intraradices* or not inoculated) and three water treatments (well watered, moderate drought stress and severe stress) were applied to sterilised sandy-loam soil. Spores were obtained from BIORIZ (Dijon, France) mixed with coarse sand and from the European Bank of Glomales (BEG) mixed with soil and some parts of roots. For the trapping culture 15-cm diameter pots were planted with 40-50 seeds/pot of *Sorghum bicolor* L. Cultures were grown in controlled environment (see above) for 4 months to increase the amount of inoculum. All trap cultures were stored for at least 30 days before spores were extracted for inoculation onto seedlings.

After 3 months, water was withheld from all well-watered maize for 5 days. During the un-watered period and after re-watering, leaf water potential and photosynthetic rate were measured.

Every morning during the 5 day unwatered period and for 7 hours after rewatering, leaf water potential was measured on the youngest fully expanded leaf (4<sup>th</sup> or 5<sup>th</sup>) by a psychrometric method. Photosynthetic rate (A) and transpiration were measured on the leaf immediately below using the CIRAS infrared gas analysis system.

Plants were harvested 98 days after sowing for determination of growth parameters (i.e. Leaf area & specific leaf area) and mycorrhizal colonisation.

## Results

### *Leaf water potential*

The results showed that during the unwatered period and after rewatering leaf water potential of mycorrhizal plants was at most times greater than in the non-mycorrhizal plants, particularly in plants infected by *Glomus mosseae*. Mycorrhizal plants were able to postpone the onset of wilting from day 3 to day 5 (Figs 1 and 2).

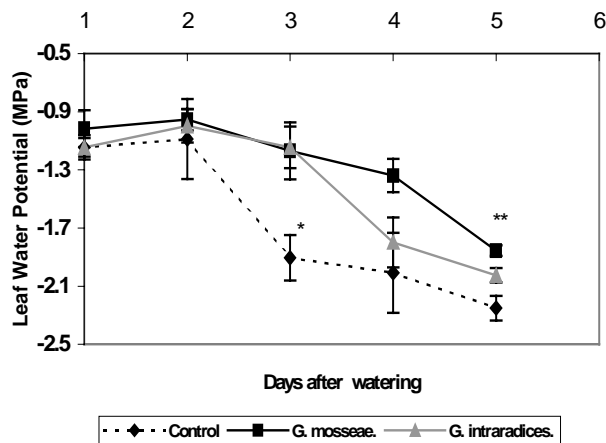


Fig. 1. Leaf water potential in maize plants infected and not-infected (control) with two species of mycorrhizal fungus measured each morning on 5 consecutive days after watering. \* wilting point in control plants, \*\*wilting point in mycorrhizal plants. Error bars represent  $\pm$  standard deviation.

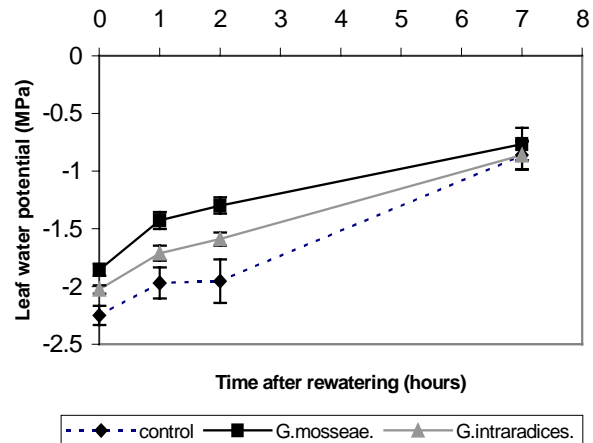


Fig. 2. Leaf water potential in maize plants infected and not-infected (control) with two species of mycorrhizal fungus measured at intervals over 7 hours after rewatering. Error bars represent  $\pm$  standard deviation.

### CO<sub>2</sub> assimilation rate

Under drought conditions and after re-watering CO<sub>2</sub> assimilation rate of mycorrhizal plants was at most times greater than that of non-mycorrhizal plants. The greatest difference between mycorrhizal plants and non-mycorrhizal plants was seen on the third day of un-watered period. (Figs 3 and 4)

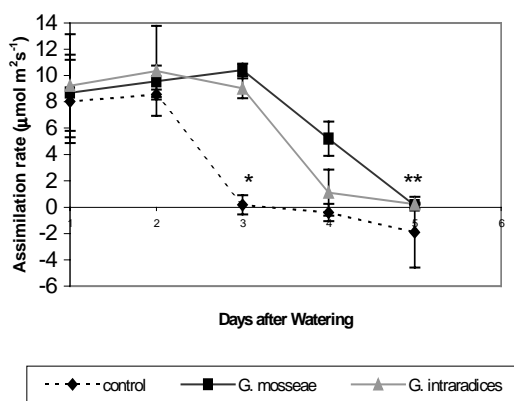


Fig. 3. Assimilation rate in maize plants infected and not-infected (control) with two species of mycorrhizal fungus measured each morning on 5 consecutive days after watering. \* wilting point in control plants, \*\*wilting point in mycorrhizal plants. Error bars represent  $\pm$  standard deviation.

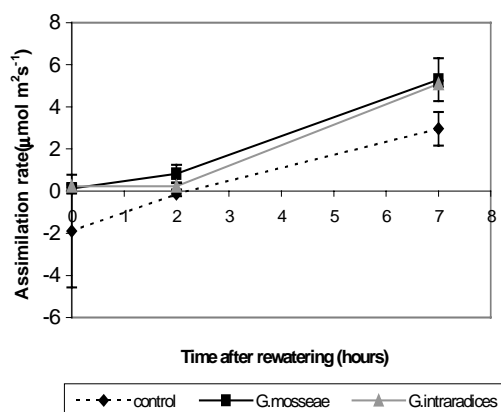


Fig. 4. Assimilation rate in maize plants infected and not-infected (control) with two species of mycorrhizal fungus measured at intervals over 7 hours after rewatering. Error bars represent  $\pm$  standard deviation.

### Transpiration rate

Mycorrhizal infection by both species of fungus affected the rate of transpiration. The greatest difference between mycorrhizal plants and non-mycorrhizal plants was seen on the third day after withholding water. When drought treatments were imposed reduction in transpiration rate of plants began. There was a rapid decline in transpiration rate after 2 days of withholding water (Fig. 5). After rewatering transpiration rate was not affected by mycorrhizal infection (Fig. 6).

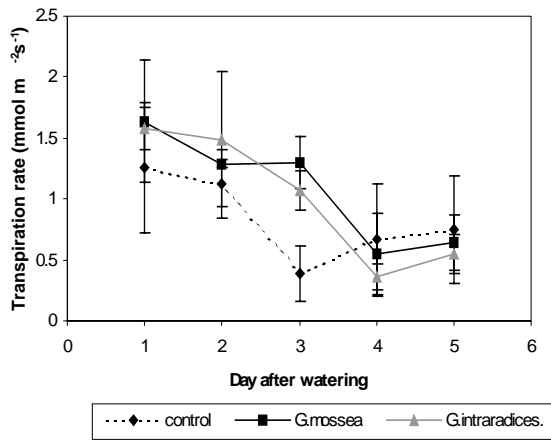


Fig. 5. Transpiration rate in maize plants infected and not-infected (control) with two species of mycorrhizal fungus measured each morning on 5 consecutive days after watering. Error bars represent ± standard deviation.

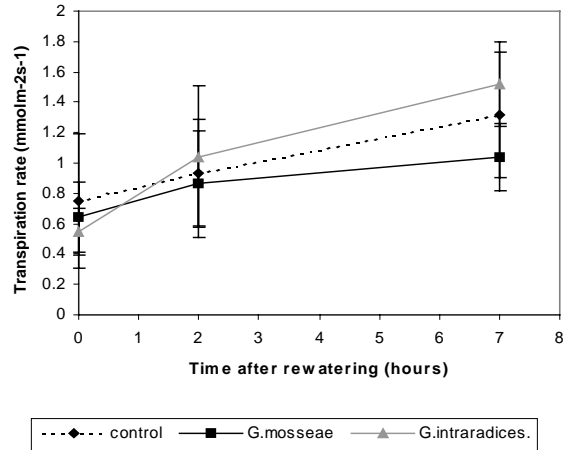


Fig. 6. Transpiration rate in maize plants infected and not-infected (control) with two species of mycorrhizal fungus measured at intervals over 7 hours after rewatering. Error bars represent ± standard deviation.

### Leaf area (LA) and Specific leaf area (SLA)

Mycorrhizal plants showed greater LA than non-mycorrhizal plants. There was no difference between moderate and severe stress.(Fig. 7) In the well watered treatment SLA in mycorrhizal plants was greater than in non-mycorrhizal plants. In moderate stress and the severe stress conditions SLA in mycorrhizal plants was greater than non-mycorrhizal plants particularly in plants infected by *G. mosseae*. (Fig. 8)

### Mycorrhizal colonisation (%)

The mycorrhizal fungal colonisation in those plants that were infected by *G. mosseae* was 93.5% while in those infected with *G. interaradices* it was 78.3%.

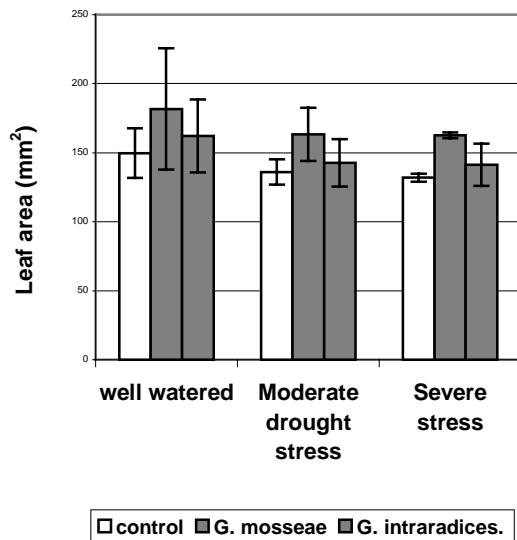


Fig. 7. Leaf surface area in maize plants infected and not-infected (control) with two species of mycorrhizal fungus in three water treatments. Error bars represent  $\pm$  Standard deviation.

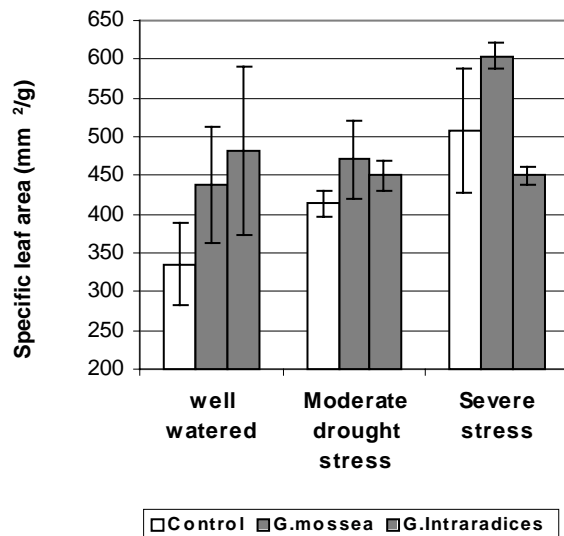


Fig. 8. Specific Leaf area in maize plants infected and not-infected (control) with two species of mycorrhizal fungus in three water treatments. Error bars represent  $\pm$  Standard deviation.

## Discussion

The AM association had a beneficial effect on the leaf water relations and CO<sub>2</sub> assimilation rate under water deficit conditions. Mycorrhizal infection by either of two fungi (*G.mosseae* or *G.interaradices*) allowed maize plants to maintain higher leaf water potential when compared with non-mycorrhizal plants. This result is similar to the observations of Subramanian *et al* 1997.

Other recent studies also found that in *Leucaena leucocephala* (Dixon *et al* 1994) and *Ziziphus mauritiana* (Mathur & Vyas 1995), mycorrhizal plants maintained higher CO<sub>2</sub> assimilation rate than non-mycorrhizal plant. The results reported here clearly showed that while transpiration rate generally decreased as drought progressed mycorrhizal infection usually had the effect of maintaining of higher rate of transpiration particularly as soil water deficits increased and plant water status declined. Others have also found higher transpiration in mycorrhizal than non-mycorrhizal plant (Augé *et al* 1986; Bildusas *et al* 1986; Augé 1989; Bryla & Duniway 1997)

The greatest difference in CO<sub>2</sub> assimilation rate and transpiration rate was seen on the third day of the unwatered period when leaf water potential was reaching low values. Plants infected with *G. mosseae* generally offered to have higher CO<sub>2</sub> assimilation rate, leaf water potential, specific leaf area and leaf area than those infected with *G. interaradices*. Mycorrhizal colonisation was higher (93.5%) with *G. mosseae* than with *G. interaradices* (73.8%) but the different were realery big. Wilting was delayed by 2 days by AM associations.

During the recovery period leaf water potential and CO<sub>2</sub> assimilation rate of mycorrhizal plants were higher than those of non-mycorrhizal plants, particularly in those plants that were infected by *G. mosseae*, but this is at least partly due to these plants having higher leaf water potential at the time of rewatering. There is some suggestion in the water potential gradients on Fig2 of higher rate of recovery in infected plants in the first 2 hours, but in Fig 4 the rate of recovery of assimilation was higher in non-mycorrhizal in the first two hours.

The present study was limited to well watered plants and plants exposed only to one rapid drought episode. Long-term responses of mycorrhizal plants to drought will form the subject of future investigations.

## Acknowledgements

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