

Perspective

Arbuscular Mycorrhiza Symbiosis as a Factor of Asteraceae Species Invasion

Sonya Sokornova ^{1,2,*} , Daniil Malygin ¹ , Anton Terentev ^{1,2}  and Viktor Dolzhenko ^{1,2}

¹ All-Russian Institute of Plant Protection, 3 Podbelskogo Str., 196608 Saint Petersburg, Russia

² World-Class Research Center «Advanced Digital Technologies», Peter the Great St. Petersburg Polytechnic University, 29 Polytechnicheskaya Str., 195251 Saint Petersburg, Russia

* Correspondence: svokornova@vizr.spb.ru

Abstract: Invasive weeds of the Asteraceae family are widespread in the world. Arbuscular mycorrhiza (AM) is one of the main factors contributing to the successful distribution of these species that is most clearly manifested in the subfamily Asteroideae. The benefits of plant-AMF symbiosis are most significant under unfavorable biotic and abiotic conditions. The specificity of the relationship between arbuscular mycorrhizal fungi (AMF) communities and plants and is determined at the presymbiotic stage. The AMF colonization level is higher in invasive species than in native ones, but AMF communities associated with Asteraceae invasive species are less diverse. AMF communities of Asteraceae invaders often include fewer common species (e.g., species belonging to Diversisporales). Invaders also reduce native AMF species richness in new areas. Arbuscular mycorrhizal fungi can form mycorrhizal networks that allow the redistribution of nutrients in plant communities. The most significant influence of AMF associated with invasive Asteraceae plants is seen in the formation of soil and rhizosphere microbiota, including the suppression of beneficial soil bacteria and fungi. This review could be useful in the development of practical recommendations for the use of AMF-based fertilizers.

Keywords: arbuscular mycorrhizal fungi community; invasive weeds; Asteraceae; common mycorrhizal networks; *Glomeromycota*; biotic and abiotic factors



Citation: Sokornova, S.; Malygin, D.; Terentev, A.; Dolzhenko, V. Arbuscular Mycorrhiza Symbiosis as a Factor of Asteraceae Species Invasion. *Agronomy* **2022**, *12*, 3214. <https://doi.org/10.3390/agronomy12123214>

Academic Editor: Alba N. Mininni

Received: 15 November 2022

Accepted: 15 December 2022

Published: 18 December 2022

Publisher's Note: MDPI stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.



Copyright: © 2022 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

1. Introduction

In the context of world economic globalization and the rapid increase in food demand due to world population growth, invasive weeds have become a serious threat to various ecosystems worldwide. Such invasions become a significant economic and ecological risk factor, providing irreparable damage to agricultural biocenosis. Among the most harmful invasive plants, there are more than three dozen Asteraceae species [1,2]. Many invasive weeds not only produce allelopathic compounds and allergenic species themselves but also may be hosts for pests and pathogens, which are transferred to agricultural crops from these new habitats [3]. One of the features of most invasive Asteraceae species, including dangerous and quarantine plants such as *Ambrosia artemisiifolia* L., *Ambrosia trifida* L., *Bidens frondosa* L., *Helianthus tuberosus* L., *Solidago canadensis* L., *Solidago gigantea* Aiton, etc., are arbuscular mycorrhizal fungi (AMF) mutualism and mycorrhizal networks formation which facilitates their successful distribution and anchoring in new territories (Table 1) [4–8].

Table 1. AMF colonization level of different Asteraceae species.

Asteraceae Species	Life Cycle	AMF Colonization Level *	Invasive/Native	References
Cardueae				
<i>Carduus acanthoides</i> L.	biennial/perennial	medium	native	[9]
<i>Carduus tenuiflorus</i> Curtis	annual/biennial	medium	native	[10]
<i>Centaurea scabiosa</i> L.	perennial	medium	introduced	[11]
<i>Centaurea stoebe</i> (= <i>Centaurea maculosa</i>) L.	biennial/perennial	medium	invasive	[12]
Cichorieae				
<i>Cichorium intybus</i> L.	perennial	high	native/introduced	[13]
<i>Lactuca serriola</i> L.	annual/biennial	medium	native	[14]
<i>Sonchus arvensis</i> L.	perennial	low	pres	[15]
<i>Taraxacum officinale</i> (L.) Weber ex F.H.Wigg.	perennial	high	pres	[16]
Senecioneae				
<i>Senecio vernalis</i> Waldst. and Kit.	biennial	low	native	[17]
<i>Tussilago farfara</i> L.	perennial	medium	native	[18]
Anthemideae				
<i>Achillea millefolium</i> L.	perennial	medium	native	[19]
<i>Artemisia vulgaris</i> L.	perennial	medium	native	[18]
<i>Matricaria discoidea</i> (= <i>Matricaria matricarioides</i>) DC.	annual	medium	native/introduced	[20]
<i>Tanacetum vulgare</i> L.	perennial	high	native	[21]
Astereae				
<i>Aster squamatus</i> (Spreng.) Hieron.	annual	medium	introduced	[14]
<i>Baccharis halimifolia</i> L.	perennial	low	native	[22]
<i>Erigeron annuus</i> (L.) Desf.	annual	high	invasive	[23]
<i>Erigeron bonariensis</i> (= <i>Conyza bonariensis</i>) L.	annual	medium	introduced	[15]
<i>Erigeron canadensis</i> (= <i>Conyza canadensis</i>) L.	annual	medium	invasive	[23]
<i>Solidago canadensis</i>	perennial	high	invasive	[23]
<i>Solidago gigantea</i>	perennial	high	invasive	[24]
<i>Solidago nemoralis</i> Aiton	perennial	medium	native	[25]
Millerieae				
<i>Galinsoga quadriradiata</i> (= <i>Galinsoga ciliata</i>) Ruiz and Pav.	annual	medium	invasive	[26]
<i>Galinsoga parviflora</i> Cav.	annual	low	invasive	[27]
Eupatorieae				
<i>Ageratina adenophora</i> (Spreng.) R.M.King and H.Rob.	perennial	medium	invasive	[28]
Coreopsideae				
<i>Bidens frondosa</i>	annual	low	native	[29]
		high	invasive	[23]

Table 1. Cont.

Asteraceae Species	Life Cycle	AMF Colonization Level *	Invasive/Native	References
<i>Bidens tripartite</i> L.	annual	medium	introduced	[30]
Heliantheae				
<i>Ambrosia artemisiifolia</i>	annual	medium	invasive	[31]
<i>Helianthus annuus</i> L.	annual	high	invasive	[21]
<i>Helianthus tuberosus</i>	perennial	medium	introduced	[32]
		high	invasive	[23]
<i>Parthenium hysterophorus</i> L.	annual	medium	native	[27]
<i>Rudbeckia laciniata</i> L.	perennial	high	invasive	[24]
<i>Xanthium albinum</i> (Widder) Scholz and Sukopp	annual	high	invasive	[23]

* low (<30%), medium (30–70%), high (>70%); assessed by histochemical method, based on counting the number of arbuscules, vesicles, and the length of mycelium.

The arbuscular mycorrhiza (AM) is formed by the fungi of the subphylum Glomeromycotina in the phylum Mucoromycota [33]. Their phylogeny has changed several times in the last two decades [33,34]. Earlier most of the AMF belonged to the major genus *Glomus*, but now many former *Glomus* species are assigned to other genera [35]. Nevertheless, this order Glomerales, which includes most of these genera, is still major in AMF communities (>70%).

There are lots of plant–AMF association benefits. First of all, it has better nutrient delivery, including phosphorus, nitrogen, sulfur, and microelements [36–41]. Mycorrhized plants are also more resistant to fungal diseases and pests [42–44]. One of the key factors affecting the effectiveness of mycorrhizal protection is the environmental conditions [42,45–47]. Under favorable environmental conditions and high availability of nutrients, arbuscular mycorrhiza does not have a significant effect on plant development, however, under adverse conditions of various nature, its effect becomes significant [8,47–49]. Symbiosis with arbuscular mycorrhizal fungi affects plant growth, increases their immunity, and helps them better tolerate drought, flooding, soil salinization and heavy metal pollution [26,48,50–53].

Research conducted on Chongming island, China, showed that the spread of Canadian goldenrod *S. canadensis* in arid areas was accompanied by increased AMF colonization, while such an effect was not observed in wet lowlands [48]. The success of plant AMF colonization may also depend on soil conditions. In the case of invasive ragweed *A. artemisiifolia* the highest degree of root mycorrhization was observed in disturbed areas, such as roadsides and wastelands, while the minimum percentage of mycorrhization was observed in natural conditions and in cultivated areas [54].

Invasive plants are colonized with AMF better compared to native plants. This was shown in *A. artemisiifolia*, *R. laciniata*, and *S. gigantea* [24,55]. The AMF community can influence the invasion of species by changing the competitive relationship between invasive and native species through changes in the abundance of AMF and their species composition. The invasion of some plants is usually accompanied by a decrease in the diversity of AMF species, but these remaining fungi help the invader. That was also shown in Asteraceae in the field [24,55,56]. As a result, native plants, dependent on mycorrhizal symbiosis, reduce or even lose their competitive advantage in the invaded area. Moreover, depending on the phytobiome and other biotic factors, the competitiveness of either invasive or native species may increase [57–59].

It is worth noting, that along with the physiological features of the development of invasive species (lengthening of the growing season, increase in the size of leaves, the number and viability of seeds, the formation of monodominant thickets, etc.), the synthesis of allelopathic compounds and other factors, and the success of expansion into new ter-

ritories by these species is determined by the ability to form arbuscular mycorrhiza and mycorrhizal networks [4–8]. Allelochemicals reduce the survival and regeneration of native plants and have a significant impact on the microbial community of the rhizosphere, due to the processes of decomposition, metabolization of labile and recalcitrant substrates, modifications of soil enzyme activity, etc. [60–67]. It was shown that allelochemical compounds, produced by *S. canadensis*, inhibit the colonization of native plants *Echinochloa crusgalli*, *Kummerowia striata*, and *Ageratum conyzoides* by AMF and change the AMF community [68]. Traditionally, allelopathy is considered to be a separate, independent mechanism of plant invasion. However, we suppose that in the case of invasive Asteraceae species this may be a first step in the two-step invasion. Thus, the release of allelochemical compounds leads to the weakening of the native flora, both directly—allelopathically and indirectly—through the suppression of their mycorrhizal symbiosis [68–70]. This leads to a change in the composition of the AMF community, which, in turn, may allow invasive plants to form their own effective symbiosis with AMF, further increasing their competitive potential. The main objective of the study was to determine the effects of AMF in symbiosis with plants on the spread of invasive Asteraceae weeds and to define its features. We compared AMF communities in native and invasive Asteraceae species, identified features of symbiotic relationships between AMF, and assessed their soil microbiota.

2. Invasive Asteraceae Species Associated with AMF

In Central Europe and European Russia, there are such associated AMF invasive species of the Asteraceae family such as fleabane *E. canadensis*, ragweed *A. artemisiifolia*, Jerusalem artichoke *H. tuberosus*, stickseed *B. frondosa*, goldenrod *S. canadensis*, pineapple weed *M. discoidea*, daisy *Symphyotrichum x salignum* (Willd.) G.L.Nesom, common cocklebur *Xanthium orientale* L., quick weed *Galinsoga parviflora*, spherical muzzle *Echinops sphaerocephalus* L., and others [32,71–76]. It is important to point out that the majority of noxious invasive Asteraceae species belong to the subfamily Asteroideae (Figure 1). It was shown that these species have the highest level of AMF colonization among other subfamilies [20,24].

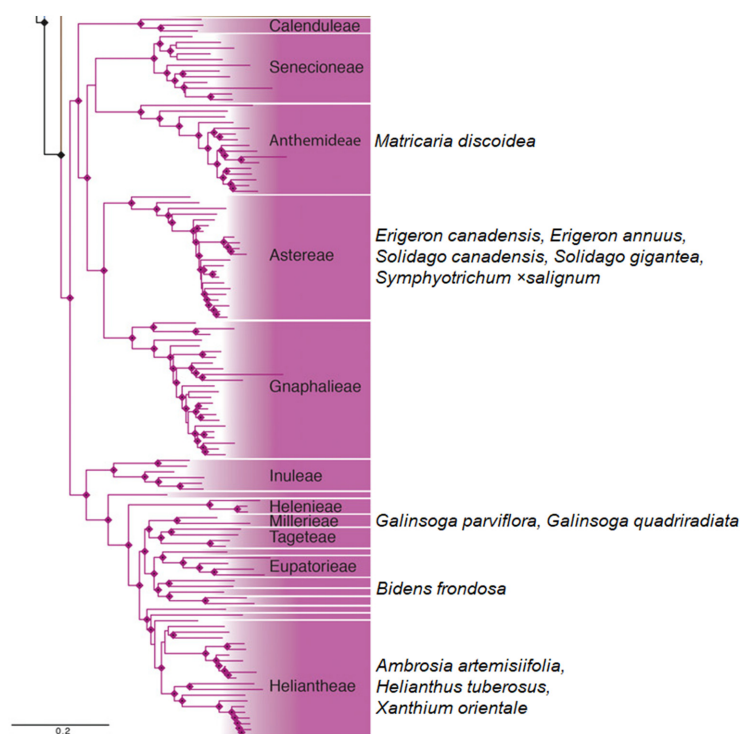


Figure 1. Phylogenetic tree of some dangerous invasive plants of subfamily Asteroideae according to Mandel et al., 2019 [77].

Depending on abiotic factors, host–plant species, and the presence of other species, the types of relationships may vary from mutualism to parasitism [46,78]. For invasive Asteraceae species, it is a powerful symbiosis. The nature of these interactions is determined by the plant species and the AMF community [79]. An analysis of the occurrence of fungal species associated with plants of the Asteroideae subfamily showed that invasive species from the tribes Anthemideae, Astereae, Cardueae, Gnaphalieae, Cichorieae, Senecioneae, and Heliantheae are often associated with such genera as *Glomus*, *Claroideoglomus*, *Rhizophagus*, *Septoglomus*, *Funneliformis*, *Paraglomus*, *Diversispora*, *Acaulospora*, *Archaeospora*, *Scutellospora*, and *Pacispora* [80]. This hypothesis is confirmed by data on a high level of arbuscular mycorrhizal fungus colonization of invasive Asteraceae species obtained in the Czech Republic, including *E. canadensis*, *S. canadensis*, *R. laciniata*, *G. parviflora*, *A. artemisiifolia*, etc. [20].

Along with widespread species of fungi, there are fewer common representatives of the Diversisporales order. The most frequent AMF associated with Asteraceae plants belongs to the genus *Glomus*. However, the AMF community of the invasive Asteroideae weeds in most cases contains Diversisporales in the field (Table 2). We suppose that the species of Diversisporales may be the key partners in the mutualistic relationships between invaders and AMF.

Table 2. Asteraceae plant species whose distribution is enhanced by AMF.

Host-Plant Species	Associated AMF Community	References
Brown knapweed <i>Centaurea jacea</i> L.	<i>Glomus</i> sp. <i>Claroideoglomus</i> sp. <i>Diversispora</i> sp. ** <i>Acaulospora</i> sp. ** <i>Archaeospora</i> sp.	[81]
Thistle <i>Cirsium purpuratum</i> (Maxim) Matsuma.	<i>Acaulospora</i> sp. ** <i>Rhizoglossum</i> sp. <i>Rhizophagus</i> sp. <i>Diversispora</i> sp. **	[82]
Canadian fleabane <i>Erigeron canadensis</i> (= <i>Conyza canadensis</i>)	<i>Glomus versiforme</i> <i>Funneliformis caledonius</i> <i>F. mosseae</i> <i>Rhizophagus intraradices</i> <i>Septoglomus constrictum</i> <i>Claroideoglomus claroideum</i> <i>C. etunicatum</i> <i>Diversispora eburnean</i> ** <i>Diversispora</i> sp. **	[23,83,84]
Canadian goldenrod <i>Solidago canadensis</i>	<i>Septoglomus constrictum</i> <i>Funneliformis mosseae</i> <i>F. geosporus</i> <i>Claroideoglomus claroideum</i> <i>C. etunicatum</i> <i>Oehlia diaphana</i> <i>Glomus versiforme</i> <i>Acaulospora excavate</i> ** <i>A. mellea</i> <i>Diversispora</i> sp.	[23,75]
Shaggy soldier <i>Galinsoga quadriradiata</i>	<i>Glomus</i> spp. <i>Claroideoglomus claroideum</i> <i>Funneliformis mosseae</i> <i>Septoglomus constrictum</i> *	[23]

Table 2. Cont.

Host-Plant Species	Associated AMF Community	References
Crofton weed <i>Ageratina adenophora</i> (= <i>Eupatorium adenophorum</i>)	<i>Claroideoglossum etunicatum</i> <i>Funneliformis geosporus</i> <i>Rhizophagus aggregatum</i> <i>Diversispora arenaria</i> **	[85,86]
Annual forb <i>Bidens pilosa</i>	<i>Septoglossum viscosum</i> <i>Septoglossum constrictum</i> <i>Glomus perpusillum</i>	[31]
Devil's beggarticks <i>Bidens frondosa</i>	<i>Claroideoglossum claroideum</i> <i>Claroideoglossum drummondii</i> <i>Septoglossum constrictum</i> <i>Diversispora</i> sp. **	[23]
Common ragweed <i>Ambrosia artemisiifolia</i>	<i>Funneliformis mosseae</i> <i>Glomus reticulatum</i> * <i>Glomus perpusillum</i> <i>Septoglossum constrictum</i> * <i>Septoglossum viscosum</i> Unidentified spores	[31,55]
Jerusalem artichoke <i>Helianthus tuberosus</i>	<i>Funneliformis mosseae</i> <i>Claroideoglossum claroideum</i> <i>Septoglossum constrictum</i> <i>Diversispora</i> sp. **	[23]
Cutleaf coneflower <i>Rudbeckia laciniata</i>	<i>Glomus macrocarpum</i> <i>Acaulospora cavernata</i> ** <i>Claroideoglossum claroideum</i> <i>Funneliformis mosseae</i> <i>Pacispora franciscana</i> ** <i>Rhizoglossum fasciculatum</i> <i>Scutellospora dipurpurea</i> ** <i>Septoglossum constrictum</i>	[24]
Cocklebur <i>Xanthium albinum</i>	<i>Funneliformis mosseae</i> <i>Claroideoglossum claroideum</i> <i>Septoglossum constrictum</i> <i>Rhizoglossum microaggregatum</i>	[23,87]

* soil samples. ** genera of order Diversisporales.

2.1. The Nature of Symbiotic Relationship between Invasive/Native Plants and AMF Communities

The plant–AMF symbiosis is mediated through plant and fungal metabolites (primary and specialized metabolites, phytohormones) that ensure partner recognition, colonization, and the establishment of a symbiotic association. During pre-symbiotic communication, root released quercetin and 2-hydroxy fatty acids lead to compound-specific morphological AM fungal responses. Then strigolactone and cutin monomers (1,16-hexadecanediol and 16-hydroxyhexadecanoic acid) trigger hyphopodium development on the root surface. It has been established that the specificity of the relationship between AMF communities and plants is determined at the presymbiotic stage [78,79]. Phytohormones are involved in the plant–AMF regulation interactions as signaling molecules. They act from the early recognition of AMF in the soil to the final formation of mycorrhiza as strigolactones, auxins, abscisic acid, brassinosteroids, and gibberellic acid [88–92]. Auxin is necessary both for the early stages of fungal growth and for the differentiation of arbuscules, while gibberellic acids modulate the formation of arbuscules [91]. During the initial colonization, plant–AMF interactions are facilitated through the regulation of signaling and carotenoid pathways. Phytohormones can modulate plant immunity by altering the balance of jasmonate and salicylic acid signaling pathways, to promote phytohormone gibberellic acid. The AMF

symbiotic association influences the primary metabolism of plants to increase the level of sugars and metabolites of the tricarboxylic acid cycle and to facilitate photosynthates sharing.

Along with the changes in the primary metabolism, the formation of arbuscular mycorrhiza also affects the synthesis of specialized metabolites. AM has a positive effect on the production of specialized metabolites either by increasing plant biomass or by stimulating metabolite biosynthetic pathways. AMF–plant symbiosis provides benefits for sucking pests by altering the plant immunity with phytohormones and influencing primary and specialized metabolites [93,94]. For example, pyrrolizidine alkaloids—the major defense compounds of plants in the *Senecio* genus, are synthesized in response to AMF colonization.

2.2. Arbuscular Mycorrhiza and Soil Microbiota

The most significant influence of arbuscular mycorrhiza is seen in the formation of soil and rhizosphere microbiomes. Thus, a community of certain microorganisms is formed in the hyphosphere of AMF (mycorrhizosphere). In this case, the mycorrhizosphere is a narrow area of soil around the hyphae, where physical, chemical, and biochemical conditions differ from the rest of the soil volume due to the influence of hyphal exudates [95]. This effect of AM fungi can be compared with the formation of the soil rhizosphere by plants. Due to their apparently close ecological interactions, mycorrhizospheric microorganisms can be assigned to the so-called «second genome» of AMF, which significantly contributes to the attraction and nutrient turnover [95]. The microbiome of the mycorrhizosphere is unique compared to other microbial communities and is characterized by less species diversity, but a larger number of cultivated bacterial species [96]. In turn, the taxonomic composition, abundance, and diversity of bacterial and fungal communities also influence the relationship between the host plant and mycorrhizal fungi. For example, the analysis of the rhizospheric microbial community of greater burdock *Arctium lappa* L. (Asteraceae) showed an exceptionally low ratio of AMF (0.05%) in the presence of a diverse bacterial community. According to the authors, the key factors that led to this result are a more diverse and numerous bacterial community and soil characteristics. For example, there are differences in the composition of the bacterial communities of *Gigaspora margarita* and *Gigaspora rosea*, as well as six strains of AMF belonging to the species *Funnelliformis mosseae*, *F. coronatum* и *Rhizophagus intraradices*. No correlation between the taxonomic status of fungi has been established [97,98]. Bacteria of the mycorrhizosphere are divided by their functions into «mycorrhiza helper bacteria» (MHB), which promote spore germination, mycelium growth and mycorrhiza formation, and «plant growth-promoting rhizobacteria» (PGPR). The PGPR provide an increase in available nutrients, protection and resistance to stress plants, improving their growth characteristics, as well as bacteria that combine the characteristics of MHB and PGPR [99–105]. The presence of *Paenibacillus* sp. in the mycorrhizosphere of *Rhizophagus irregularis* led to an increase in the amount of nitrogen from chitin [64,66,67,106,107]. Under field conditions, the synergistic effects promote the growth of sunchoke *H. tuberosus* by *Rhizophagus intraradices* KKKU-Wh and *Klebsiella variicola* UDJA102 × 89–9 [32]. A growth-stimulating effect was also observed with the combined action of the endophytic *Exserohilum rostratum* NMS1.5 and AMF *Glomus etunicatum* (= *Claroideoglomus etunicatum*) UDCN52867 [108]. It is interesting to note that a decrease in the proportion of arbuscular mycorrhiza fungi was accompanied by an increase in the proportion of asco- and basidiomycetes [65]. In general, invasive plants have a significant impact on local soil pathogens, which, in turn, affects the success of their spread in new territories [43]. There are soil bacteria that can inhibit the development of extraradical mycelium of AMF. Thus, the influence of AMF on the ecosystem depends on the soil microbiome [109]. *Gigaspora rosea* (Diversisporales) suppresses the beneficial soil bacteria *Pseudomonas putida* and fungi *Trichoderma pseudokoningii* [110,111].

The increase in disease and pest resistance, as well as the increased growth of plants colonized by arbuscular mycorrhiza, is the result of complex interactions between plants, pathogens and AMF. For example, mycorrhized plants of various families showed resistance

to soil phytopathogens *Aphanomyces*, *Cylindrocladium spathiphylli*, *Fusarium*, *Macrophomina phaseolina*, *Phytophthora*, *Pythium*, *Rhizoctonia*, *Sclerotinium*, *Verticillium*, *Thielaviopsis basicol*, and nematodes *Heterodera*, *Meloidogyne*, *Pratylenchus* и *Radopholus* [42–44]. It was shown that the resistance of *Leucanthemum vulgare* (Vaill.) Lam. (Asteraceae) to pathogens is not associated with changes in the root architecture and depends on the species composition of the AMF community [112]. It is supposed that there are many possible mechanisms to exhibit plant immunity against pathogens and pests. For example, the resistance of mycorrhized plants to soil pathogens may be associated with a nonspecific immune response that occurs in host plants, changes in the hormonal status of plants, and the endophytic community of microorganisms [45,113,114]. Arbuscular mycorrhiza is involved in signaling between infected and healthy plants, thereby contributing to the expression of PR protein genes (PR1, PR2, PR5) in uninfected plants and the formation of immune responses in plants [115].

2.3. Common Mycorrhizal Networks

AMF can also influence the dynamics of plant communities through the formation of mycorrhizal networks [116–119]. Mycorrhizal networks or common mycorrhizal networks (CMN) are networks of hyphae of mycorrhizal fungi that simultaneously colonize the root systems of some plants. A necessary condition for the formation and functioning of a mycorrhizal network is the ability of neighboring plants to be colonized by the same mycorrhizal fungi. The impact on intraspecific and interspecific competition is carried out due to the redistribution of mineral nutrients between plants, as well as the exchange of various signal and allelochemical compounds [120–130]. The structures of mycorrhizal networks depend on the species composition of plants growing in this area, and, in some cases, on their anatomical features (leaf size, etc.) [7,129]. Thus, a study conducted with 22 plant species formed in different communities showed that in the presence of several host plants, arbuscular mycorrhiza fungi prefer certain species [7].

The formation of arbuscular-mycorrhizal networks is shown for such Asteraceae plants as Canadian goldenrod *S. canadensis*, and common chicory *C. intybus* [72]. Plants connected by mycorrhizal networks exhibit greater plasticity in response to adverse external factors. This is manifested by a change in the growth rate of roots and shoots, the processes of photosynthesis and nutrition, and the occurrence of plant defense reactions. In the event of a stressor, plants associated with the CMN can exchange warning signals about the stress sources [131]. The laboratory experiments have shown the ability of mycorrhizal networks to redistribute nutrient flows between connected plants. The mycorrhizal network, connecting invasive *S. canadensis* and native *Kummerowia striata* (Thunb.) Schindl. (Fabaceae), enhanced the growth of Canadian goldenrod and the influx of nitrogen and phosphorus compounds. At the same time, the growth and the number of available nutrients decreased in *K. striata* [72]. Thus, due to the uneven distribution of nutrients, arbuscular mycorrhizal fungi are able to change plant communities, facilitating the invasion of some species. It is interesting to note that nitrogen compounds are most often supplied by CMN to big photophilous plants [129].

3. Discussion

One of the important factors in the spread of invasive Asteraceae is the plant-associated AMF community. As a result of symbiotic relationships, weeds receive serious advantages over native species. These advantages are most significant under unfavorable biotic and abiotic conditions. The formation of arbuscular mycorrhiza improves nutrition (including phosphorus, nitrogen, sulfur, trace elements), and water supply, increases stress resistance of plants, and reduces their susceptibility to diseases and attractiveness for leaf-eating insects, including the increased synthesis of specialized plant metabolites. The influence of AMF and mycorrhizal networks on the soil microbiota, as well as the suppression of phytopathogens and nematodes, are important.

AMF communities associated with invasive and native plants have a number of significant differences. Firstly, the AMF community of Asteraceae invasive species is less diverse. Invaders also decrease AMF species richness in invaded ecosystems [24,56,132]. Secondly, the rate of AMF colonization of invaders is higher than that of native species [55]. Thirdly, AMF communities of Asteraceae invaders often include fewer common species (such as species of the order Diversisporales). Species of Diversisporales are quite difficult to identify by morphological features since the diversity of spores is high. The suppressive effect of *Gigaspora rosea* (Diversisporales) on soil bacteria and fungi was shown, while representatives of the order Glomerales generally demonstrate a synergetic effect on plants [110,111]. The question of whether there is an interaction between the AMF communities of invasive and native plant species remains open. Unfortunately, all commonly used approaches have some weaknesses. The classical histochemical method of assessment of fungal colonization through calculating the length of hyphae and the number of arbuscules and vesicles may reduce the value due to the fact that some AMF genera do not form arbuscules or form mainly exomycelium. These species are stably present in the AMF community associated with invasive weeds and may play a key role in the symbiosis. A discrepancy between the level of AMF colonization obtained by the histochemical method and the level of expression of genes, the products of which are involved in symbiosis, was revealed (Krukov unpublished). Therefore, the assessment of the level of colonization by physiological and biochemical plant parameters may lead to correction of existing conclusions and hypotheses.

It should be noted that most studies on mycorrhiza are carried out in vitro by inoculating test plants or their seeds with a spore suspension of well-known arbuscular mycorrhizal fungi, such as *Funneliformis mosseae*, *Rhizophagus intraradices*, and several *Glomus* spp., which are commonly used in agricultural biotechnology. The relationships between them and agricultural plants are well studied, so they are often used as the basis for fertilizers [101,102,108]. Species of Diversisporales order are used for these purposes in rarely cases. The peculiarities of these interactions are studied poorly.

Although such studies show the positive effects of mycorrhiza on plants overall, due to the limited number of species used, they do not reflect situations in nature, especially in complex ecosystems with large numbers of potential interactions between their components (Figure 2). There are few studies that reveal the features of plant–AMF interactions in natural conditions. This is due to the complexity of the planning and methodological base of such experiments. In our opinion, a combination of several approaches is necessary, specifically histochemical, molecular and biochemical approaches.

It is also necessary to take into account the relationship of AMF with the soil bacterial community [117,118]. Despite the large number of articles pointing to the possibility of synergy with the simultaneous use of bacteria-based fertilizers and AMF, it is also important to consider which types of fungi and bacteria are used in the fertilizer. Otherwise, the opposite effect to the expected one can be achieved.

CMNs can greatly enhance the capabilities of invasive plants associated with AMF. For example, they may form friendly phytobiota, redistribute excess nutrients and water, or signal about threats [115,125–128]. The species composition of AMF involved in CMN is poorly understood. However, in our opinion, the data on the species composition is extremely important, since they determine the specificity of these relationships.

It should be noted that the identification of AMF species associated with invasive plants is rather complicated. It is difficult to distinguish them by morphological features, since they are located inside plant cells, and are capable of forming anastomoses. They also may not be cultivated on artificial nutrient media. When using molecular methods of AMF DNA identification, there is a risk of contamination with the genetic material of the soil mycobiota or the host plant. Another difficulty lies in the fact that the loci traditionally used for fungal identification have high interspecific and intraspecific genetic polymorphism [47,133,134]. Many authors associate the solution to these problems with a wider introduction of new generation sequencing (NGS) methods into the research process

and a more thorough analysis of genome and transcriptome data [135–137]. At the same time, the identification of key AMF genera associated with invasive plants, in our opinion, would make it possible to develop probes for their rapid identification and quantification by molecular methods. This is necessary to effectively control the number of AMF-associated invasive weeds.

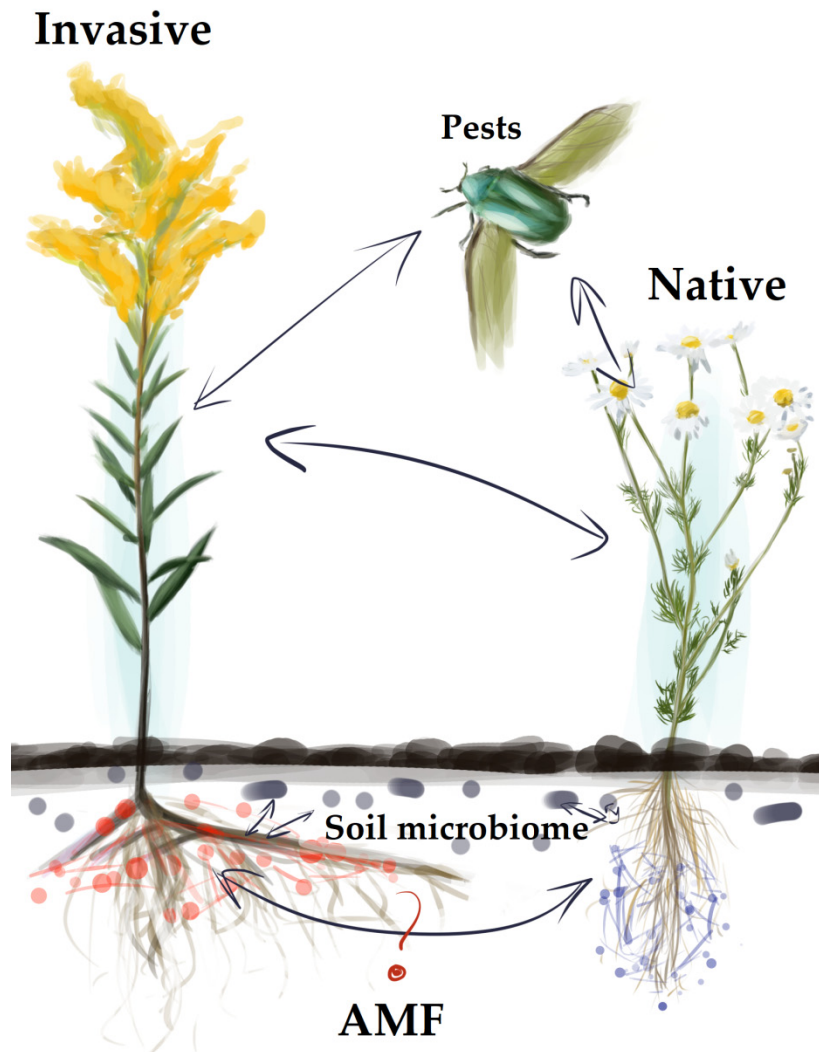


Figure 2. Interactions with invasive Asteraceae species in phytocenoses.

4. Conclusions

Thus, one of the important factors in the spread of invasive Asteraceae is the plant-associated AMF community. As a result of symbiosis, weeds receive serious advantages over native species. These advantages are most significant under unfavorable biotic and abiotic conditions.

It has been shown that the species of the host plant determine the species composition of the AMF communities. In turn, the AMF communities closely interact with soil biota. The influence of AMF communities on the phytocenoses as a whole is still insufficiently known. There is an opinion that AMF communities are rather «passengers» than «drivers» of Asteraceae invasions [138]. However, there are other opinions on this matter, and emerging data do not support this [57,132].

Cultivation of Asteraceae such as *H. annuus*, and *H. tuberosus* can affect the soil and rhizosphere microbiota. It is also necessary to monitor invasive Asteraceae weeds as *A. artemisiifolia*, *B. frondosa*, *S. canadensis*, etc. because these species have a significant impact on ecosystems. Thus, this factor of invasion must be considered while planning agrotechnical

measures to limit the distribution of weeds, developing measures for the conservation of native plants, and using AMF-based fertilizers.

Author Contributions: Conceptualization, S.S. and D.M.; methodology S.S. and D.M.; supervision, V.D.; writing: original draft, S.S. and D.M.; writing: review and editing, A.T.; project administration V.D.; funding acquisition, A.T. All authors have read and agreed to the published version of the manuscript.

Funding: The research is funded by the Ministry of Science and Higher Education of the Russian Federation under the strategic academic leadership program “Priority 2030” (Agreement 075-15-2021-1333 dated 30.09.2021).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

References

- Medve, R. The Mycorrhizae of Pioneer Species in Disturbed Ecosystems in Western Pennsylvania. *Am. J. Bot.* **1984**, *71*, 787–794. [\[CrossRef\]](#)
- Mehraj, G.; Khuroo, A.; Hamid, M.; Muzafar, I.; Rashid, I.; Malik, A. Floristic Diversity and Correlates of Naturalization of Alien Flora in Urban Green Spaces of Srinagar City. *Urban Ecosyst.* **2021**, *24*, 1231–1244. [\[CrossRef\]](#)
- Day, N.; Dunfield, K.; Antunes, P. Fungi from a Non-Native Invasive Plant Increase Its Growth but Have Different Growth Effects on Native Plants. *Biol. Invasions* **2016**, *18*, 231–243. [\[CrossRef\]](#)
- Bongard, C.; Butler, K.; Fulthorpe, R. Investigation of Fungal Root Colonizers of the Invasive Plant *Vincetoxicum rossicum* and Co-Occurring Local Native Plants in a Field and Woodland Area in Southern Ontario. *Nat. Conserv.* **2013**, *4*, 55–76. [\[CrossRef\]](#)
- Yuan, Y.; Tang, J.; Leng, D.; Hu, S.; Yong, J.W.H.; Chen, X. An Invasive Plant Promotes Its Arbuscular Mycorrhizal Symbioses and Competitiveness through Its Secondary Metabolites: Indirect Evidence from Activated Carbon. *PLoS ONE* **2014**, *9*, e97163. [\[CrossRef\]](#)
- Li, Y.-P.; Feng, Y.-L.; Kang, Z.-L.; Zhang, J.-L.; Yajun, C. Changes in Soil Microbial Communities Due to Biological Invasions Can Reduce Allelopathic Effects. *J. Appl. Ecol.* **2017**, *54*, 1281–1290. [\[CrossRef\]](#)
- Chagnon, P.; Bradley, R.L.; Klironomos, J.N. Mycorrhizal Network Assembly in a Community Context: The Presence of Neighbours Matters. *J. Ecol.* **2020**, *108*, 366–377. [\[CrossRef\]](#)
- Qin, F.; Yu, S. Arbuscular Mycorrhizal Fungi Protect Native Woody Species from Novel Weapons. *Plant Soil* **2019**, *440*, 39–52. [\[CrossRef\]](#)
- Rydlová, J.; Vosátka, M. Associations of Dominant Plant Species with Arbuscular Mycorrhizal Fungi during Vegetation Development on Coal Mine Spoil Banks. *Folia Geobot.* **2001**, *36*, 85–97. [\[CrossRef\]](#)
- Torreillas, E.; Alguacil, M.M.; Roldán, A. Host Preferences of Arbuscular Mycorrhizal Fungi Colonizing Annual Herbaceous Plant Species in Semiarid Mediterranean Prairies. *Appl. Environ. Microbiol.* **2012**, *78*, 6180–6186. [\[CrossRef\]](#)
- Gucwa-Przepióra, E.; Błaskowski, J. Arbuscular Mycorrhiza of Plants Spontaneously Colonizing the Soda Heap in Jaworzno (Southern Poland). *Acta Soc. Bot. Pol.* **2011**, *76*, 69–74. [\[CrossRef\]](#)
- Mummey, D.L.; Rillig, M.C. The Invasive Plant Species *Centaurea maculosa* Alters Arbuscular Mycorrhizal Fungal Communities in the Field. *Plant Soil* **2006**, *288*, 81–90. [\[CrossRef\]](#)
- Selvaraj, T.; Murugan, R.; Bhaskaran, C. Arbuscular Mycorrhizal Association of Kashini (*Cichorium intybus* L.) in Relation to Physicochemical Characters. *Mycorrhiza News* **2001**, *13*, 14–16.
- Oliveira, R.S.; Vosátka, M.; Dodd, J.C.; Castro, P.M.L. Studies on the Diversity of Arbuscular Mycorrhizal Fungi and the Efficacy of Two Native Isolates in a Highly Alkaline Anthropogenic Sediment. *Mycorrhiza* **2005**, *16*, 23–31. [\[CrossRef\]](#) [\[PubMed\]](#)
- Dhar, P.P.; Al-Qarawi, A.A.; Mridha, M.A.U. Arbuscular Mycorrhizal Fungal Association in Asteraceae Plants Growing in the Arid Lands of Saudi Arabia. *J. Arid Land* **2015**, *7*, 676–686. [\[CrossRef\]](#)
- Allen, N.; Nordlander, M.; McGonigle, T.; Basinger, J.; Kaminskyj, S. Arbuscular Mycorrhizae on Axel Heiberg Island (80° N) and at Saskatoon (52° N) Canada. *Can. J. Bot.* **2006**, *84*, 1094–1100. [\[CrossRef\]](#)
- Renker, C.; Blanke, V.; Buscot, F. Diversity of Arbuscular Mycorrhizal Fungi in Grassland Spontaneously Developed on Area Polluted by a Fertilizer Plant. *Environ. Pollut.* **2005**, *135*, 255–266. [\[CrossRef\]](#) [\[PubMed\]](#)
- Gorbunova, A.O.; Sumina, O.I. Dynamics of mycorrhization in some plant species during progressive succession on sand quarries (Leningrad region). *Bot. Zhurnal* **2021**, *106*, 22–42. [\[CrossRef\]](#)
- Sinegani, A.; Yeganeh, M. The occurrence of arbuscular mycorrhizal fungi in soil and root of medicinal plants in Bu-Ali Sinagarden in Hamadan, Iran. *Biol. J. Microorg.* **2017**, *5*, 43–59. [\[CrossRef\]](#)

20. Štajerová, K.; Smilauerová, M.; Šmilauer, P. Arbuscular Mycorrhizal Symbiosis of Herbaceous Invasive Neophytes in the Czech Republic. *Preslia* **2009**, *81*, 341–355.
21. Crişan, I.; Vidican, R. Root Colonization by Micromycetes in Ten Asteraceae Species from Cluj County. *J. Hortic. For. Biotechnol.* **2019**, *23*, 15–57.
22. Paudel, S.; Baer, S.G.; Battaglia, L.L. Arbuscular Mycorrhizal Fungi (AMF) and Success of *Triadica sebifera* Invasion in Coastal Transition Ecosystems along the Northern Gulf of Mexico. *Plant Soil* **2014**, *378*, 337–349. [[CrossRef](#)]
23. Majewska, M.L.; Błaszowski, J.; Nobis, M.; Rola, K.; Nobis, A.; Łakomiec, D.; Czachura, P.; Zubek, S. Root-Inhabiting Fungi in Alien Plant Species in Relation to Invasion Status and Soil Chemical Properties. *Symbiosis* **2015**, *65*, 101–115. [[CrossRef](#)]
24. Zubek, S.; Majewska, M.L.; Błaszowski, J.; Stefanowicz, A.M.; Nobis, M.; Kapusta, P. Invasive Plants Affect Arbuscular Mycorrhizal Fungi Abundance and Species Richness as Well as the Performance of Native Plants Grown in Invaded Soils. *Biol. Fertil. Soils* **2016**, *52*, 879–893. [[CrossRef](#)]
25. Cumming, J.R.; Kelly, C.N. *Pinus virginiana* Invasion Influences Soils and Arbuscular Mycorrhizae of a Serpentine Grassland. *J. Torrey Bot. Soc.* **2007**, *134*, 63–73. [[CrossRef](#)]
26. Liu, G.; Liu, R.-L.; Zhang, W.-G.; Yang, Y.-B.; Bi, X.-Q.; Li, M.-Z.; Chen, X.-Y.; Nie, H.; Zhu, Z.-H. Arbuscular Mycorrhizal Colonization Rate of an Exotic Plant, *Galinsoga quadriradiata*, in Mountain Ranges Changes with Altitude. *Mycorrhiza* **2021**, *31*, 161–171. [[CrossRef](#)]
27. Fracchia, S.; Aranda, A.; Gopar, A.; Silvani, V.; Fernandez, L.; Godeas, A. Mycorrhizal Status of Plant Species in the Chaco Serrano Woodland from Central Argentina. *Mycorrhiza* **2009**, *19*, 205–214. [[CrossRef](#)]
28. Li, L.-Q.; Zhang, M.-S.; Liang, Z.-P.; Xiao, B.; Wan, F.; Liu, W.-X. Arbuscular Mycorrhizal Fungi Enhance Invasive Plant, *Ageratina adenophora* Growth and Competition with Native Plants. *Chin. J. Ecol.* **2016**, *35*, 79–86. [[CrossRef](#)]
29. Stevens, K.J.; Wall, C.B.; Janssen, J.A. Effects of Arbuscular Mycorrhizal Fungi on Seedling Growth and Development of Two Wetland Plants, *Bidens frondosa* L., and *Eclipta prostrata* (L.) L., Grown under Three Levels of Water Availability. *Mycorrhiza* **2011**, *21*, 279–288. [[CrossRef](#)]
30. Sun, Y.; Umer, M.; Wu, P.; Guo, Y.; Ren, W.; Han, X.; Li, Q.; Wu, B.; Shen, K.; Xia, T.; et al. Indigenous Microorganisms Offset the Benefits of Growth and Nutrition Regulated by Inoculated Arbuscular Mycorrhizal Fungi for Four Pioneer Herbs in Karst Soil. *PLoS ONE* **2022**, *17*, e0266526. [[CrossRef](#)]
31. Zhang, F.; Li, Q.; Yerger, E.; Chen, X.; Shi, Q.; Wan, F. AM Fungi Facilitate the Competitive Growth of Two Invasive Plant Species, *Ambrosia artemisiifolia* and *Bidens pilosa*. *Mycorrhiza* **2018**, *28*, 703–715. [[CrossRef](#)] [[PubMed](#)]
32. Nacoon, S.; Jogloy, S.; Riddech, N.; Mongkolthanaruk, W.; Ekprasert, J.; Cooper, J.; Boonlue, S. Combination of Arbuscular Mycorrhizal Fungi and Phosphate Solubilizing Bacteria on Growth and Production of *Helianthus tuberosus* under Field Condition. *Sci. Rep.* **2021**, *11*, 6501. [[CrossRef](#)]
33. Spatafora, J.; Chang, Y.; Benny, G.; Lazarus, K.; Smith, M.; Berbee, M.; Bonito, G.; Corradi, N.; Grigoriev, I.; Gryganskyi, A.; et al. A Phylum-Level Phylogenetic Classification of Zygomycete Fungi Based on Genome-Scale Data. *Mycologia* **2016**, *108*, 1028–1046. [[CrossRef](#)] [[PubMed](#)]
34. Hibbett, D.S.; Binder, M.; Bischoff, J.F.; Blackwell, M.; Cannon, P.F.; Eriksson, O.E.; Huhndorf, S.; James, T.; Kirk, P.M.; Lücking, R.; et al. A Higher-Level Phylogenetic Classification of the Fungi. *Mycol. Res.* **2007**, *111*, 509–547. [[CrossRef](#)] [[PubMed](#)]
35. James, T.Y.; Stajich, J.E.; Hittinger, C.T.; Rokas, A. Toward a Fully Resolved Fungal Tree of Life. *Annu. Rev. Microbiol.* **2020**, *74*, 291–313. [[CrossRef](#)]
36. Karandashov, V.; Bucher, M. Symbiotic Phosphate Transport in Arbuscular Mycorrhizas. *Trends Plant Sci.* **2005**, *10*, 22–29. [[CrossRef](#)]
37. Govindarajulu, M.; Jin, H.; Abubaker, J.; Douds, D.; Allen, J.; Bücking, H.; Lammers, P.; Shachar-Hill, Y. Nitrogen Transfer in the Arbuscular Mycorrhizal Symbiosis. *Nature* **2005**, *435*, 819–823. [[CrossRef](#)]
38. Cavagnaro, T.R. The Role of Arbuscular Mycorrhizas in Improving Plant Zinc Nutrition under Low Soil Zinc Concentrations: A Review. *Plant Soil* **2008**, *304*, 315–325. [[CrossRef](#)]
39. Allen, J.W.; Shachar-Hill, Y. Sulfur Transfer through an Arbuscular Mycorrhiza. *Plant Physiol.* **2009**, *149*, 549–560. [[CrossRef](#)]
40. Lehmann, A.; Rillig, M.C. Understanding Mechanisms of Soil Biota Involvement in Soil Aggregation: A Way Forward with Saprobic Fungi? *Soil Biol. Biochem.* **2015**, *88*, 298–302. [[CrossRef](#)]
41. Kobae, Y.; Ohtomo, R.; Morimoto, S.; Sato, D.; Nakagawa, T.; Oka, N.; Sato, S. Isolation of Native Arbuscular Mycorrhizal Fungi within Young Thalli of the Liverwort *Marchantia paleacea*. *Plants* **2019**, *8*, 142. [[CrossRef](#)] [[PubMed](#)]
42. Harrier, L.A.; Watson, C.A. The Potential Role of Arbuscular Mycorrhizal (AM) Fungi in the Bioprotection of Plants against Soil-Borne Pathogens in Organic and/or Other Sustainable Farming Systems: Role of Arbuscular Mycorrhizal Fungi in Bioprotection of Plants. *Pest Manag. Sci.* **2004**, *60*, 149–157. [[CrossRef](#)] [[PubMed](#)]
43. Zhang, S.; Jin, Y.; Tang, J.; Chen, X. The Invasive Plant *Solidago canadensis* L. Suppresses Local Soil Pathogens through Allelopathy. *Appl. Soil Ecol.* **2009**, *41*, 215–222. [[CrossRef](#)]
44. Zhang, S.; Zhu, W.; Wang, B.; Tang, J.; Chen, X. Secondary Metabolites from the Invasive *Solidago canadensis* L. Accumulation in Soil and Contribution to Inhibition of Soil Pathogen *Pythium ultimum*. *Appl. Soil Ecol.* **2011**, *48*, 280–286. [[CrossRef](#)]
45. Qu, L.; Wang, M.; Biere, A. Interactive Effects of Mycorrhizae, Soil Phosphorus, and Light on Growth and Induction and Priming of Defense in *Plantago lanceolata*. *Front. Plant Sci.* **2021**, *12*. [[CrossRef](#)]

46. Hoeksema, J.; Chaudhary, B.; Gehring, C.; Johnson, N.; Karst, J.; Koide, R.; Pringle, A.; Zabinski, C.; Bever, J.; Moore, J.; et al. A Meta-Analysis of Context-Dependency in Plant Response to Inoculation with Mycorrhizal Fungi. *Ecol. Lett.* **2010**, *13*, 394–407. [\[CrossRef\]](#)
47. Sandrini, M.; Nerva, L.; Sillo, F.; Balestrini, R.; Chitarra, W.; Zampieri, E. Abiotic Stress and Belowground Microbiome: The Potential of Omics Approaches. *Int. J. Mol. Sci.* **2022**, *23*, 1091. [\[CrossRef\]](#)
48. Jin, L.; Gu, Y.; Xiao, M.; Chen, J.; Li, B. The History of *Solidago canadensis* Invasion and the Development of Its Mycorrhizal Associations in Newly-Reclaimed Land. *Funct. Plant Biol.* **2004**, *31*, 979. [\[CrossRef\]](#)
49. Höpfner, I.; Beyschlag, W.; Bartelheimer, M.; Werner, C.; Unger, S. Role of Mycorrhization and Nutrient Availability in Competitive Interactions between the Grassland Species *Plantago lanceolata* and *Hieracium pilosella*. *Plant Ecol.* **2015**, *216*, 887–899. [\[CrossRef\]](#)
50. Jentschke, G.; Godbold, D. Metal Toxicity and Ectomycorrhizas. *Physiol. Plant.* **2000**, *109*, 107–116. [\[CrossRef\]](#)
51. Whipps, J.M. Prospects and Limitations for Mycorrhizas in Biocontrol of Root Pathogens. *Can. J. Bot.* **2004**, *82*, 1198–1227. [\[CrossRef\]](#)
52. Smith, S.E.; Read, D.J. *Mycorrhizal Symbiosis*, 3rd ed.; Academic Press: Amsterdam, The Netherlands; Boston, MA, USA, 2008.
53. Adolfsson, L.; Solymosi, K.; Andersson, M.X.; Keresztes, Á.; Uddling, J.; Schoefs, B.; Spetea, C. Mycorrhiza Symbiosis Increases the Surface for Sunlight Capture in *Medicago truncatula* for Better Photosynthetic Production. *PLoS ONE* **2015**, *10*, e0115314. [\[CrossRef\]](#) [\[PubMed\]](#)
54. Fumanal, B.; Plenchette, C.; Chauvel, B.; Bretagnolle, F. Which Role Can Arbuscular Mycorrhizal Fungi Play in the Facilitation of *Ambrosia artemisiifolia* L. Invasion in France? *Mycorrhiza* **2006**, *17*, 25–35. [\[CrossRef\]](#) [\[PubMed\]](#)
55. Kong, L.; Chen, X.; Yerger, E.H.; Li, Q.; Chen, F.; Xu, H.; Zhang, F. Arbuscular Mycorrhizal Fungi Enhance the Growth of the Exotic Species *Ambrosia artemisiifolia*. *J. Plant Ecol.* **2022**, *15*, 581–595. [\[CrossRef\]](#)
56. Řezáčová, V.; Řezáč, M.; Gryndler, M.; Hřelová, H.; Gryndlerová, H.; Michalová, T. Plant Invasion Alters Community Structure and Decreases Diversity of Arbuscular Mycorrhizal Fungal Communities. *Appl. Soil Ecol.* **2021**, *167*, 104039. [\[CrossRef\]](#)
57. Bunn, R.; Ramsey, P.; Lekberg, Y. Do Native and Invasive Plants Differ in Their Interactions with, Arbuscular Mycorrhizal Fungi? A Meta-Analysis. *J. Ecol.* **2015**, *103*, 1547–1556. [\[CrossRef\]](#)
58. Zhang, F.-J.; Li, Q.; Chen, F.-X.; Xu, H.-Y.; Inderjit, W.; Wan, F.-H. Arbuscular Mycorrhizal Fungi Facilitate Growth and Competitive Ability of an Exotic Species *Flaveria bidentis*. *Soil Biol. Biochem.* **2017**, *115*, 275–284. [\[CrossRef\]](#)
59. Cheng, J.-K.; Yue, M.-F.; Yang, H.-R.; Chen, B.-M.; Xin, G.-R. Do Arbuscular Mycorrhizal Fungi Help the Native Species *Bidens biternata* Resist the Invasion of *Bidens Alba*? *Plant Soil* **2019**, *444*, 443–455. [\[CrossRef\]](#)
60. Klironomos, J. Feedback with Soil Biota Contributes to Plant Rarity and Invasiveness in Communities. *Nature* **2002**, *417*, 67–70. [\[CrossRef\]](#)
61. Ashton, I.; Hyatt, L.A.; Howe, K. Invasive Species Accelerate Decomposition and Litter Nitrogen Loss in a Mixed Deciduous Forest. *Ecol. Appl.* **2005**, *15*, 1263–1272. [\[CrossRef\]](#)
62. Stinson, K.; Campbell, S.; Powell, J.; Wolfe, B.; Callaway, R.; Thelen, G.; Hallett, S.; Prati, D.; Klironomos, J. Invasive Plant Suppresses the Growth of Native Tree Seedlings by Disrupting Belowground Mutualisms. *PLoS Biol.* **2006**, *4*, e140. [\[CrossRef\]](#) [\[PubMed\]](#)
63. Vogelsang, K.; Bever, J. Mycorrhizal Densities Decline in Association with Nonnative Plants and Contribute to Plant Invasion. *Ecology* **2009**, *90*, 399–407. [\[CrossRef\]](#) [\[PubMed\]](#)
64. Sun, X.; Chen, W.; Ivanov, S.; MacLean, A.; Wight, H.; Ramaraj, T.; Mudge, J.; Harrison, M.; Fei, Z. Genome and Evolution of the Arbuscular Mycorrhizal Fungus *Diversispora epigaea* (Formerly *Glomus versiforme*) and Its Bacterial Endosymbionts. *New Phytol.* **2018**, *221*, 1556–1573. [\[CrossRef\]](#) [\[PubMed\]](#)
65. Xing, Y.; Yang, Y.; Xu, L.; Hao, N.; Zhao, R.; Wang, J.; Li, S.; Zhang, D.; Zhang, T.; Kang, T. The Diversity of Associated Microorganisms in Different Organs and Rhizospheric Soil of *Arctium lappa* L. *Curr. Microbiol.* **2020**, *77*, 746–754. [\[CrossRef\]](#)
66. Emmett, B.; Lévesque-Tremblay, V.; Harrison, M. Conserved and Reproducible Bacterial Communities Associate with Extraradical Hyphae of Arbuscular Mycorrhizal Fungi. *ISME J.* **2021**, *15*, 2276–2288. [\[CrossRef\]](#)
67. Rozmoš, M.; Bukovská, P.; Hřelová, H.; Kotianová, M.; Dudáš, M.; Gančarčíková, K.; Jansa, J. Organic Nitrogen Utilisation by an Arbuscular Mycorrhizal Fungus Is Mediated by Specific Soil Bacteria and a Protist. *ISME J.* **2021**, *16*, 676–685. [\[CrossRef\]](#)
68. Zhang, Q.; Yao, L.; Yang, R.; Yang, X.; Tang, J.; Chen, X. Potential Allelopathic Effects of an Invasive Species *Solidago canadensis* on the Mycorrhizae of Native Plant Species. *Allelopathy J.* **2007**, *20*, 71–77.
69. Thorpe, A.S.; Thelen, G.C.; Diaconu, A.; Callaway, R.M. Root Exudate Is Allelopathic in Invaded Community but Not in Native Community: Field Evidence for the Novel Weapons Hypothesis. *J. Ecol.* **2009**, *97*, 641–645. [\[CrossRef\]](#)
70. Kato-Noguchi, H.; Kato, M. Allelopathy and Allelochemicals of *Solidago canadensis* L. and *S. altissima* L. for Their Naturalization. *Plants* **2022**, *11*, 3235. [\[CrossRef\]](#)
71. Dong, L.-J.; Yu, H.-W.; He, W.-M. What Determines Positive, Neutral and Negative Impacts of *Solidago canadensis* Invasion on Native Plant Species Richness? *Sci. Rep.* **2015**, *5*, 16804. [\[CrossRef\]](#)
72. Awaydul, A.; Zhu, W.; Yuan, Y.; Xiao, J.; Hu, H.; Chen, X.; Koide, R.T.; Cheng, L. Common Mycorrhizal Networks Influence the Distribution of Mineral Nutrients between an Invasive Plant, *Solidago canadensis*, and a Native Plant, *Kummerowia striata*. *Mycorrhiza* **2019**, *29*, 29–38. [\[CrossRef\]](#) [\[PubMed\]](#)
73. Langeroudi, A.R. To What Extent Arbuscular Mycorrhiza Can Protect Chicory (*Cichorium intybus* L.) against Drought Stress. *Sci. Hortic.* **2019**, *263*, 109109. [\[CrossRef\]](#)

74. Řezáčová, V.; Rezác, M.; Gryndlerová, H.; Wilson, G.; Michalová, T. Arbuscular Mycorrhizal Fungi Favor Invasive *Echinops sphaerocephalus* When Grown in Competition with Native *Inula conyzae*. *Sci. Rep.* **2020**, *10*, 20287. [[CrossRef](#)] [[PubMed](#)]
75. Dong, L.-J.; Ma, L.-N.; He, W.-M. Arbuscular Mycorrhizal Fungi Help Explain Invasion Success of *Solidago canadensis*. *Appl. Soil Ecol.* **2021**, *157*, 103763. [[CrossRef](#)]
76. Stahlhut, K.; Dowell, J.; Temme, A.; Burke, J.; Goolsby, E.; Mason, C. Genetic Control of Arbuscular Mycorrhizal Colonization by *Rhizophagus intraradices* in *Helianthus annuus* (L.). *Mycorrhiza* **2021**, *31*, 723–734. [[CrossRef](#)] [[PubMed](#)]
77. Mandel, J.R.; Dikow, R.B.; Siniscalchi, C.M.; Thapa, R.; Watson, L.E.; Funk, V.A. A Fully Resolved Backbone Phylogeny Reveals Numerous Dispersals and Explosive Diversifications throughout the History of Asteraceae. *Proc. Natl. Acad. Sci. USA* **2019**, *116*, 14083–14088. [[CrossRef](#)] [[PubMed](#)]
78. Kaur, S.; Campbell, B.J.; Suseela, V. Root Metabolome of Plant–Arbuscular Mycorrhizal Symbiosis Mirrors the Mutualistic or Parasitic Mycorrhizal Phenotype. *New Phytol.* **2022**, *234*, 672–687. [[CrossRef](#)]
79. Kaur, S.; Suseela, V. Unraveling Arbuscular Mycorrhiza-Induced Changes in Plant Primary and Secondary Metabolome. *Metabolites* **2020**, *10*, 335. [[CrossRef](#)]
80. Malygin, D.; Mandryk-Litvinkovich, M.; Sokornova, S. Does Arbuscular Mycorrhiza Favor Invasion of Some Asteraceae Tribes? *Plant Prot. News* **2021**, *104*, 144–152. [[CrossRef](#)]
81. Davison, J.; Moora, M.; Öpik, M.; Adholeya, A.; Ainsaar, L.; Bå, A.; Burla, S.; Diedhiou, A.G.; Hiiesalu, I.; Jairus, T.; et al. Global Assessment of Arbuscular Mycorrhizal Fungus Diversity Reveals Very Low Endemism. *Science* **2015**, *349*, 970–973. [[CrossRef](#)]
82. Wu, B.; Hogetsu, T.; Isobe, K.; Ishii, R. Community Structure of Arbuscular Mycorrhizal Fungi in a Primary Successional Volcanic Desert on the Southeast Slope of Mount Fuji. *Mycorrhiza* **2007**, *17*, 495–506. [[CrossRef](#)] [[PubMed](#)]
83. Shah, M.; Callaway, R.; Shah, T.; Houseman, G.; Pál, R.; Xiao, S.; Luo, W.; Rosche, C.; Reshi, Z.; Khasa, D.; et al. *Conyza canadensis* Suppresses Plant Diversity in Its Nonnative Ranges but Not at Home: A Transcontinental Comparison. *New Phytol.* **2014**, *202*, 1286–1296. [[CrossRef](#)] [[PubMed](#)]
84. Shah, M.; Beaulieu, M.-E.; Reshi, Z.; Qureshi, S.; Khasa, D. A Cross-City Molecular Biogeographic Investigation of Arbuscular Mycorrhizas in *Conyza canadensis* Rhizosphere across Native and Non-Native Regions. *Ecol. Process.* **2015**, *4*, 7. [[CrossRef](#)]
85. Sun, X.; Gao, C.; Guo, L.-D. Changes in Arbuscular Mycorrhizal Fungus Community along an Exotic Plant *Eupatorium adenophorum* Invasion in a Chinese Secondary Forest. *J. Microbiol.* **2013**, *51*, 295–300. [[CrossRef](#)]
86. Shen, K.; Cornelissen, J.H.C.; Wang, Y.; Wu, C.; He, Y.; Ou, J.; Tan, Q.; Xia, T.; Kang, L.; Guo, Y.; et al. AM Fungi Alleviate Phosphorus Limitation and Enhance Nutrient Competitiveness of Invasive Plants via Mycorrhizal Networks in Karst Areas. *Front. Ecol. Evol.* **2020**, *8*, 125. [[CrossRef](#)]
87. Tang, J.S.; Zhao, Z.L.; Ma, M. *Glomus mosseae* Promotes *Xanthium italicum* Invasion. *Sains Malays.* **2020**, *49*, 2425–2432. [[CrossRef](#)]
88. Martín, J.; Morcillo, R.; Vierheilig, H.; Ocampo, J.; Ludwig-Müller, J.; Garrido, J. Ethylene-dependent/Ethylene-independent ABA Regulation of Tomato Plants Colonized by Arbuscular Mycorrhiza Fungi. *New Phytol.* **2011**, *190*, 193–205. [[CrossRef](#)]
89. Bitterlich, M.; Krügel, U.; Boldt-Burisch, K.; Franken, P.; Kühn, C. The Sucrose Transporter SISUT2 from Tomato Interacts with Brassinosteroid Functioning and Affects Arbuscular Mycorrhiza Formation. *Plant J.* **2014**, *78*, 877–889. [[CrossRef](#)]
90. Etemadi, M.; Gutjahr, C.; Couzigou, J.-M.; Zouine, M.; Audran, C.; Timmers, A.; Bouzayen, M.; Guillaume, B.; Combier, J.-P. Auxin Perception Is Required for Arbuscule Development in Arbuscular Mycorrhizal Symbiosis. *Plant Physiol.* **2014**, *166*, 281–292. [[CrossRef](#)]
91. Dehua, L.; Wang, S.; Cui, M.; Liu, J.; Chen, A.; Xu, G. Phytohormones Regulate the Development of Arbuscular Mycorrhizal Symbiosis. *Int. J. Mol. Sci.* **2018**, *19*, 3146. [[CrossRef](#)]
92. Wu, F.; Gao, Y.; Yang, W.; Sui, N.; Zhu, J. Biological Functions of Strigolactones and Their Crosstalk With Other Phytohormones. *Front. Plant Sci.* **2022**, *13*. [[CrossRef](#)] [[PubMed](#)]
93. Koricheva, J.; Gange, A.C.; Jones, T. Effects of Mycorrhizal Fungi on Insect Herbivores: A Meta-Analysis. *Ecology* **2009**, *90*, 2088–2097. [[CrossRef](#)] [[PubMed](#)]
94. Jiang, D.; Tan, M.; Wu, S.; Zheng, L.; Wang, Q.; Wang, G.; Yan, S. Defense Responses of Arbuscular Mycorrhizal Fungus-Colonized Poplar Seedlings against Gypsy Moth Larvae: A Multiomics Study. *Hortic. Res.* **2021**, *8*, 245. [[CrossRef](#)] [[PubMed](#)]
95. Zhang, L.; Jiachao, Z.; George, T.; Limpens, E.; Feng, G. Arbuscular Mycorrhizal Fungi Conducting the Hyphosphere Bacterial Orchestra. *Trends Plant Sci.* **2021**, *27*, 402–411. [[CrossRef](#)]
96. Gahan, J.; Schmalenberger, A. Arbuscular Mycorrhizal Hyphae in Grassland Select for a Diverse and Abundant Hyphospheric Bacterial Community Involved in Sulfonate Desulfurization. *Appl. Soil Ecol.* **2015**, *89*, 113–121. [[CrossRef](#)]
97. Long, L.; Zhu, H.; Yao, Q.; Ai, Y. Analysis of Bacterial Communities Associated with Spores of *Gigaspora margarita* and *Gigaspora rosea*. *Plant Soil* **2008**, *310*, 1–9. [[CrossRef](#)]
98. Agnolucci, M.; Battini, F.; Cristani, C.; Giovannetti, M. Diverse Bacterial Communities Are Recruited on Spores of Different Arbuscular Mycorrhizal Fungal Isolates. *Biol. Fertil. Soils* **2015**, *51*, 379–389. [[CrossRef](#)]
99. Frey-Klett, P.; Garbaye, J.; Tarkka, M. The Mycorrhiza Helper Bacteria Revisited. *New Phytol.* **2007**, *176*, 22–36. [[CrossRef](#)]
100. Pivato, B.; Offre, P.; Marchelli, S.; Barbonaglia, B.; Mougél, C.; Lemanceau, P.; Berta, G. Bacterial Effects on Arbuscular Mycorrhizal Fungi and Mycorrhiza Development as Influenced by the Bacteria, Fungi, and Host Plant. *Mycorrhiza* **2008**, *19*, 81–90. [[CrossRef](#)]
101. Battini, F.; Grönlund, M.; Agnolucci, M.; Giovannetti, M.; Jakobsen, I. Facilitation of Phosphorus Uptake in Maize Plants by Mycorrhizosphere Bacteria. *Sci. Rep.* **2017**, *7*, 4686. [[CrossRef](#)]

102. Gopal, S.; Shagol, C.; Kim, K.; Han, S.; Sa, T. Spore Associated Bacteria Regulates Maize Root K⁺/Na⁺ Ion Homeostasis to Promote Salinity Tolerance during Arbuscular Mycorrhizal Symbiosis. *BMC Plant Biol.* **2018**, *18*, 109. [\[CrossRef\]](#)
103. Turrini, A.; Avio, L.; Giovannetti, M.; Agnolucci, M. Functional Complementarity of Arbuscular Mycorrhizal Fungi and Associated Microbiota: The Challenge of Translational Research. *Front. Plant Sci.* **2018**, *9*, 1407. [\[CrossRef\]](#)
104. Diagne, N.; Ngom, M.; Djighaly, P.I.; Fall, D.; Hoche, V.; Svistoonoff, S. Roles of Arbuscular Mycorrhizal Fungi on Plant Growth and Performance: Importance in Biotic and Abiotic Stressed Regulation. *Diversity* **2020**, *12*, 370. [\[CrossRef\]](#)
105. Ujvári, G.; Turrini, A.; Avio, L.; Agnolucci, M. Possible Role of Arbuscular Mycorrhizal Fungi and Associated Bacteria in the Recruitment of Endophytic Bacterial Communities by Plant Roots. *Mycorrhiza* **2021**, *31*, 527–544. [\[CrossRef\]](#) [\[PubMed\]](#)
106. Tisserant, E.; Malbreil, M.; Kuo, A.; Kohler, A.; Symeonidi, A.; Balestrini, R.; Charron, P.; Duensing, N.; Frei Dit Frey, N.; Gianinazzi-Pearson, V.; et al. Genome of an Arbuscular Mycorrhizal Fungus Provides Insight into the Oldest Plant Symbiosis. *Proc. Natl. Acad. Sci. USA* **2013**, *111*, 20117–20122. [\[CrossRef\]](#)
107. Iffis, B.; St-Arnaud, M.; Hijri, M. Bacteria Associated with Arbuscular Mycorrhizal Fungi within Roots of Plants Growing in a Soil Highly Contaminated with Aliphatic and Aromatic Petroleum Hydrocarbons. *FEMS Microbiol. Lett.* **2014**, *358*, 44–54. [\[CrossRef\]](#)
108. Khaekhum, S.; Ekprasert, J.; Suebrasri, T.; Seemakram, W.; Mongkolthanaruk, W.; Riddech, N.; Jogloy, S.; Boonlue, S. Co-Inoculation of an Endophytic and Arbuscular Mycorrhizal Fungus Improve Growth and Yield of *Helianthus tuberosus* L. under Field Condition. *J. Fungi* **2021**, *7*, 976. [\[CrossRef\]](#)
109. Svenningsen, N.; Watts-Williams, S.; Joner, E.; Battini, F.; Efthymiou (Katerina), A.; Cruz-Paredes, C.; Nybroe, O.; Jakobsen, I. Suppression of the Activity of Arbuscular Mycorrhizal Fungi by the Soil Microbiota. *ISME J.* **2018**, *12*, 1296–1307. [\[CrossRef\]](#)
110. Martinez, A.; Obertello, M.; Pardo, A.; Ocampo, J.A.; Godeas, A. Interactions between *Trichoderma pseudokoningii* Strains and the Arbuscular Mycorrhizal Fungi *Glomus mosseae* and *Gigaspora rosea*. *Mycorrhiza* **2004**, *14*, 79–84. [\[CrossRef\]](#)
111. Gamalero, E.; Berta, G.; Massa, N.; Glick, B.R.; Lingua, G. Interactions between *Pseudomonas putida* UW4 and *Gigaspora rosea* BEG9 and Their Consequences for the Growth of Cucumber under Salt-Stress Conditions: Salt Affects Bacteria–AM Fungi Interactions. *J. Appl. Microbiol.* **2010**, *108*, 236–245. [\[CrossRef\]](#)
112. Lewandowski, T.; Dunfield, K.; Antunes, P. Isolate Identity Determines Plant Tolerance to Pathogen Attack in Assembled Mycorrhizal Communities. *PLoS ONE* **2013**, *8*, e61329. [\[CrossRef\]](#) [\[PubMed\]](#)
113. Eschen, R.; Hunt, S.; Mykura, C.; Gange, A.; Sutton, B. The Foliar Endophytic Fungal Community Composition in *Cirsium arvense* Is Affected by Mycorrhizal Colonization and Soil Nutrient Content. *Fungal Biol.* **2010**, *114*, 991–998. [\[CrossRef\]](#) [\[PubMed\]](#)
114. Hanlon, M.T.; Coenen, C. Genetic Evidence for Auxin Involvement in Arbuscular Mycorrhiza Initiation. *New Phytol.* **2011**, *189*, 701–709. [\[CrossRef\]](#)
115. Cabral, C.; Wollenweber, B.; Antonio, C.; Ravnskov, S. Activity in the Arbuscular Mycorrhizal Hyphosphere Warning Neighbouring Plants. *Front. Plant Sci.* **2019**, *10*, 511. [\[CrossRef\]](#)
116. Selosse, M.; Richard, F.; Simard, S. Mycorrhizal Networks: Des Liaisons Dangereuses? *Trends Ecol. Evol.* **2006**, *21*, 621–628. [\[CrossRef\]](#)
117. Horton, T.; van der Heijden, M.G.A. The Role of Symbioses in Seedling Establishment and Survival. In *Seedling Ecology and Evolution*; Leck, M.A., Parker, V.T., Simpson, R.L., Eds.; Cambridge University Press: Cambridge, UK, 2008; pp. 189–213.
118. van der Heijden, M.G.A.; Horton, T. Socialism in Soil? The Importance of Mycorrhizal Fungal Networks for Facilitation in Natural Ecosystems. *J. Ecol.* **2009**, *97*, 1139–1150. [\[CrossRef\]](#)
119. *Mycorrhizal Networks*, 1st ed.; Horton, T.R. Springer: Dordrecht, The Netherlands, 2015.
120. Barto, E.; Antunes, P.; Stinson, K.; Koch, A.; Klironomos, J.; Cipollini, D. Differences in Arbuscular Mycorrhizal Fungal Communities Associated with Sugar Maple Seedlings in and Outside of Invaded Garlic Mustard Forest Patches. *Biol. Invasions* **2011**, *13*, 2755–2762. [\[CrossRef\]](#)
121. Walder, F.; Niemann, H.; Mathimaran, N.; Lehmann, M.; Boller, T.; Wiemken, A. Mycorrhizal Networks: Common Goods of Plants Shared under Unequal Terms of Trade. *Plant Physiol.* **2012**, *159*, 789–797. [\[CrossRef\]](#)
122. Babikova, Z.; Gilbert, L.; Bruce, T.; Birkett, M.; Caulfield, J.; Woodcock, C.; Pickett, J.; Johnson, D. Underground Signals Carried through Neighbouring Plants of Aphid Attack. *Ecol. Lett.* **2013**, *16*, 835–843. [\[CrossRef\]](#)
123. Merrild, M.; Ambus, P.; Rosendahl, S.; Jakobsen, I. Common Arbuscular Mycorrhizal Networks Amplify Competition for Phosphorus between Seedlings and Established Plants. *New Phytol.* **2013**, *200*, 229–240. [\[CrossRef\]](#)
124. Weremijewicz, J.; Janos, D. Common Mycorrhizal Networks Amplify Size Inequality in *Andropogon gerardii* Monocultures. *New Phytol.* **2013**, *198*, 203–213. [\[CrossRef\]](#) [\[PubMed\]](#)
125. Fellbaum, C.; Mensah, J.; Cloos, A.; Strahan, G.; Kiers, T.; Bücking, H. Fungal Nutrient Allocation in Common Mycelia Networks Is Regulated by the Carbon Source Strength of Individual Host Plants. *New Phytol.* **2014**, *203*, 646–656. [\[CrossRef\]](#) [\[PubMed\]](#)
126. Johnson, D.; Gilbert, L. Interplant Signalling through Hyphal Networks. *New Phytol.* **2014**, *205*, 1448–1453. [\[CrossRef\]](#) [\[PubMed\]](#)
127. Jakobsen, I.; Hammer, E. Nutrient Dynamics in Arbuscular Mycorrhizal Networks. *Mycorrhizal Netw.* **2015**, *20*, 91–131. [\[CrossRef\]](#)
128. Walder, F.; van der Heijden, M.G.A. Regulation of Resource Exchange in the Arbuscular Mycorrhizal Symbiosis. *Nat. Plants* **2015**, *1*, 15159. [\[CrossRef\]](#)
129. Weremijewicz, J.; Sternberg, L.; Janos, D. Common Mycorrhizal Networks Amplify Competition by Preferential Mineral Nutrient Allocation to Large Host Plants. *New Phytol.* **2016**, *212*, 461–471. [\[CrossRef\]](#)
130. Weremijewicz, J.; Sternberg, L.; Janos, D. Arbuscular Common Mycorrhizal Networks Mediate Intra- and Interspecific Interactions of Two Prairie Grasses. *Mycorrhiza* **2018**, *28*, 71–83. [\[CrossRef\]](#)

131. Song, Y.; Wang, M.; Zeng, R.; Groten, K.; Baldwin, I.T. Priming and Filtering of Antiherbivore Defences among *Nicotiana attenuata* Plants Connected by Mycorrhizal Networks. *Plant Cell Environ.* **2019**, *42*, 2945–2961. [[CrossRef](#)]
132. Horn, S.; Hempel, S.; Verbruggen, E.; Rillig, M.C.; Caruso, T. Linking the Community Structure of Arbuscular Mycorrhizal Fungi and Plants: A Story of Interdependence? *ISME J.* **2017**, *11*, 1400–1411. [[CrossRef](#)]
133. Malbreil, M.; Tisserant, E.; Martin, F.; Roux, C. Genomics of Arbuscular Mycorrhizal Fungi: Out of the Shadows. *Adv. Bot. Res.* **2014**, *70*, 259–290.
134. Delavaux, C.; Ramos, R.; Stürmer, S.; Bever, J. Environmental Identification of Arbuscular Mycorrhizal Fungi Using the LSU rDNA Gene Region: An Expanded Database and Improved Pipeline. *Mycorrhiza* **2022**, *32*, 145–153. [[CrossRef](#)] [[PubMed](#)]
135. Krüger, M.; Stockinger, H.; Krüger, C.; Schüßler, A. DNA-based Species Level Detection of *Glomeromycota*: One PCR Primer Set for All Arbuscular Mycorrhizal Fungi. *New Phytol.* **2009**, *183*, 212–223. [[CrossRef](#)] [[PubMed](#)]
136. Stefani, F.; Bencherif, K.; Sabourin, S.; Lounès-Hadj Sahraoui, A.; Banchini, C.; Séguin, S.; Dalpé, Y. Taxonomic Assignment of Arbuscular Mycorrhizal Fungi in an 18S Metagenomic Dataset: A Case Study with Saltcedar (*Tamarix aphylla*). *Mycorrhiza* **2020**, *30*, 243–255. [[CrossRef](#)] [[PubMed](#)]
137. Kolaříková, Z.; Slavíková, R.; Belz, C.; Krüger, M.; Kohout, P. PacBio Sequencing of Glomeromycota rDNA: A Novel Amplicon Covering All Widely Used Ribosomal Barcoding Regions and Its Applicability in Taxonomy and Ecology of Arbuscular Mycorrhizal Fungi. *New Phytol.* **2021**, *231*, 490–499. [[CrossRef](#)] [[PubMed](#)]
138. Řezáčová, V.; Řezáč, M.; Líblová, Z.; Michalová, T.; Heneberg, P. Stable Colonization of Native Plants and Early Invaders by Arbuscular Mycorrhizal Fungi after Exposure to Recent Invaders from the Asteraceae Family. *Invasive Plant Sci. Manag.* **2021**, *14*, 147–155. [[CrossRef](#)]