Aspects of Applied Biology ***113****, 2011*
Making Crop Rotations Fit for the Future

The importance of no-till in the development of cropping systems to maximize benefits of arbuscular mycorrhiza symbiosis

By ISABEL BRITO[1], MÁRIO CARVALHO[1] and MICHAEL J GOSS[2]

[1]University of Évora, ICAAM, Apartado 94, 7002–540 Évora, Portugal
[2]University of Guelph, Kemptville Campus, Kemptville, Ontario K0G 1J0, Canada

Summary

The symbiosis of arbuscular mycorrhizal fungi (AMF) with plant roots supports several benefits to agricultural systems, including improved soil structure, resistance of crops to drought and soil pathogens, and its importance to crop production is likely to increase in the future due to the scarcity of P reserves in the world.

No-till is a powerful tool to manage AMF in the cropping systems as it allows the use of extraradical mycelium developed in the previous year and the extraradical mycelium developed by weeds in the beginning of the cropping year, as a major source of inoculum for the new crop. Therefore the design of crop rotations to take full advantage of AMF symbiosis, like an enhanced ability to uptake P, must consider both the tillage system to be adopted and appropriate weed management strategies.

Key words: Arbuscular mycorrhiza, tillage system, crop rotation, weed control

Introduction

The symbiosis of arbuscular mycorrhizal fungi (AMF) with plant roots supports several benefits to agricultural systems, including improved soil structure, resistance of crops to drought and soil pathogens, and its importance for crop P nutrition will increase in the future due to the increasing cost of phosphorus fertiliser due to the scarcity of P reserves in the world. Given that large-scale inoculation with AMF is generally impractical in most regions and we have little understanding about the consequences of using inocula (Schwartz *et al*., 2006), the development of management practices that maximise the benefits of this naturally occurring symbiosis is important.

Spores, root fragments and extraradical mycelium (ERM) are the sources of AMF inoculum in the soil, but when colonisation is started by ERM there are timing (Martins & Read, 1997) and energetic benefits (Dodd *et al*., 2000). In agricultural systems ERM can be produced in association with crops and weeds roots, and therefore both crop rotation and weed management are important tools to manage AMF within the cropping system. Tillage, associated with crop establishment and weed control selectively interferes with different AMF depending on their life and colonising strategies, by disrupting the ERM (Evans & Miller, 1990) and mixing surface residues into the soil profile (Abbott & Robson, 1991; Kabir *et al*., 1998). Tillage may therefore have a range of direct impacts on the diversity and colonisation potential of AMF.

Results from three different experiments are discussed to illustrate the relative importance of different components of the cropping systems in the management of AMF.

Materials and Methods

Experiment 1 (Expt 1) was designed to investigate the summer survival of AMF extraradical mycelium. It was composed of three steps, clay pots were used, and wheat was the host plant in all the steps of the experiment. In the first step different amounts of ERM were obtained by contrasting soil disturbance treatments according to the technique developed by Fairchild & Miller (1988); a more detailed description can be found in Goss *et al.* (2011) in this volume. During the second step the pots were buried over summer, finally (step 3) wheat was planted in the next season without further soil disturbance and allowed to grow for 10, 21 and 35 days, after which the AMF colonisation rate was assessed.

Experiment 2 (Expt 2) was designed to investigate the effect of soil disturbance on the interactions between the germinating crop and the ERM developed by weeds previously present in the soil. It was arranged as a two step experiment. In the first step a mixture of three common grass weeds were grown for 4 weeks and then controlled either by soil disturbance or by glyphosate (at a rate equivalent to 1080 g of active ingredient ha-1). Wheat was planted without further soil disturbance in Step 2 and shoot dry weight, P uptake and AMF colonisation rate were assessed after 21 days.

Experiment 3 (Expt 3) involved a field experiment comparing no-till (NT) and conventional tillage (CT) together with the combined effect of crop and preceding crop (wheat after sunflower and triticale after wheat). The soil type was a Luvisol located in the south of Portugal and the experimental design was a complete randomised block. The treatments had already been in place for 6 years when measurements were made. Roots samples were collected during the vegetation period to assess the AMF colonisation rate of wheat and triticale. Soil samples (0–10 cm) were collected to analyse AMF diversity by nested PCR.

Results

In Experiment 1, the AMF colonisation rate of the wheat planted at step 3 of the experiment was significantly increased 21 and 35 days after sowing in the treatments which had been undisturbed during step 1 compared with the disturbed soils. where larger amounts of ERM were present (undisturbed soil) when the pots were buried (Fig. 1).

In Experiment 2, soil disturbance to control weeds reduced both the AMF colonisation rate and the P uptake of the wheat crop (Fig. 2).

In Experiment 3, under NT the colonisation rate by AMF was much greater that under CT and the impact of tillage was greater than that of different crops in rotation (crop and preceding crop) (Table 1). Despite the fact that triticale seemed to be more mycotrophic than wheat, under NT wheat had a significantly greater AMF colonisation rate than triticale. The AMF colonisation rate of NT relative to CT [(NT/CT - 1) × 100] was 152%, while the AMF colonisation rate of triticale relative to wheat [(triticale/wheat - 1) × 100] was 39%.

Eleven different operational taxonomic units (OTUs) were identified (Table 2). Eight different OTUs were identified in the soil under NT and only five were identified under CT. Diversity of AMF was 60% higher under NT than under CT (Table 2).

Table 1. *Effect of tillage system [No till (NT) or Conventional tillage (CT)] and the combined effect of crop and preceding crop on arbuscular mycorrhizal colonisation rate*

	NT	CT	Mean
Wheat after sunflower	17.8 *b*	6.5 *c*	12.2
Triticale after wheat	23.9 *a*	10.0 *c*	17.0
Mean	20.9	8.3	

Letters indicate significant differences between treatments (*P* = 0.05).

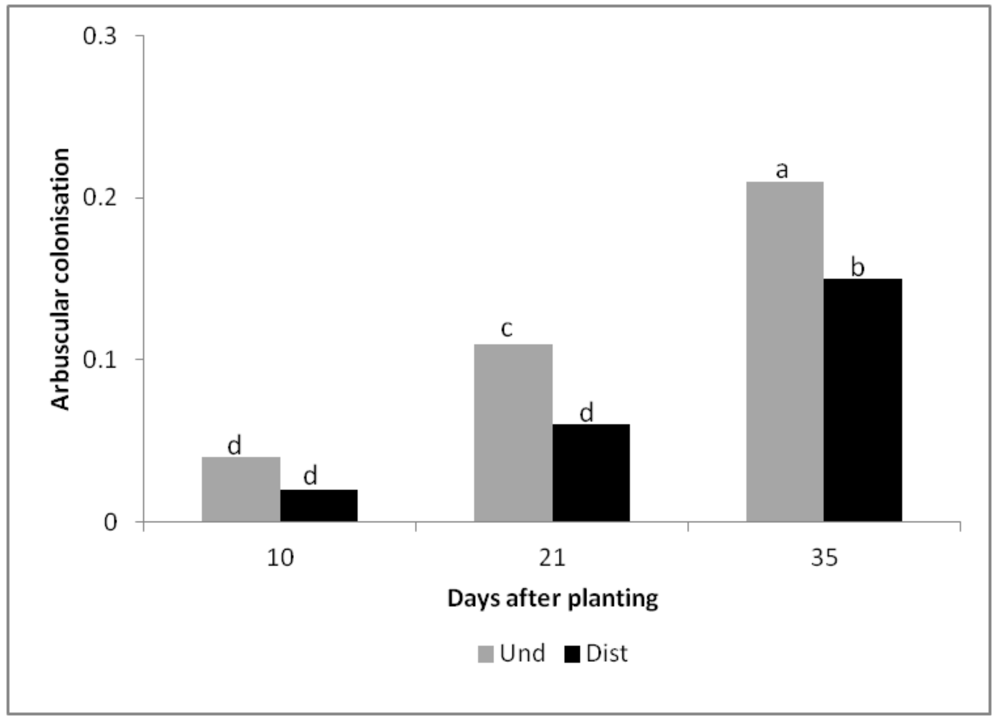

Fig. 1. Differential AM colonisation rate of wheat plants as the result of the summer survival of ERM. Grey bars – Undisturbed soil, Black bars - Disturbed soil. Letters indicate significant differences between treatments (*P* = 0.05).

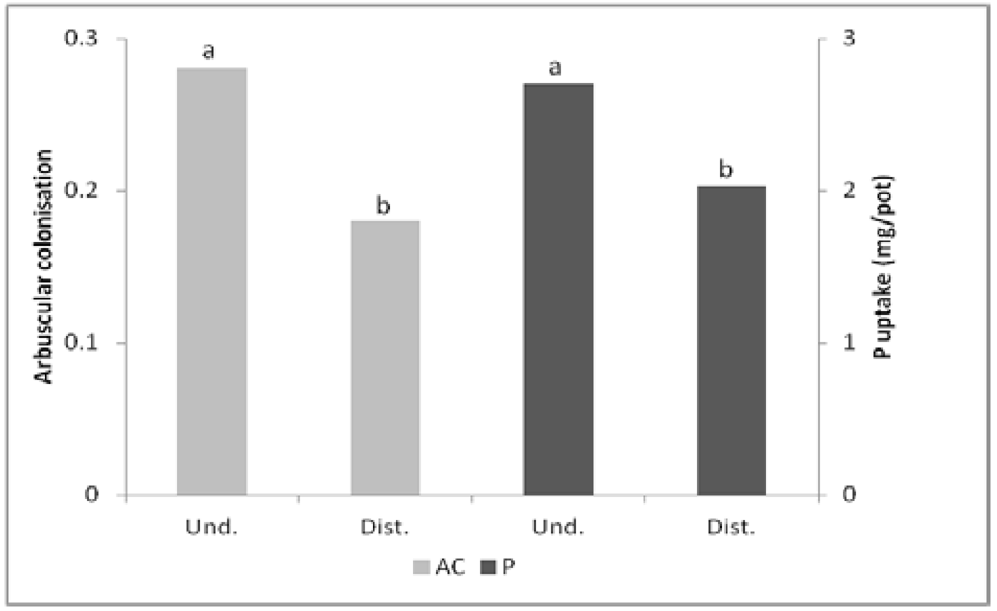

Figure. 2. Effect of weed control method on AMF colonisation of wheat (AC – left axis) and P uptake (P – right axis) after 21 days. Means followed by the same letter are not significantly different (*P* = 0.05).

Table 2. *AMF operational taxonomic units (OTUs) identified in the soil in Experiment 3 and their frequency in the two tillage treatments*

AMF operational taxonomic unit	Tillage system	
	No till	Conventional tillage
Glomus I	1	0
Glomus II	3	0
Glomus III	1	0
Glomus IV	1	0
Glomus V	1	0
Glomus VI	2	0
G. Scutellospora	0	2
G. cloroidium	0	3
G. ocultum	0	3
G. mosseae	24	32
G. intrarradices	3	7

Discussion

The ERM available in the soil at the time of sowing might have been produced by the previous crop or/and by the weeds, especially when the sowing occurs several weeks after the beginning of the rainy season. However, tillage reduces this type of inoculum by disrupting the ERM.

These experiments indicate that ERM is able to survive through the summer and remain infective, even in hot and dry Mediterranean conditions. ERM developed in association with weeds also promotes early AMF colonisation of the crop as long as it is kept intact, and consequently enhances the early P uptake of the crop. When ERM is the available, AM colonisation starts earlier and initial plant P uptake is enhanced. These results are supported by observations made under field conditions. In spite of the significant effect of the crop and preceding crop on AMF colonisation rate, the effect of NT overrules the combined effect of crop and preceding crop. Under NT, the ERM, either produced in the previous year or by the weeds in the cropping year, remains intact and is probably the major source of AMF inoculum, while under CT only spores and root fragments are available for AMF inoculation of the new crop. Tillage also affects the AM fungal diversity (Table 2), with soil under NT presenting a larger number of operational taxonomic units and therefore increasing the chances of having a functional AMF to help cope with biotic or abiotic stresses.

No-till is a powerful tool to manage AMF in the cropping systems as it allows ERM developed in the previous year and the ERM developed by weeds in the beginning of the cropping year to form a major source of inoculum for the new crop. Therefore, if rotations are to take full advantage of the AMF symbiosis, e.g. an enhanced ability to take up P, careful attention must be paid to interactions with the tillage system and weed management.

References

Abbott L K, Robson, A D. 1991. Field management of VA mycorrhizal fungi. In *The Rhizosphere and Plant Growth*, pp. 355–362. Eds Keister D L and P B Cregan. Kluwer. Netherlands: Kluwer Academic Publishers.

Dodd J C, Boddington C L, Rodriguez A, Gonzalez-Chavez C, Mansur I. 2000. Mycelium of arbuscular mycorrhizal fungi (AMF) from different genera: form, function and detection. *Plant and Soil* **226**:131–151.

Evans D G, Miller M H. 1990. The role of the external mycelial network in the effect of soil disturbance upon vesicular-arbuscular mycorrhizal colonization of maize. *New Phytologist* **114**: 65–71.

Fairchild G L, Miller M H. 1988. Vesicular-arbuscular mycorrhizas and the soil-disturbance-induced reduction of nutrient absorption in maize. II. Development of the effect. *New Phytologist* **110**:75–84.

Goss M J, Brito I, Carvalho M, Sabaruddin K, deVarennes A. 2011. Below-ground interactions for sustainable cropping systems. *Aspects of Applied Biology* **113**, *Making Crop Rotations Fit for the Future*, pp. xx–xx.

Kabir Z, O'Halloran I P, Widden P, Hamel C. 1998. Vertical distribution of arbuscular mycorrhizal fungi under corn (Zea mays L.) in no-till and conventional tillage systems. *Mycorrhiza* **8**:53–55.

Martins M A, Read D J. 1997. The effects of disturbance on the external mycelium of arbuscular mycorrhizal fungi on plant growth. *Pesquisa Agropecuária Brasileira* **32**:1183–1189.

Schwartz M W, Hoeksema J D, Gehring C A, Johnson N C, Klironomos J N, Abbott L K, Pringle A. 2006. The promise and the potential consequences of the global transport of mycorrhizal fungal inoculum. *Ecology Letters* **9**:501–515.