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A review on arbuscular mycorrhizal fungal communities in response to disturbance

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Abstract. Disturbance, both natural and anthropogenic, is considered a major structuring force in communities and influences overall species. Arbuscular mycorrhizal (AM), a symbiosis between plants and members of Glomeromycota fungi, enhances water and nutrient supply. These fungi play a significant role in the establishment and resilience of vegetation. Understanding arbuscular mycorrhizal (AM) fungus response to disturbance is necessary to preserve and rehabilitate functional plant communities in a post-disturbance landscape. The methods used in this study is a literature review. Firstly, the researcher determines the scope definition of the disturbance type used in the study. The next step is to find a research study that describes the community response, such as the diversity and community changes of AM fungi. The researcher then analyzes the response in different types of disturbances and synthesizes AM fungal diversity and community structure responses. In some studies, soil disturbance reduces AM fungal diversity, spore density, and changes or unchanged in community composition. These findings indicated various responses to disturbance in diversity and community structure.

1. Introduction

AM fungi form symbiotic associations with 70-90% of land plants, ~ 250 000 plant species in all the major biomes, enhance uptake of mineral nutrients, particular phosphorus, influences plant-plant interactions and the structure of plant communities, and thus it can affect agricultural production and the conservation and restoration of ecosystems [1,2]. AM fungi becomes an important part from the very beginning of primary succession and because they show different relationships with pioneer and late-successional species, which suggests they may be involved in important, ecological mechanisms of succession [3]. Study of Garcia de leon *et al*. [4] about plant and AM fungal communities' dynamics reported that in the early stage of succession, AM fungal colonizers such as *Glomus* spp. and *Claroideoglomus* spp. found, were followed by other *Glomus* spp. in the later successional stages. This study suggests that AM fungi are involved in early succession and in the late succession.

Disturbance, from a mycocentric perspective, occurs when hyphal networks are destroyed [5], either by physical disruption of the soil structure or by faunal grazing. Thus, it could shift the community, render the disturbance an ecological filter selecting for disturbance-tolerant AM fungi that enable rapid colonization. By applying C-S-R (competitor, stress tolerator, ruderal) framework [6] to AM fungi community, advance our understanding of their life history strategies with response to disturbance. ‘Competitors’ evolve in low stress and low disturbance environments; ‘Stress tolerator’ endure suboptimal environments owing to resource conservation strategies; Disturbance-tolerant are categorized as 'Ruderal' evolve with frequent of disturbance, high colonization ability, rapid production of low-cost biomass, and short reproductive cycles [5,7,8].

The impact of disturbance has been studied in many types of ecosystems and groups of organisms or particularly in AM fungal communities [9-11]. For unstable topographic such as volcanic slopes, the trap culture approach is more appropriate [12,13]. The purpose of discussing disturbance impact on AM fungi communities is to improve the understanding how ecosystem will change after disturbance. However, knowledge about the fungi' species composition and their disturbance tolerance are essential for successful application of AM fungi for restoration of the ecosystem. In some studies, soil disturbance reduces AM fungal diversity, spore density, changes or unchanged in community composition. It is not yet clear what drives the variation in disturbance response among studies. In this study, the impact of AM fungi communities of different disturbance types will assess through the diversity impact assessment.

2. Methods

This study is reviewed from previous research that related to assessing impact on AM fungi communities through diversity and community changed. To investigate this study, we refer to the previous articles related to AM fungi communities' impact on different types of disturbance.

The following steps were taken to investigate the impact if AM fungi communities on different types of disturbance: (1) Determines the scope definition of the disturbance type used in the study, (2) selected research articles that provide number of species and community analysis that describe impact of disturbance, (3) investigate the information about the impact of disturbance through the number of species, i.e. increasing and decreasing number of species post-disturbance, and community analysis describing the impact, e.g. dissimilarity analysis calculation, (4) analysed the mechanism related with community responsiveness towards the disturbance.

Articles selection started from peer-reviewed research journals in the Google Scholar database. The keywords used in the search are 'arbuscular mycorrhiza', 'disturbance', and 'responses' from 2010 to 2019. In the beginning, the researchers used the Google Scholar website "https://scholar.google.com/" a total of more than 200 full texts was found, and then only peer-reviewed research articles were selected. At the second phase screening, the researchers excluded articles from the research articles that were not giving information about phylotype data of AMF responses in different types of disturbance and imply the diversity response after the disturbance experiment. As a result, seven articles were identified for thorough analysis according to the research question.

3. Results and discussion

3.1. Type of disturbance

Disturbances is an event within a particular time that can cause the change resources or in the physical environment and can influence community structure. In this study, we define "disturbance" as the physical or chemical phenomena that disrupt fungal communities and ecosystems. Types of disturbance selected in this study are mechanical soil disturbance, agricultural activities, host disturbance and chemical disturbance (Table 1).

In mechanical soil disturbance, hyphal networks disrupted by physical disruption, which are known reduce root colonization, means giving effect on fungal biomass on the soil. Sieving methods, tillage on agricultural practices, and disturbance in post-fire habitat caused by land clearing activities are mechanisms giving physical stressing on fungal biomass, particularly on extraradical hypha. Other disturbances involve chemical additions, such as fertilization. Thus, disturbance may be directly affected to the fungal communities seen in Table 1, various responses of fungal communities affected by these physical or chemical disturbances. Study comparison of different disturbances showed that Mechanical and agricultural disturbance was the most disruptive than others because mechanical disturbance is typically embedded within most agricultural practices [14].

Table 1. AM fungal communities' response on different disturbance types.

Disturbance type	Disturbance mechanism	AMF response		Source
		Richness	Community composition	
Mechanical soil disturbance	Disruption of hyphal network: sieving	Decrease OTU	Compositional changes	Atunnisa & Ezawa, 2019 [12]
Mechanical soil disturbance	Disruption of hyphal network: sieving	Increase OTU	Compositional changes	Kawahara &Ezawa, 2013 [13]
Mechanical soil disturbance	Disruption of hyphal network: tillage	Decrease OTU	Compositional changes	Schnoor *et al.*, 2010 [9]
Agriculture activities	Fertilization, plant-mediated, tillage	Decrease OTU	Compositional changes	Manoharan *et al.*, 2017 [15]
Host disturbance	Disruption of hyphal network, Plant-mediated	Not significant change	Not significant change	Lekberg *et al.*, 2012 [10]
Host disturbance	Slash and burn,	Decrease OTU	Compositional changes	Sharmah & Jha, 2014 [16]
Chemical	Long term fertilization	Decrease OTU	Compositional changes	Chen *et al.*, 2014 [17]

3.2. AM fungal responses to disturbance
Seven research articles were selected used in this study, represented different types of disturbance. Mechanical soil disturbance by disruption of hyphal network through sieving and tillage activity in agricultural practice negatively impacts AM fungal diversity i.e. decreasing the number of species, species richness and changed the composition [9,12,15]. Disturbance type of host perturbation and chemical showed a similar trend, decreasing and changed in community composition [10,16,17]. Other studies showed that community post-disturbance was steady condition, species richness and community composition were not changed, imply that AM fungal community unresponsive to disturbance [10,13]. These results showed that there are various responses of AM fungal communities against disturbance.

The significant decline in AM fungal richness in response to soil disturbance has also been observed in other studies [10,18]. The declining trend demonstrates that the diversity of AM fungal communities is sensitive to soil disturbance; those that require a more extended period to exist are less competitive or become vanish [10]. Selection in this process would be explained in terms of the charges on population survival and the need for rapid growth and reproduction at the high level of disturbance, i.e. disturbance-tolerant species, where fewer lineages have successfully responded evolve the complex adaptations needed. These findings imply that in most studies, AM fungal communities are sensitive to soil disturbance.

Increasing and decreasing species abundance as a response against disturbance raises a new question of how the community maintained ecologically. The early-on niche theory states that no two species with identical niches can coexist indefinitely. Moreover, neutral theory [19] in which the functional equivalence was proposed explained that the abundance of each species increases or decreases randomly. Furthermore, diversity in the community depends on the dynamic equilibrium between speciation (or immigration) and extinction. Accordingly, Increasing and decreasing species abundance might be one mechanism to maintain the equilibrium state under pressure conditions.

Lekberg *et al*. [10] observed high resilience of the AM fungal communities after severe disturbance in a semi-natural grassland and suggested they were unexpectedly disturbance-tolerant. Applying the intermediate disturbance hypothesis [20], the destruction of hyphal networks by the trap culture might reset competition among the fungi, which could increase AM fungal richness via providing an equal chance to colonize the roots, not only for the dominants but also for the rare species [13]. In this context, increasing the number of species in the post-disturbance might represent the intermediate level of disturbance.

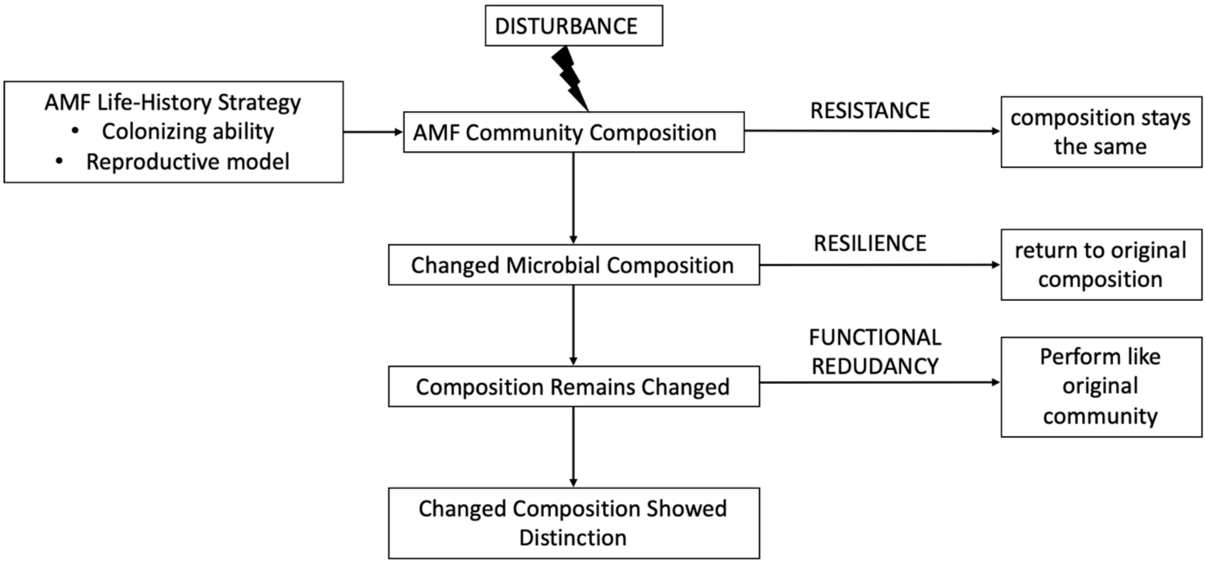

Figure 1. A schematic model to illustrate the potential impacts of a disturbance on AM fungal communities.

3.3. Resistance in AM fungal communities
Resistance, resilience, and redundancy were proposed by Allison and Martiny [21] in the microbial community. Using this model, we propose the modified model to illustrate the potential impacts of a disturbance on AM fungal communities (Figure 1). AM fungal community might be resistant to the disturbance, which means withstand disturbances without any change in the composition. High resistance in communities likely due to disturbance-tolerance fungi. In another scenario, if the community is sensitive and shape the communities, it could be resilient. By the time the community could recover to its initial composition, however, the community whose composition is sensitive and not resilient might produce similar rates to the initial community if the member is functionally redundant. The last scenario is if the community composition is sensitive to a disturbance, not resilient, and not have a similar function as its original community; then, the community will completely change from its original.

We argue that a life-history strategy also plays an essential role in the AM fungal community impact of disturbance. A life-history strategy provides an ecological description of how an organism fulfills its life-cycle requirements. In turn, those strategies could be used to predict biodiversity patterns and successional trajectories in a tractable way.

4. Conclusion
There is considerable evidence that AM fungi are sensitive to a wide range of disturbance types. The impact of disturbance on AM fungal communities is inconsistent. Accordingly, applying temporal study in AM fungi communities that occur in periodically disturbance may provide important clues about life-history strategy in response to soil disturbance.

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