Effect of biochar on arbuscular mycorrhizal colonisation, growth, P nutrition and leaf gas exchange of wheat and clover influenced by different water regimes

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Abstract
Biochar (biomass-derived carbon) can influence arbuscular mycorrhizal colonisation, plant growth, P nutrition and water relations but research is not conclusive. Therefore, a glasshouse experiment was conducted using wheat and clover with three water regimes, two biochar rates (0, 6 t/ha) with a series of harvests. Mycorrhizal colonisation was altered by water regimes. Shoot and root dry weight increased in well-watered compared to water-stressed conditions. Root length and colonised root length increased in the biochar treatment for wheat, especially in the well-watered treatment. Leaf gas exchange was higher in the presence of biochar indicating increased water availability to plants growing in biochar treated soil.

Key Words
Arbuscular mycorrhizal fungi, biochar, clover, growth, leaf gas exchange, wheat.

Introduction
Water deficit is considered one of the most important abiotic factors limiting plant growth and yield in many areas on earth; especially in the context of changing climates and agricultural areas expected to experience increased frequency of dry seasons. Several eco-physiological studies have demonstrated that the arbuscular mycorrhizal (AM) symbiosis can result in an altered rate of water movement into, through and out of the host plants, with the consequent effects on tissue hydration and plant physiology. It is now accepted that the contribution of AM symbiosis to plant drought tolerance is the result of accumulative physical, nutritional, physiological and cellular effects (Al-Karaki *et al.* 2004;Ruiz-Lozano 2003). Application of biochar (pyrolised biomass) to soil can result in significant responses by both plants and mycorrhizal fungi. Biochar has been shown to increase mycorrhizal root colonisation and create a microhabitat in soil (Saito 1990; Warnock *et al.* 2007). Based on recent research in Western Australia biochar may encourage colonisation by mycorrhizal fungi and improve plant water supply in drought risk environments (Blackwell *et al.* 2007). The aim of the present study was to determine (i) the effect of water regimes on mycorrhizal colonisation, plant growth, P nutrition and water relations of wheat and clover (ii) the interaction between biochar and water regimes on mycorrhizal colonisation and (iii) the effect of biochar on leaf gas exchange in relation to water availability.

Material and methods
The experiment was arranged in a factorial and randomized complete block design with six treatments and three replications. The treatments included three water regimes, two biochar levels, two crops and four harvests as bellow: water regimes: I1: 80% of F.C (well-watered); I2, 40% of F.C (water stressed), and I3, intermittently watered (periodic water stressed). Jarrah biochar was obtained from a 35 years old stockpile of metallurgical charcoal at the site of an iron foundry at Wundowie, WA. The pH of biochar was 4.8 and this acidity was unusual compared to the other biochars and applied at 0 and 6 t/ha. There were 3 water regimes × 2 biochars × 2 crops × 4 harvests ×3 replications (144 pots). Each pot contained 1 kg of field soil of sandy clay loam collected from Walkaway, WA amended with western mineral fertilser as a basal at 50 kg/ha. Five seeds of each wheat (*Triticum aestivum* L.var. Brookton) and subterranean clover (*Trifolium subterranean* L. var. Seaton Park) were sown and allowed to grow for 5 days after germination. The three most vigorous plants were retained in each pot and harvested 14, 24, 34 and 44 days after sowing. Data collected were: shoot and root dry weight; % root length colonised by AM fungi; total and colonised root length, phosphorus concentration in shoot, and leaf gas exchange such as photosynthesis, stomatal conductance, internal CO_2 concentration and transpiration. Leaf gas exchange was measured using a Li-Cor 6400 photosynthesis system (Li-Cor, Lincoln, NE, USA).

Results

AM colonisation increased significantly in the biochar treatment for wheat grown in well-watered and periodic water stressed treatments (Figure 1). Total plant root length and AM colonised root length increased significantly ($p \leq 0.05$) in the biochar treatment for wheat but only in colonised root length was increased for subterranean clover ($p \leq 0.05$) (Figure 1). The effect of water regimes on AMF colonisation, plant biomass, and root length were all significant ($p \leq 0.05$). The effect of biochar and water regimes on leaf gas exchange such as photosynthesis, stomatal conductance, internal CO_2 concentration and transpiration were significant ($p \leq 0.05$) (Figure 2).

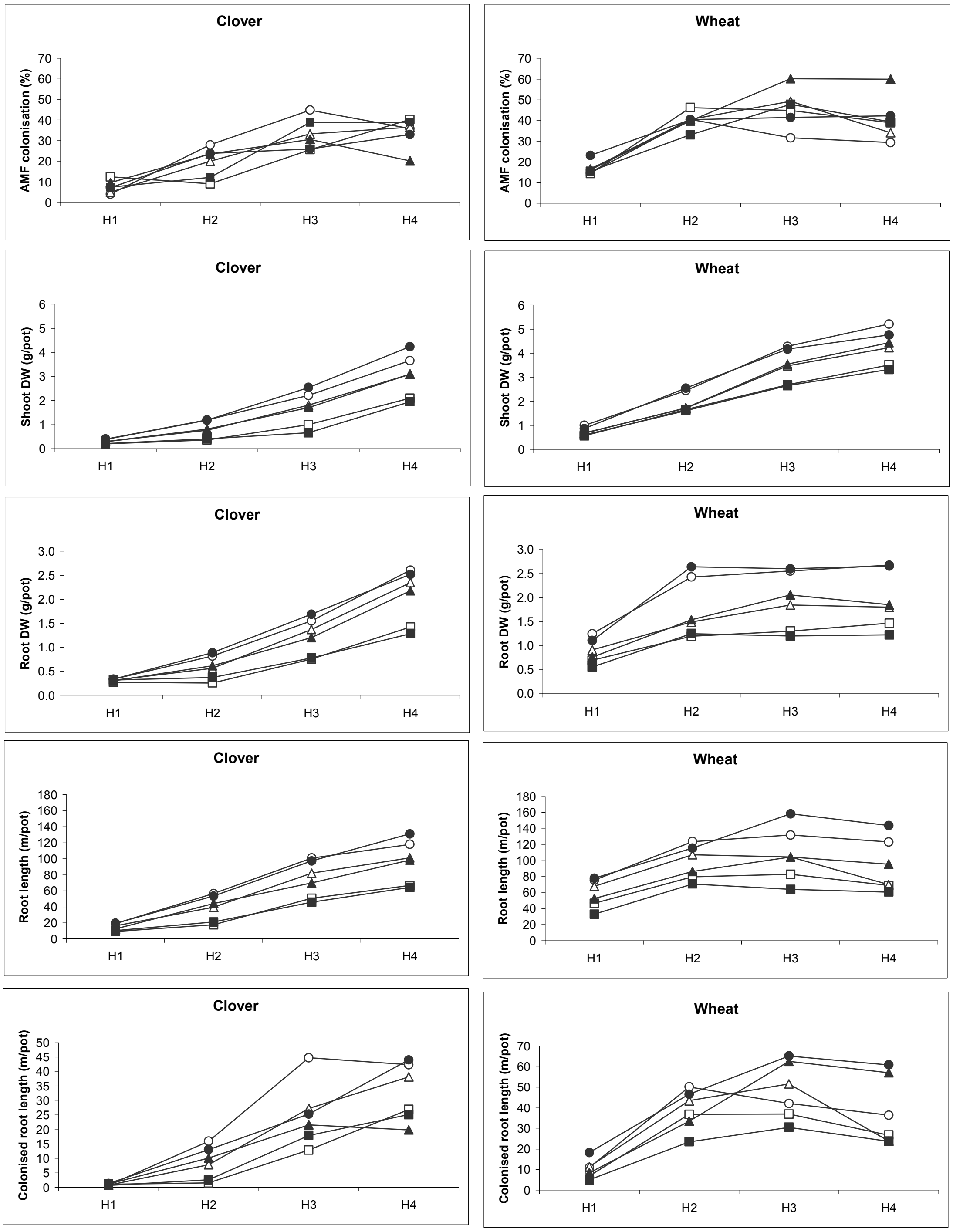

Figure 1. Effect of biochar and water regimes on mycorrhizal colonisation, plant biomass and root length of subterranean clover and wheat; O, well-watered; □, water-stressed and Δ, periodic water-stressed; biochar - closed symbol, no biochar – open symbol; H1-4 harvests.

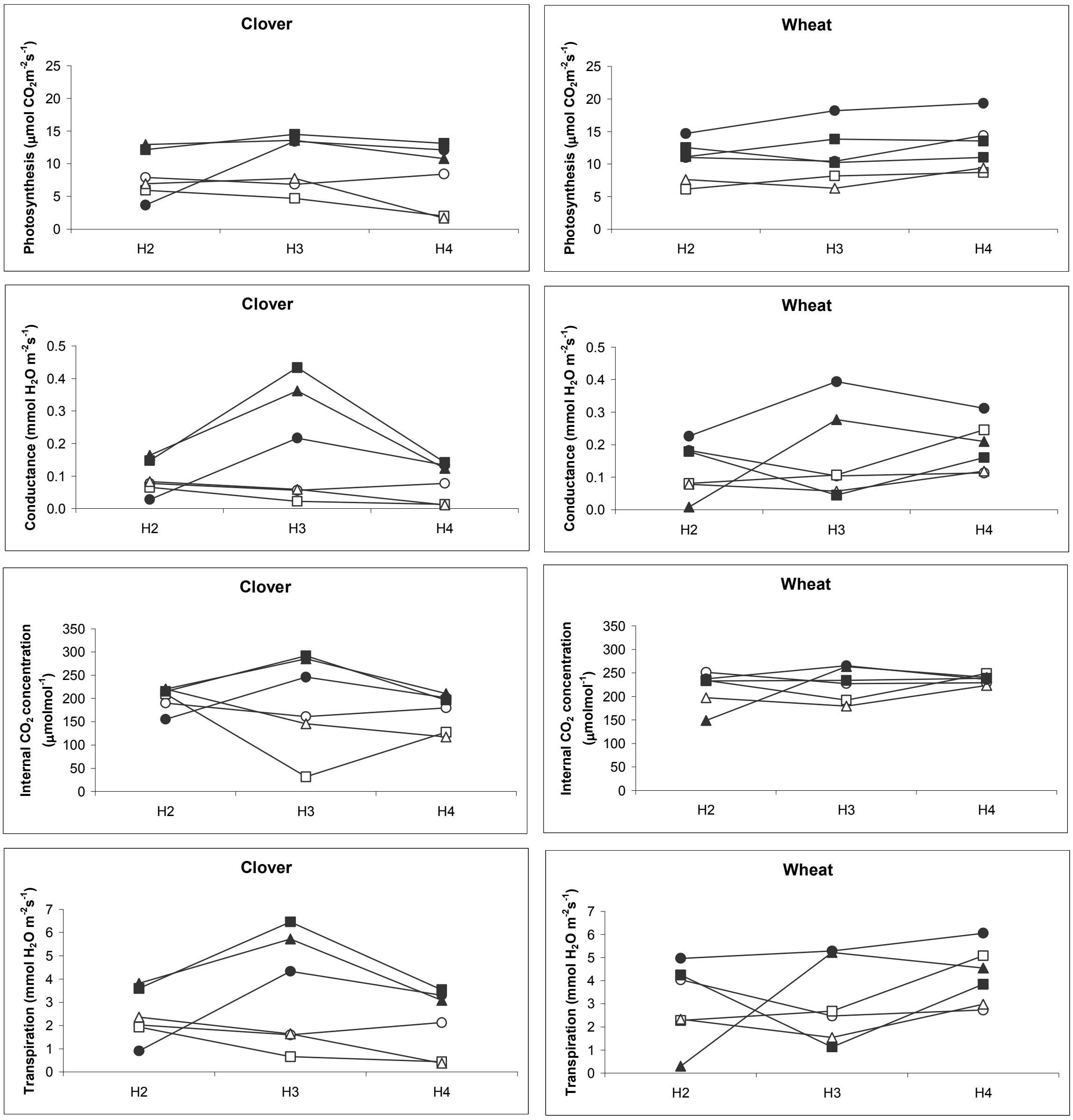

Figure 2. Effect of biochar and water regimes on leaf gas exchange of clover and wheat; O, well-watered; □, water-stressed and Δ, periodic water-stressed; biochar - closed symbol, no biochar – open symbol; H1-4 harvests.

Conclusion

The effect of biochar application on AM colonisation, plant growth, root length, P nutrition was positive, especially in wheat strongly influenced by different water regimes. Leaf gas exchange was significantly higher in biochar treated plants suggesting increased water availability in the rhizosphere of biochar treated plants. These data support the expectation that biochar application may assist water supply in a dry season in a field experiment with the same biochar, fertiliser regime and soil.

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