# ARBUSCULAR MYCORRHIZAL DYNAMICS THROUGHOUT CORN GROWING SEASON

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## Abstract

Phosphorous is an essential plant nutrient and is the second most common fertilizer nutrient applied in crop production. The role of mycorrhizal fungi in phosphorous (P) nutrition of corn (*Zea mays* L.) in high fertility soils in unclear. A study was conducted to determine the effect of extractable P on mycorrhizal biomass and to evaluate the temporal dynamics of mycorrhizal fungi during the growing season in two irrigated corn fields in Nebraska. The objectives were addressed by the installation of soil-containing chambers prior to tasseling, and sequential removal of the chambers during the reproductive period. These chambers were assembled with and without P amendment and then enclosed with mesh that allowed or excluded root penetration. Mycorrhizal biomass was measured using the biomarker fatty acid C16:1*cis*11. Root length increased from VT to R4 at one site, and in the other from VT to R2. In both corn fields the mycorrhizal biomarkers inside the chambers increased 55 to 67% throughout the reproductive stages of the crop from tasseling to maturity, confirming translocation of C from the plant to the mycorrhizal symbiont. This increase in mycorrhizal biomass was greatest in chambers where the bioavailability of P was low and roots were present, suggesting a possible role in P acquisition. Further work is needed to quantify the mycorrhizal contribution to P uptake during the reproductive stages of corn

## Introduction

Phosphorous is an essential plant nutrient and following N, is the second most common fertilizer nutrient applied in crop production. In corn, P accumulates steadily until maturity, with a higher proportion being absorbed during the reproductive period (Karlen et al.1988). A large proportion of P accumulates after root biomass reaches a maximum (Plenet 1995). Radical hairs developed before and after tasseling may have a high efficiency in P uptake and may create a depletion zone around the root. Arbuscular mycorrhiza (AM) fungi form symbiotic relationships with up to 80% of land plants and also are recognized for their positive effects on plant growth and soil quality (Smith and Read 1997). It also has been observed, in high production systems, that mycorrhizal biomass increases throughout the corn-growing season (Drijber 2004), and by bridging this depletion zone, may be the main mechanism for P uptake after tasseling. Management systems that enhance natural mechanisms for P acquisition will help optimize use of P fertilizer resources. Vesicular AM may play an important role in plant P nutrition, but factors influencing that role and temporal dynamics are poorly understood. Plant growth dynamics and nutrient accumulation patterns leave uncertainty about the mechanism for nutrient uptake. On-farm experiments conducted in Nebraska (Drijber 2004) showed that fatty acids methyl ester (FAMEs) signaled increased growth of mycorrhizal biomass from V14 onward.

Seasonal variations in microbial community composition were greater than those associated with either tillage or residue management regime (Speeding et al. 2004).
Larsen et al. (1998) utilized the fatty acid signatures to study mycelial interactions between AM fungi and saprotrophic fungus in root-free soil. The C18:2*cis*9,12 was the dominant fatty acid of the saprotrophic fungi while it was negligible in mycelium of *Glomus intraradices*. The fatty acids 16:1*cis*11, 20:4 and 20:5 were found in this AM fungi, but not in the saprotrophic one. Fatty acid analysis performed on the spores of several AM fungi showed 16:1*cis*11 to be the dominant fatty acid present (Madan et al.2002). Olsson and Johansen (2000) found that the amount of phospho lipid fatty acid 16:1*cis*11 per unit biomass of two AM species (*Glomus intraradices* and *G. clarideum*) remained rather constant as the mycelium aged, and its distribution between the mycelium and hyphae was highly consistent making it a suitable biomass indicator.

The objectives of this study were (i) to study the influence in extractable P on mycorrhizal biomass, (ii) to evaluate the temporal dynamic of mycorrhizal fungi during the reproductive part of the corn season in high productivity systems, and (iii) to study the response to differences in soil characteristics in the mycelia development.

## Materials and Methods

This research was conducted in two irrigated corn fields: one in Lincoln and the other near Shelton, NE. Soil samples were collected at 0-15 cm depth during the corn season (V6, Vt, R2, R3-4 and R5). A 2*2 factorial experiment was established in each site: chambers with and without P (+P, -P) and chambers with a mesh that allowed root and mycelial passage (nylon mesh 1 mm), and mesh that allowed only mycelial passage (RM, M) (nylon mesh 0.045 mm). The difference in inorganic P applied to these chambers coupled with the different mesh used permitted the evaluation of the mycorrhizal response in these two sites with different levels of available P. Microbial community structure was based on digestion-extraction of FAMEs by mild alkaline hydrolysis. Lipid analysis was conducted on the soil from the chambers and the samples taken throughout the season. A better understanding of the role mycorrhiza play in P nutrition of corn and the effect P availability (Table 1) has on mycorrhizal dynamics may have implications for P fertilizer recommendations.

Table 1. Availability of P in two fields in study.

| Location | Sites | Bray P | Organic P |
|---|---|---|---|
| | | ----------mg $g^{-1}$ soil---------- | |
| Shelton, NE | Low Bray P | 13.26 | 115.30 |
| | High Bray P | 41.93 | 126.82 |
| Lincoln, NE | Regular fertilization | 57.59 | 191.18 |
| | Low fertilization | 84.06 | 235.59 |

## Results and discussion

From middle July (Vt) until middle September (R5-6) there was an increase in the mycorrhizal marker in the soil samples from the two fields. The amount of AM marker in the soils from

Shelton (4.53 nmol $g^{-1}$ at Vt and 6.47 nmol $g^{-1}$ at R5-6) was higher than the soils from Lincoln (2.21 in Vt and 4.5 at R5-6). In Shelton there was a 40% increase in the marker from the vegetative stages till middle September when the corn was at R5-6 (Figure 1). No differences were observed in the C16*cis*11 marker during the vegetative phases. The AM fungi biomass was consistently smaller in the sites of higher Bray P, responding to the availability of P, however this difference was not significant. At Lincoln, there was 15% less mycorrhizal biomass in the soil under higher fertilization than the one under recommended fertilization (Figure 2). The increase in AM marker from Vt to R5-6 was 104%, and was much greater than the increase at Shelton. At Lincoln, in sites with recommended and high fertilization, P availability significantly reduced AM fungal biomass. It is evident that the corn crop was allocating part of the photoassimilates to mycorrhizal biomass, thereby supporting the symbiotic relationship with the fungi.

The chamber experiment at Shelton showed that inherent P availability of the soil was important when mycorrhizal fungi colonized the introduced chambers during the reproductive stages of the crop. We observed a reduction in AM fungal biomass of 27% in sites with high Bray P compared to low Bray P. The presence of roots inside the chambers was an important factor to the amount of C16*cis*11 found. Chambers that allowed the passage of roots (1mm pore mesh) had a 11% higher AM biomass than those chambers without corn roots (0.045 mm pore mesh). In this field, under these soil conditions, the presence of roots facilitated the colonization of new sites by the fungi. The increase of fungal marker inside the chambers throughout time supports our previous hypothesis: the crop was allocating C to its symbiotic fungi. At Lincoln we also found a 67% increase in the mycorrhizal marker inside the chambers from Vt to R5-6 that was higher than the 55% increase found Shelton. The influence of higher P availability was similar to that shown for Shelton, but was not significant. The addition of P to the chambers did not influence the extent of mycorrhizal colonization of the chambers at either Shelton of Lincoln.

Olsson et al (1997) showed that fatty acid signatures of AM fungi facilitate the study of AM fungal growth under differing soil conditions, and found that AM mycelium was negatively influenced by P availability. In addition, spore germination and hyphal growth of mycorrhizal fungi is known to be heavily dependent on the availability of soil P (De Miranda and Harris 1994); thus, mycorrhizal biomass decreased as the availability of P increased in the soil.

## Conclusions

The increase in mycorrhiza biomass was greatest where the inherent bioavailability of P was low. This suggests a possible role of AM fungi in P acquisition in highly fertile cropping systems. Further work is needed to quantify the mycorrhizal contribution to P uptake during the reproductive stages of corn.

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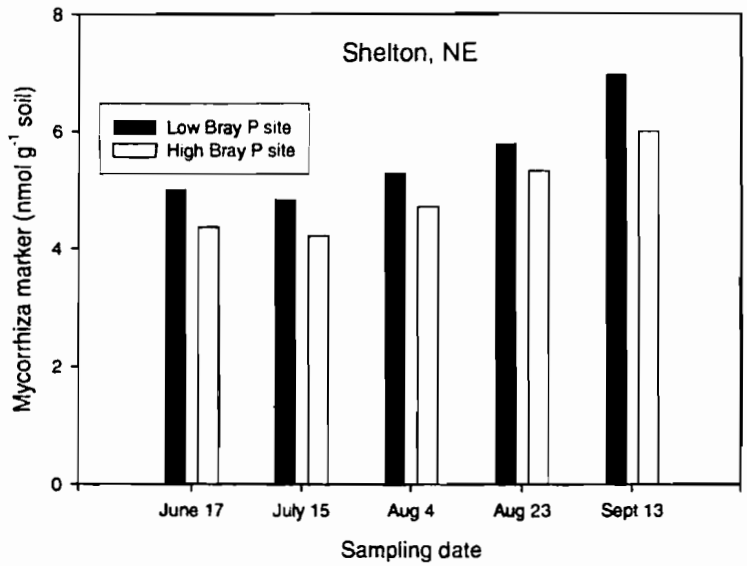


Figure 1. Dynamics of mycorrhizal biomass in soil samples taken throughout the season

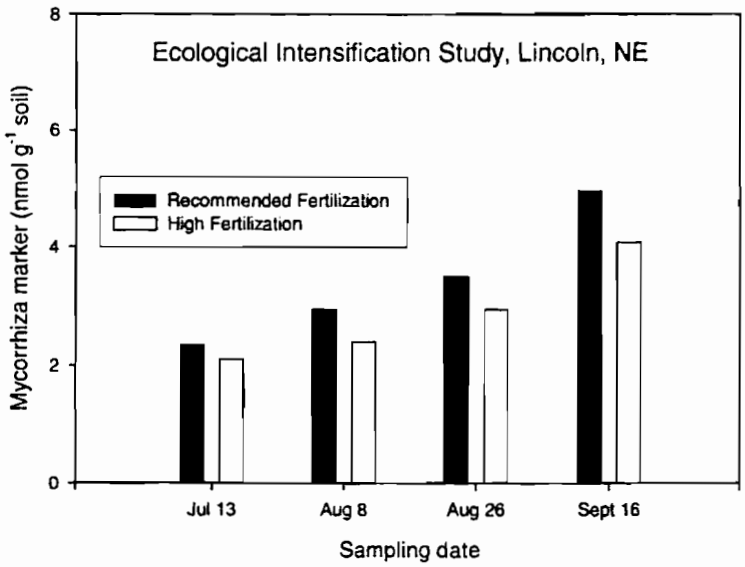


Figure 2. Dynamics of mycorrhizal biomass in soil samples taken throughout the season in Lincoln.

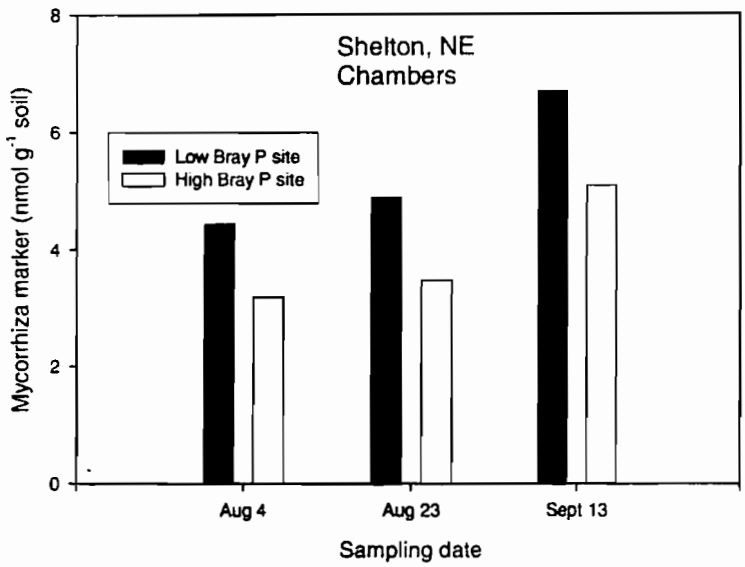


Figure 3. Biomass of mycorrhizal marker in the chambers from Shelton.

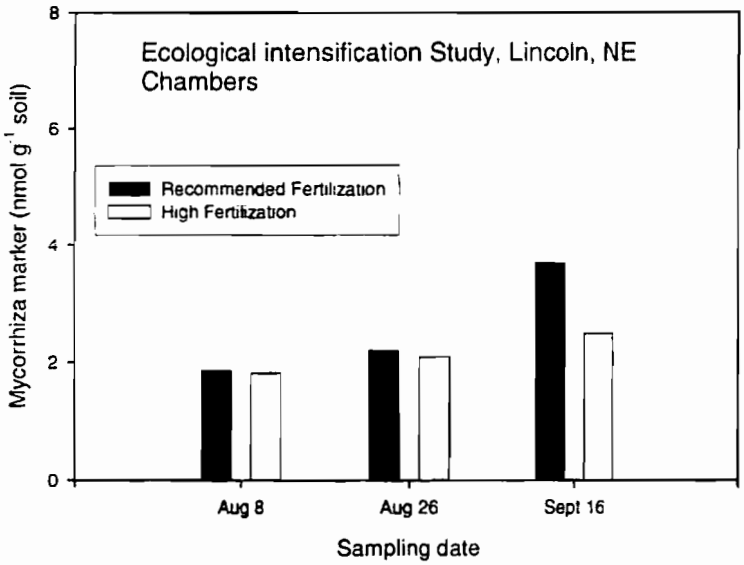


Figure 4. Biomass of mycorrhizal marker in the chambers from Lincoln.

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