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COMMENTARY

Restoring grasslands with arbuscular mycorrhizal fungi around remnant patches

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Abstract

Ecological restoration of species-rich grasslands remains a priority for conservation of biodiversity. Torrez et al. (*Applied Vegetation Science*, this issue) determined if plant species recolonization of degraded nutrient-poor grasslands could be increased by adding a local source of arbuscular mycorrhizal fungal (AMF) inoculum at different distances from intact remnant grasslands. They highlight the important role of below-ground processes on restoration success.

Restoring degraded ecosystems to their previous 'natural' state is major societal challenge. There are important constraints that reduce the likelihood of successful restoration, such as simultaneous environmental changes that tend to overwhelm land managers as to which best practice to deploy (Perring et al. 2015). Soil biota is another critical constraint that is, however, more feasible to incorporate into best practices during ecological restoration (Middleton & Bever 2012). In natural grasslands, arbuscular mycorrhizal fungi (AMF) are common and key root symbionts that appear to maintain plant diversity (van der Heijden 2002). Torrez et al. (2016) demonstrated that custom-made AMF inoculum derived from surrounding vegetation could increase the establishment of plant species on degraded nutrient-poor grasslands. Furthermore, they showed that the positive effects of AMF additions, such as increased species richness, were short term and larger closer to intact remnant grassland patches. Improving nutrient uptake and soil conditions via AMF inoculations is hypothesized to lead to successful restoration, particularly in nutrient-poor grasslands, where numerous plant species depend on AMF for survival and growth (Smith & Read 2008).

Torrez et al. (2016) examined the beneficial effects of AMF inoculations, within a spatial context, on indicators such as richness, diversity and similarity of recolonizing plant communities to nearby intact grasslands. They also determined if the effects of the AMF inoculum would vary among plants with different inherent mycorrhizal dependencies and seed dispersal adaptations. Torrez et al. (2016) hypothesized that: (1) AMF inoculum would enhance establishment of AMF-dependent plant species only; (2) establishment success of specialist species of nutrient-poor grasslands and plant species with poor seed dispersal capacities would decrease with distance from intact grassland patches; and (3) recolonization by AMF-dependent plant species would decrease with increasing distance from the intact patches. They showed a general positive effect of AMF inoculum on richness of all plant species, which appeared mostly to be driven by a strong positive effect from the AMF-dependent species. The positive effect was only found near (5 and 10 m) intact grassland patches and was invariable to seed dispersal adaptations.

The study of Zhang et al. (2012) had already demonstrated strong positive effects of local-sourced AMF inoculum on plant species richness and productivity in grasslands of Central Asia, yet Torrez et al. (2016) explored the spatial dependencies and duration of AMF additions on plant species recolonization. Furthermore, they suggested that priority effects explained the decline in species richness at the furthest distances from the intact grassland patches. Priority effects occur when previously established plant species affect the recolonization, growth or fitness of later arriving species (Grman & Suding 2010). In the study of Torrez et al. (2016), priority effects likely arose from soil legacies left behind by the well-dispersed generalist plant species, particularly at 20 m from the intact patches. These soil legacies likely contributed to the strong priority effects on the AMF-dependent species.

The findings of Torrez et al. (2016) imply that successful restoration can be improved by AMF additions in the short term and only at relatively close distances to intact grassland patches. Positive responses of plants to general soil inoculations (including all soil biota) have been critical to restoration of late successional plant communities elsewhere (Middleton & Bever 2012). Interestingly, the

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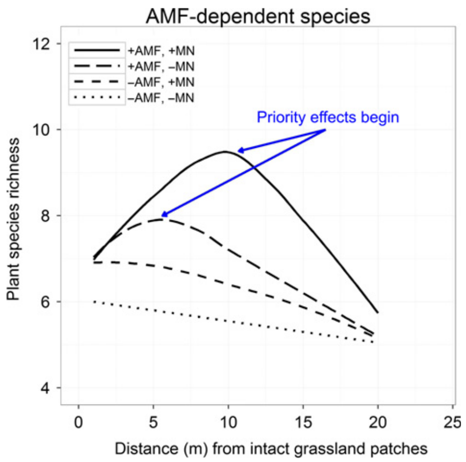

Fig. 1. Predicted effects of AMF additions (+AMF) and presence of mycorrhizal networks (+MN) on plant species richness for AMF-dependent plant species. Priority effects and facilitating MN effects are hypothesized from the results of Torrez et al. (2016) and the literature. No additions of AMF: –AMF; restricting the formation of MN: -MN.

benefits of those inoculations spread to neighbouring plants and thus, I suggest that mycorrhizal networks (Teste & Simard 2008) may have played an additional beneficial role close to intact patches (Fig. 1). Mycorrhizal networks formed by AMF have been shown to improve survival, growth and nutrient status of 'connected' establishing plants (van der Heijden 2004; van der Heijden & Horton 2009) and thus, can potentially further facilitate successful restoration of degraded sites (Perring et al. 2015).

The role of mycorrhizal networks in a spatial and restoration context has been investigated in ectomycorrhizal systems (Teste & Simard 2008; Teste et al. 2010). In AM-dominated plant communities, mycorrhizal networks may also aid plants in recolonizing degraded sites by facilitating rapid root colonization and higher protection from pathogens, thereby promoting the spread of AMF-dependent species and over larger distances, and ultimately reducing the extent of priority effects (Fig. 1). Grassland plant species also host other ubiquitous symbionts, such as leaf endophytes, that have been shown to suppress AMF root colonization, ultimately impacting plant performance (Omacini et al. 2012). The interaction between leaf endophytes and mycorrhizal networks appears intriguing since both agents are important in channeling resources within plants (Teste et al. 2010; Omacini et al. 2012), and thus merits further investigation.

I suggest further research is necessary to fully elucidate the effects of AMF additions on plant fitness and to explore the long-term and context-dependent effects of mycorrhizal networks and leaf endophytes. I propose that AMF additions and functional mycorrhizal networks are key to successfully restoring self-sustaining diverse grasslands, particularly on nutrient-poor soils, and the work of Torrez et al. (2016) provides good evidence for this likely necessity.

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