Table 1: Key traits, their hypothesized function, and methods for trait measurement

Fungal and fungal mycorrhizal traits	**Hypothesized symbiotic effects**	AM fungi	Plant	Soil*	Qualitative/quantitative (unit)	References - methods on how to measure the traits	References**
Spores							
Number	-fitness/competitive ability -dispersal -carbon storage	x x x		x	Quantitative: number of spores/g soil Spores/meter of mycelia	Spores extracted by wet-sieving ((Gerdemann & Nicolson, 1963)) and sucrose gradient centrifugation (Ba, 1982) and counted under dissecting microscope	(Bever *et al.*, 1996), (Chaudhary *et al.*, 2020)
size - diameter	-fitness/competitive ability -dispersal -energy to support hyphal growth in absence of host -carbon storage -resistance to abiotic and biotic stress	x x x x x		x x	Quantitative: size measured in µm	Spore diameter measured intact in water using a dissecting or optical microscope ((Morton, 1995, 1996))	(Chaudhary *et al.*, 2020; Deveautour *et al.*, 2020)
germination rate	-	x			Quantitative: % of	(Douds & Schenck,	(Tommerup, 1983), (Maia &

% of total	fitness/competitive ability -carbon storage			x	germination	1991), Spores over filter paper in a soil-filled Petri plate (Koske, 1981)	Yano-Melo, 2001)
germination timing	- fitness/competitive ability -resistance to abiotic and biotic stress	x x		x x	Quantitative - % germination per unit of time Qualitative - stratification needed	(Koske, 1981)	(Tommerup, 1984, 1985), (Koske *et al.*, 1996) (Douds & Schenck, 1991) (Juge *et al.*, 2002)
color	- dispersal - palatability - UV protection - germination duration	x x			Qualitative: color based on CMYK color chart Quantitative: RGB color channels extracted from digitized images (JPG, TIF), calculation of luminance and saturation	Spores observed under a dissecting microscope and compared with color chart (Morton, 1996) or imaged and analyzed using computer software (Deveautour et al. 2020)	Deveautour et al. (2020),(Zanne *et al.*, 2020)
ornamentation	-dispersal -resistance to abiotic and biotic stress	x x		x	Qualitative: type of ornamentation. Quantitative: size in µm	Spores mounted on slides and observed under microscope Koske and Walker, 1985	Chaudhary et al. (2020)

wall thickness	- dispersal -palatability - carbon storage - resistance to abiotic and biotic stress	x x x		x	Quantitative: thickness in µm	Spores mounted on slides and thickness measured under microscope Morton (1995, 1996)	(Pawlowska *et al.*, 1999) (Moore *et al.*, 1985)
wall number	-dispersal -resistance to abiotic and biotic stress	x x		x	Quantitative: number of walls	Spores mounted on slides and observed under microscope Morton (1995, 1996)	(Walker, 1983)
sporocarps	-dispersal	x		x	Size and existence of fungal peridium on the sporocarp surface.	Sporocarps are measured under a microscope for size (Redecker *et al.*, 2007) and existence of peridium (Schüßler *et al.*, 2011)	(Mangan & Adler, 2002)
wall chemical receptors	- perception of host/soil environmental cues affecting germination	x	x			Knowledge gap (develop a method to identify specific receptors)	Knowledge gap (are there specific receptors on the spore wall that trigger germination?)
Spore nuclear content	-spore viability and germination - colonization ability after dispersal	x x	x x	x	Number of nuclei per spore	Confocal microscopy, Flow cytometry	(Kokkoris *et al.*, 2020, 2021) (Bianciotto *et al.*, 1995; Marleau *et al.*, 2011)

Elemental composition	-Energy support for hyphal growth	x		x	Elemental composition	Proton-induced X-ray emission	(Hammer *et al.*, 2011)
Extraradical Hyphae							
length	– nutrient/water acquisition -carbon storage -soil aggregation -plant productivity -resistance to abiotic and biotic stress	x x x x	x x x x x	x x x x x	Quantitative: hypha length in m/g dry soil	(Miller *et al.*, 1995)	(Wilson *et al.*, 2009) (Johnson *et al.*, 2015)
architecture (branching rate, anastomoses rate, absorptive/runner hypha)	– nutrient/water acquisition -carbon storage -soil aggregation -plant productivity -resistance to abiotic and biotic stress	x x x x x	x x x x x	x x x x	Qualitative Quantitative: Using image analysis in *in vitro* systems	(Friese & Allen, 1991) or (Bago *et al.*, 1998b) in monoxenic conditions (Hammer *et al.*, 2023)	Knowledge gap (e.g., is hyphal architecture akin to root architecture for nutrient acquisition? how does hyphal architecture influence soil aggregate stability?)
inter-host connection	- transfer of nutrient/water/signals among hosts -resistance to abiotic and biotic stress	x x	x x	x	Quantitative: amount of nutrient/signal transferred Number of hosts connected by the same fungus	(Weremijewicz & Janos, 2019) (Frey & Schüepp, 1993)	Knowledge gap (e.g., are there fungi that interconnect more hosts than others? can common mycorrhizal networks provide additional pathogen protection?)

hyphal diameter	–carbon storage - resistance to abiotic and biotic stress - palatability	x x x	 x	x	Quantitative: in µm	(Friese & Allen, 1991)	(Klironomos & Kendrick, 1996)
growth rate	– nutrient/water acquisition - carbon storage - resistance to abiotic and biotic stress	x x x	x x x	x x	Quantitative: hyphal growth in mm/day	(Schütz *et al.*, 2022)	(Jakobsen *et al.*, 1992b)
hyphal lifespan/turnover	- carbon storage - nutrient/water acquisition	x x	x x	x x	Qualitative	(Pepe *et al.*, 2018)	(Pepe *et al.*, 2018)
Genetic organization/hyphal fusion (homokaryon/dikaryon) (note: also applies to spores)	-fitness – nutrient/water acquisition -carbon storage -soil aggregation -plant productivity -resistance to abiotic and biotic stress - hyphal network interconnectedness	x x x x x x x	 x x x x x x	 x x x	Quantitative ddPCR: number of nuclei?	(Cornell *et al.*, 2022)	(Cornell *et al.*, 2022) (Serghi *et al.*, 2021)
Exudation rate/leakiness	-carbon storage -influence soil pH	x x	x x	x x	Quantitative: measure release	(Tawaraya *et al.*, 2006)	(Tawaraya *et al.*, 2006)

	and fertility -soil aggregation -resistance to abiotic and biotic stress	 x x	 x x	x	of a molecule in µM		
absorptive capacity	– nutrient/water acquisition	x	x	x	Quantitative: mol m^{-1} s^{-1} or % of nutrient taken up	(Frey & Schüepp, 1993), (Jakobsen *et al.*, 1992a)	(Frey & Schüepp, 1993)
color	-resistance to abiotic and biotic stress	x	x		Qualitative: color described by CMYK model	(de la Providencia *et al.*, 2005) using transformed roots and (Koske, 1981) using spores over filter paper on soil-filled Petri plate	Knowledge gap (are darker hyphae, more melanized, more resistant to fungivores?)
wall/membrane chemical composition	-resistance to abiotic and biotic stress -nutrient/water acquisition -fungal recognition (anastomosis) -palatability	x x x x	 x	x x	Quantitative: in µg	(Bethlenfalvay *et al.*, 1981) for chitin. (Frey *et al.*, 1992, 1994) for chitin and ergosterol (Butler & Lachance, 1986) for melanin; (Harrison & Vanbuuren, 1995) for P transporters	(Deveautour *et al.*, 2020)
pattern of anastomosis	- fungal recognition - fitness	x x			Quantitative: number of anastomosis per hyphal length (cm) or percentage of	(de la Providencia *et al.*, 2005)	(de la Providencia *et al.*, 2005)

					anastomosis (%)		
Intraradical Hyphae							
-hyphal thickness	-Resource flux/exchange -resistance to abiotic and biotic stress	x x	x x		Quantitative: in µm	(Abbott, 1982)	Knowledge gap (e.g., are thicker hyphae more resistant to pathogens? Is there a tradeoff between nutrient transfer and biotic resistance in terms of hyphal thickness?)
-pattern of colonization (localized / widespread)	-Resource flux/exchange -resistance to abiotic and biotic stress	x x	x x		Qualitative	(Dickson, 2004) (McGONIGLE *et al.*, 1990) (Abbott, 1982)	Knowledge gap (e.g., is resource exchange more/less efficient when colonization is localized or widespread?)
-rate of root colonization	-Resource flux/exchange -resistance to abiotic and biotic stress	x	x		Quantitative: % of root colonization over time	(Dickson, 2004)	(Campo *et al.*, 2020)
Arbuscules							
- architecture (Paris/Arum type)	- resource flux/exchange -resistance to abiotic and biotic stress	x x	x x		Qualitative	(Dickson, 2004)	(van Aarle *et al.*, 2005)

- turnover rate	-resource flux/ exchange	x	x		Quantitative: number of days	(Alexander *et al.*, 1989)), (Toth & Miller, 1984)	Knowledge gap (e.g., are some arbuscules more short lived than others? How does arbuscule turnover affect resource exchange?)
-number	-resource flux/ exchange	x	x		Quantitative: number of arbuscules	Quantification of Arbuscules Using Morphometric Cytology - (Toth, 1992) Magnified intersections method - (McGONIGLE *et al.*, 1990) Image analysis - (Smith & Dickson, 1991) Direct count - (Menge *et al.*, 1978)	(Koch *et al.*, 2017)
Vesicles							
-size and form (globose/lobbed)	- carbon storage - resistance to abiotic and biotic stress	x x	x x		Quantitative: in µm (for size). Qualitative (for form)	(Abbott, 1982)	Knowledge gap (e.g., are fungi with larger vesicles more resistant to stress?)
-number	- carbon storage	x	x		Quantitative: number per root	(Abbott, 1982), (Menge *et al.*, 1978)	(Kobae *et al.*, 2016)

					length		
-chemical composition (C/lipid storage)	- carbon storage	x	x		Quantitative: % total lipids/ fatty acids	(Jabaji-Hare *et al.*, 1984)	(Jabaji-Hare *et al.*, 1984)
Turnover rate	- carbon storage	x	x	x	Quantitative: number of days	Knowledge gap (adapt the method used for arbuscules)	Knowledge gap (e.g., are some vesicles more short lived than others? How does vesicle turnover affect C storage?)
Other genetic traits							
Genome size	-reproductive rate - survival					Whole genome sequencing Flow cytometry	Sperschneider et al., 2023 (Hosny *et al.*, 1998)
GC content of the genome	- mycorrhizal host response -host preference	x	x x	x		Whole genome sequencing Knowledge gap (missing genomes across phylogeny)	(Malar C *et al.*, 2022)

*abiotic and/or biotic

**Examples/papers showing the relationship between measuring the trait its function. References might not necessarily represent best practice.