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# **How important is arbuscular mycorrhizal colonization in wetland and aquatic habitats?**

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**A B S T R A C T**

Plants that live in aquatic habitats are frequently subjected to oxygen limitation and many of them modify their anatomy and physiology to counteract hypoxia. In these habitats, the role of plant associations with arbuscular mycorrhizal fungi (AMF), which are widespread in terrestrial environments and frequently confer benefits to the associated plant, is still debated. Starting from data taken from 34 selected papers, this study focuses on the occurrence of AMF in the roots of wetland and aquatic plants, taking into account the hydrological conditions of the sites, the plant wetland indicators and life forms, plant taxonomy and colonization by dark septate endophytes. The results have demonstrated the importance of hydrology in controlling the frequency and intensity of AMF root colonization, which tends to be low in obligate wetland plants. Moreover, colonization is generally lower and, possibly, less functional in monocots than in dicots. We suggest that the hydrological conditions, by filtering species according to their water tolerance, shape plant community composition, and that although AMF colonization is one of the traits that may increase plant fitness, it is not the most important one. In fact, a range of nutritional and growth strategies, which are more variegated than in terrestrial habitats, exists in wetland/aquatic habitats, and these strategies may rely, or not, on AMF colonization, as a consequence of the habitat and species.

*Keywords*  
Aerenchyma  
Arbuscular mycorrhizal colonization  
Dicots  
Hydrological conditions  
Monocots  
Wetland Indicator

## 1 **1. Introduction**

2  
3 Aquatic plants, in the broadest sense, include species that are either emergent, floating or  
4 submerged, which habitually live along an ecological continuum from wetland conditions,  
5 where the soil is saturated with water or occasionally flooded, to permanent depth waters  
6 (Eckert et al., 2016). Oxygen limitation is a typical feature of these aquatic habitats (. Plants,  
7 under long-lasting flooding, may respond with different adaptations to root hypoxia (Loreti et  
8 al., 2016). Constitutive or inducible root aerenchyma, for example, allows gas exchanges  
9 with the environment and within the plant, and supports continued root growth (Loreti et al.,  
10 2016; García et al., 2008; Colmer, 2003). Changes in the architecture of a root system i.e. an  
11 increase in the number of superficial adventitious roots (Steffens and Rasmussen, 2016;  
12 Visser et al., 2000), root impermeabilization to reduce radial oxygen loss (Colmer, 2003),  
13 taller plants to restore contact with the atmosphere and changed leaf morphology to favour  
14 gas exchanges (Colmer and Voesenek, 2009; Mommer and Visser, 2005), are other examples  
15 of plant responses to the aquatic environment. Moreover, since the depletion of CO<sub>2</sub>  
16 characterizes many aquatic systems, some plants have ameliorated CO<sub>2</sub> exploitation through  
17 morphological/anatomical adaptations and/or by adopting carbon concentration mechanisms,  
18 such as the use of bicarbonate, which is common, or the CAM and the C<sub>4</sub> metabolisms,  
19 which are more rare (see for example Shao et al., 2017; Klavsen et al., 2011).

20 It is known that plant roots are colonized by a great variety of both mycorrhizal and non-  
21 mycorrhizal fungi (Vandenkoornhuysen et al., 2002), and that the association of the roots with  
22 rhizospheric fungi may help plants to grow and adapt (Smith and Read, 2008).

23 Among the known mycorrhizal associations, arbuscular mycorrhizae (AM) are  
24 widespread. More than 200000 species of Angiosperms, out of about 280000, are regularly  
25 mycorrhizal (Brundrett, 2009), and although there are some exceptions, AM occurrence is  
26 almost the norm for herbaceous plants. The reason for this is that AM fungi (AMF) play a  
27 fundamental role in the life of terrestrial plants (Smith and Read, 2008), and the colonization  
28 of emerged lands was suggested, on the basis of fossil records, to have been mainly favoured  
29 by the association of plants with AMF (Redecker et al., 2000). In exchange for  
30 photosynthetic sugars, AMF provide the host plant with mineral nutrients, especially  
31 phosphate, and water, which the extraradical mycelium acquires beyond the root-hair zone or  
32 from the soil pores that are too small for the root hairs (Smith and Read, 2008). Arbuscules,  
33 that is, finely branched hyphae that develop inside root cortical cells, and which are the main

1 site of plant-fungus nutritional exchange, are central to this association (Smith and Read,  
2 2008).

3 However, the beneficial effects of AMF on plants go beyond a mere nutritional  
4 facilitation. Through influencing the growth and physiology of the host plants, AM fungi can  
5 increase plant competitiveness, with important consequences on the structure of the plant  
6 community (Sikes et al., 2009, van der Heijden and Horton, 2009).

7 In certain stressful conditions, which occur, for example, in alpine, aquatic and epiphytic  
8 habitats, plants tend to be non-mycorrhizal or facultatively mycorrhizal (Brundrett, 2009).  
9 Nevertheless, AMF, despite their aerobic life-style, have been observed in the roots of many  
10 aquatic and wetland plant species in different sites around the world, and are now recognized  
11 as the most common type of mycorrhizal fungi in these environments (Kohout et al., 2012,  
12 Stevens et al., 2011; Wang et al., 2011; Khan and Belik, 1995). Despite this, the main factors  
13 that influence AMF colonization are still controversial, and the functional roles of AMF in  
14 such ecosystems is still poorly understood, although an ecological role in mediating the  
15 coexistence of different species in plant communities, similar to that found in terrestrial  
16 ecosystems, is very likely (Zhang et al., 2014; Stevens et al., 2011; Wang and Zhao, 2006;  
17 Wolfe et al., 2006).

18 Apart from mycorrhizal fungi, the roots of aquatic plants are also associated with dark  
19 septate endophyte (DSE) fungi, which are characterized by pigmented or hyaline hyphae and  
20 microsclerotia (Seerangan and Thangavelu, 2014; Kohout et al., 2012). Our knowledge of the  
21 role of DSEs in plant ecophysiology and their importance in terrestrial ecosystem functioning  
22 is still limited in general and it is almost unknown as far as aquatic ecosystems are concerned  
23 (Kohout et al., 2012). However, the role of DSEs in solubilizing inorganic phosphate and  
24 mineralizing the organic forms (Della Monica et al., 2015) that increase phosphorus  
25 availability for plant absorption, and the occurrence of DSE in many aquatic habitats (Kohout  
26 et al., 2012) suggest an important ecological role for these fungi in these environments  
27 (Kandalepas et al., 2010). Moreover, DSE and AMF frequently colonize the same roots (de  
28 Marins et al., 2009, Weishampel and Bedford, 2006), thus the outcomes of their interactions  
29 in aquatic environments for the host is intriguing.

30 In this paper, based on the results of a set of selected papers, we have determined the  
31 levels of AM colonization in the herbaceous Angiosperms that live in wetland/aquatic  
32 environments at the species, family and class levels. We tested whether (1) the occurrence of  
33 AMF colonization is in fact lower in aquatic environments than in terrestrial ones; (2) the  
34 hydrological conditions and the occurrence of DSE influence AMF colonization; (3) the

1 wetland indicator categories, which classify the typical habitat associated with each plant  
2 species, and the plant life forms are correlated to the occurrence and/or intensity of AMF  
3 colonization; (4) differences in AMF colonization exist between monocots and dicots.

4 Our analysis could lay the foundations for future studies on the investigation of how the  
5 occurrence and frequency of AM fungi in wetlands and aquatic habitats are influenced by  
6 rapidly evolving environmental and climatic conditions, and could thus throw more light on  
7 the significance of these symbioses in these ecosystems.

## 8 9 10 **2. Materials and Methods**

### 11 12 *2.1. Mycorrhizal survey*

13 In June 2016, we searched peer reviewed articles that had dealt with AMF root  
14 colonization of herbaceous or shrubby Angiosperms in wetlands and aquatic habitats, by  
15 using the Web of Sciences database (<http://apps.webofknowledge.com/>). We considered  
16 articles from the year 2000 and looked for the following terms: (endomycorrhiza\* or  
17 mycorrhiza\* or arbuscul\* or AMF) and (wet or wetland\* or water\* or aquatic or flood\* or  
18 fen\* or hydro\* or lake\* or marsh\* or stream\* or submerged). We identified the studies where  
19 AMF abundance was analyzed in the roots of plants that grew in natural environments and  
20 where it was quantified as percent of root length colonization. We discarded articles where  
21 only a plant per species was analysed, and we chose papers where the percentage of  
22 colonization was expressed as mean  $\pm$  standard deviation,  $\pm$  standard error or where the  
23 authors claimed to have analyzed at least three plants per species. This search resulted in 16  
24 papers being considered for the present study. In order to increase our database, we searched  
25 for the most frequently quoted articles from the references of the selected papers, and made a  
26 further search using Google Scholar ([scholar.google.com](http://scholar.google.com)) to check for the possible existence  
27 of other papers not covered by WoS. New articles were added, provided that they fulfilled  
28 the above conditions. A total of 34 articles were selected (Reference list A1, appendix).

### 29 30 *2.2. Classification, features and mycorrhizal status of the species and families*

31 For each species, when not given by authors, the following data were searched for:

32 (1) the family, order and class identity, using the GBIF Online Resource Centre  
33 (<http://www.gbif.org/species>) and the USDA Plants Database of the United States  
34 Department of Agriculture (<http://plants.usda.gov/core/wetlandSearch>);

1 (2) the plant life span (annual, biennial or perennial) (USDA Plant Database and the  
2 Encyclopedia of Life database, <http://eol.org/pages>);

3 (3) the wetland indicator (WI) category (<https://plants.usda.gov/wetinfo.html>). According  
4 to this indicator, plant species can be classified as OBL (obligate wetland, almost always  
5 occurring in wetlands), FACW (facultative wetland, usually occurring in wetlands, but may  
6 occur in non-wetlands), FAC (facultative, occurring in wetlands and non-wetlands), FACU  
7 (facultative upland, usually occurring in non-wetlands, but possibly occurring in wetlands) or  
8 UPL (obligate upland, almost never occurring in wetlands). When a species lacked WI  
9 category but all the species of the genus had the same indicator and the same growth habit,  
10 we assigned the same indicator to the species, after checking the features of the habitat  
11 investigated in the original paper.

12 While the UPL, FACU, FAC and FACW wetland categories indicate terrestrial/emergent  
13 plants that live in more or less wet or inundated soils, the OBL plants include plants with a  
14 large variety of life forms (LF) which reflect adaptations to the aquatic environment  
15 (Bowden et al., 2006). Hence, we recognized the following sub-categories: rooted emergent  
16 (E) plants; rooted plants with floating (FL) or submerged (S) leaves; not anchored to the  
17 substrate, free floating (FF) and free submerged (FS) plants. The last categories were  
18 considered together for some analyses (FL/S) because of the low number of species; the same  
19 was done for the FACU and UPL categories (FACU/UPL). These plant features, when not  
20 reported by the authors, were deducted from the species details reported in the Encyclopedia  
21 of Life database, whenever possible. When these searches did not return any results, we used  
22 the Google search engine, because it covers the whole content of the documents, instead of  
23 just the title, abstract and key words, of a huge variety of publications. We assigned a number  
24 from 0 (UPL) to 6 (OBL-FF/FS) to each category.

25 As mentioned above, we included only experiments that reported the percentage  
26 colonization of roots. When necessary, the mean colonization was retrieved from the graphs.  
27 Species were classified as AM(1), when they were mycorrhizal and only found once in the  
28 selected papers, AM when the species resulted to be mostly mycorrhizal, AM-NM when  
29 approximately equivalent mycorrhizal and non-mycorrhizal reports were found, NM(1) and  
30 NM when the species was non-mycorrhizal and only one and more data, respectively, were  
31 retrieved. A similar criterion, in accordance with Brundrett (2009), was applied to families,  
32 which were classified as AM when the % of AM species was > 75%, AM-NM when it was  
33 between 75 and 25%, and NM when it was < 25%.

34 We grouped the percentages of root colonization into six classes. The class 0 included the

1 non-mycorrhizal plants (% AMF colonization = 0) while the colonized plants were  
2 subdivided into five classes with width 20. In addition to the % of AMF colonization, we  
3 recorded the percentages of arbuscular and DSE colonization, when available.

### 5 *2.3. Features of the collection sites*

6 Only a few papers reported the water depth, and the environmental characteristics of the  
7 sites were often difficult to define. For this reason, we tentatively classified the environments  
8 into five numerical categories, on the basis of their hydrological conditions (HC): (1) wet to  
9 saturated soils, but dry in summer; (2) periodically flooded soils with water fluctuations or  
10 dry in summer, and wetland with a low water level; (3) permanently flooded soils; (4) lakes  
11 and permanent freshwaters; (5) streams and rivers. Fens and bogs were assigned to different  
12 categories, according to the authors' description.

13 The pH, and the P and N contents expressed as  $\text{mg}\cdot\text{L}^{-1}$  or  $\text{mg}\cdot\text{g}^{-1}$ , the electrical  
14 conductivity and the soil humidity, which were the most frequently reported parameters in  
15 the selected articles, were reported for the collection site of each species.

### 17 *2.3. Statistical analysis*

18 We calculated the frequency distribution of the species in relation to the class of AMF  
19 colonization, the HC and the WI/LF categories, the presence/absence of DSE/AMF and the  
20 percentages of the AM, AM-NM and NM species and families. When a single species was  
21 analyzed by different authors, and different levels of colonization or HCs were reported, we  
22 spread the colonization over more classes/categories, standardizing to a total of 1 for each  
23 species. The numeric codes assigned to the AMF colonization class (0-5), the HCs (1-5) and  
24 the WI/LF categories (1-6) were used to calculate the mean values of the classes and  
25 categories. Regression and  $\chi^2$  analyses were implemented in XLSTAT 2017 (Data Analysis  
26 and Statistical Solution for Microsoft Excel. Addinsoft, Paris, France 2017).

27 The plant families were treated as follows:

28 (1) we conducted a correlation analysis for the families where at least three species were  
29 recorded, on the following variables: the mean HC, the % of perennial species, three  
30 parameters related to the intensity of colonization (the mean class of colonization, the % of  
31 non-mycorrhizal species, i.e. 0 class, and the % of heavily colonized species, i.e. 4+5 classes),  
32 as well as on the habits associated with the species (the mean WI/LF, the % of OBL and of  
33 the FL/S OBL species). The resulting data set combined eight variables and 288 characters.  
34 A Kendall tau correlation coefficient was calculated to determine the strength of the



1 relationships between the selected characters. The results were also compared with those of  
2 another non-parametric method, that is, Spearman's correlation coefficient. Regression  
3 analysis was also applied to the pairwise data series that resulted to be most closely  
4 correlated.

5 (2) A principal component analysis (PCA) was conducted in Past 3.10 (Hammer et al.,  
6 2001) considering the same seven parameters used for the correlation analysis of the plant  
7 families, except for the % of FL/S OBL species which, when considered, led to an unclear  
8 family distribution in the plot due to their general, but not exclusive, occurrence in the NM  
9 plants and their rather additive effect on the OBL %. A variance-covariance matrix was  
10 computed on a multivariate data set consisting of 252 characters (the data were transformed  
11 by adjusting them to standard deviates, because the considered variables were measured at  
12 different scales; McCune and Grace, 2002).

13 The analysis investigated the overall variation pattern, and the extracted axes were those  
14 that corresponded to components with larger eigenvalues than 1. The PCA results were  
15 presented as a two-dimensional scatter plot, in which each point represents one plant family,  
16 and the proportion of variation (Eigenvalues) expressed by PC1 and PC2 is presented as a  
17 percentage of their total sum.

18

### 19 **3. Results**

20

#### 21 *3.1. Collection sites and plant species*

22 The analysis was based on 13 papers from North America, including 2 from Canada, as  
23 well as 8 from Europe, 5 from India and 4 from China. The remaining papers included 3  
24 from the South America and one from New Zealand (Fig. 1) (Table A1, appendix). Lakes  
25 and streams, with their surrounding zones, represented the largest part of the analysed  
26 European and Chinese habitats. Other habitats in Europe included acidic peat bogs and fens,  
27 and freshwater marshes were included in China. In India, nearly 40% of the plant species  
28 were sampled in lakes, streams and the adjoining areas, while the remaining ones were  
29 sampled in ponds and other water-holding areas. Lakes were the only habitat analyzed in  
30 New Zealand. Different types of wetlands and two peatlands were the most represented sites  
31 in the USA. Peatlands were also the most abundant habitats in Canada. Floodplains with  
32 channels and backwaters were the most analyzed habitats in South America, along with two  
33 areas of the flooded Pampas.

1 We ordered all the species from the selected papers according to their family, order and  
2 class, and found that they belonged to 27 orders (21 dicots; 6 monocots), 70 families (51  
3 dicots; 19 monocots) and 416 species (220 dicots; 196 monocots). As far as dicots are  
4 concerned, the orders with the highest number of species were Lamiales (42 species),  
5 Asterales (37) and Caryophyllales (29), while the orders with the highest number of  
6 monocots were Poales (138) and Alismatales (46) (Fig. 2; Table B1, appendix). Thirty-six  
7 families with at least three species were analysed and were used for correlation and PCA  
8 analyses.

9

### 10 3.2. AMF colonization of the species

11 Most of the dicot species were colonized, with the sum of AM and AM(1) species  
12 accounting for 62.7%. The % of colonized monocot species was significantly lower ( $P =$   
13 0.001), that is, 46.4%. The percentages of non-colonized NM + NM(1) species were also  
14 different for the two plant classes, although the significance of difference was lower (30.4  
15 and 39.8%, respectively,  $P = 0.046$ ) (Fig. 3).

16 The frequency distribution of the species over the six classes of colonization showed that  
17 the % of species decreased as the colonization increased. The 0 class was higher in the  
18 monocots than in the dicots ( $P = 0.007$ ), while the opposite occurred in the highest  
19 colonization classes (Fig. 4a). The decrease in colonization fitted a linear regression for both  
20 the monocots and dicots (adjusted  $R^2 = 0.798$ ;  $P = 0.010$  and adjusted  $R^2 = 0.874$ ;  $P = 0.004$ ,  
21 respectively), and the % of monocots decreased linearly with increasing colonization  
22 (adjusted  $R^2 = 0.941$ ;  $P = 0.001$ ) (Fig. 4b).

23 The % of arbuscule colonization was analyzed in 8 papers (120 species of dicots and 51  
24 of monocots). Using the available data, we found that 87.1% of the colonized samples had  
25 arbuscules, with a significantly higher % ( $P < 0.0001$ ) in the dicots (95.0%) than in the  
26 monocots (66.7%). Regression analysis of the arbuscule colonization % vs. that of the AMF  
27 colonization showed a highly significant relation for both the monocots and the dicots ( $R^2 =$   
28 0.213,  $P = 0.0008$  and  $R^2 = 0.331$ ,  $P < 0.0001$ , respectively) and a higher  
29 arbuscular/mycorrhizal colonization ratio for the dicots (Fig. 4c and d).

30 Most of the analysed plant species were perennial, with significantly higher percentages  
31 in the monocots than in the dicots (about 80% and 62%, respectively;  $P < 0.0001$ ). The  
32 regression analysis showed that the % of AMF colonization and that of perennial plants were  
33 not linearly related (not shown).

34

### 3.3. *The influence of the environmental conditions and DSEs on AMF root colonization*

The hydrological conditions (HC) had a strong impact on AMF colonization; the regression analysis showed a negative linear relationship of the mean class of colonization with the corresponding HCs (adjusted  $R^2 = 0.807$ ;  $P = 0.025$ ; Fig. 5a) and a positive one with the % of the 0 class (adjusted  $R^2 = 0.849$ ;  $P = 0.017$ ). A different distribution of the AMF colonization classes was found for the dicots and monocots (Fig. 5b and c). In the dicots, 97.5% of the species were colonized in the most terrestrial habitat vs 55.7% in the monocots. Moreover, most of the dicotyledonous species were relatively well colonized in this habitat, as the % of species belonging to the 1<sup>st</sup> class of colonization was very low (4.5%). The percentage of colonized species diminished gradually as the habitat became more aquatic, but despite this, 12.9 and 18.9% of the species living in lakes and streams had a higher colonization than 60% (Fig. 5b). On the other hand, the percentages of classes 0 and 1 were higher for the monocots in the most terrestrial environment, and the % of the 0 class abruptly increased in lakes and streams (Fig 5c). No significant linear relationships were found between the HCs and the % of monocots or for the % of perennial plants (not shown).

The soil pH was analyzed in 13 papers (Table A1, appendix). It was between 5 and 8 in almost all the sites, with the most frequent values being between 7 and 8, and was positively correlated with the % of AMF root colonization in the dicots (adjusted  $R^2 = 0.184$ ,  $P < 0.0001$ ). The electrical conductivity, moisture, P and N contents (both as  $\mu\text{g}\cdot\text{L}^{-1}$  and  $\mu\text{g}\cdot\text{g}^{-1}$ ) did not show any relationship with the % of colonization (not shown), possibly as a result of the low number of data, except for the negative correlation found between the % of root colonization and the P content measured as  $\text{mg}\cdot\text{g}^{-1}$  and  $\text{mg}\cdot\text{L}^{-1}$  (adjusted  $R^2 = 0.213$  and  $0.189$ , respectively,  $P < 0.0001$ ).

Among the biological factors that could be related to AMF colonization, the presence of DSE was analysed in 6 papers. DSE colonization was relatively abundant under the 1 to 3 HCs (78.8 and 77.3% of the monocot and dicot species, respectively) (Fig. 6a). On the other hand, it was rarely observed in the lakes and in the streams. In fact, considering monocots and dicots as a whole, only 2.85% of the species living in these habitats were infected by DSE (Fig. 6a) (for comparison purposes, it should be considered that AMF colonization in these environments occurred in 12.3% of the species for the same data set). The % of species colonized by DSE was significantly higher ( $P = 0.0017$ ) for the dicots; the monocots instead showed the highest % of totally non-colonized plants ( $P = 0.001$ ) (Fig. 6b and c).

### 3.4. *Wetland indicator categories and life forms*

1 We distinguished the different species within each colonization class according to their  
2 wetland indicator (WI) category, and classified the OBL plants according to their life forms  
3 (LF). The regression analysis showed that the mean WI-LF category was inversely related to  
4 both the AMF colonization class (adjusted  $R^2 = 0.552$ ,  $P = 0.021$ ) (Fig. 7a) and the % of the  
5 4+5 classes (adjusted  $R^2 = 0.531$ ,  $P = 0.024$ ); moreover, it was positively related to the % of  
6 the 0 class (adjusted  $R^2 = 0.833$ ,  $P = 0.001$ ).

7 The OBL category was the most abundant, and the highest % was found in the 0 class,  
8 for both the monocots and dicots. The % of OBL plants decreased as colonization increased,  
9 with a similar trend to that of the mean WI-LF category (regression analysis, adjusted  $R^2 =$   
10  $0.988$ ,  $P = < 0.0001$ ). Among the OBL species, the emergent ones were the most abundant  
11 LF category, with the floating/submerged (FL/S) and the intermediate situations (E-FL/S)  
12 being represented approximately equally (Fig. 7b and c). The frequency distribution of the  
13 monocots showed a steady decrease in the OBL plant % as the colonization increased, which  
14 was accompanied by a corresponding increase in the FACW and FACU/UPL plants (Fig. 7c).  
15 The dicots instead showed a less regular decrease because, within the colonized classes, the  
16 2<sup>nd</sup> and 3<sup>rd</sup> classes had the highest OBL % and the lowest FACU/UPL plant % (Fig. 7b).

17 An analysis of arbuscule colonization in the different wetland categories showed that  
18 arbuscule and AMF colonization were positively related in the dicotyledonous OBL and  
19 FACW plants (adjusted  $R^2 = 0.608$ ,  $P = < 0.0001$  and adjusted  $R^2 = 0.135$ ,  $P = 0.010$ ,  
20 respectively) (Fig. C1, appendix). The relationships between the same parameters, although  
21 significant, were weaker in the monocots (adjusted  $R^2 = 0.146$ ,  $P = 0.031$  and adjusted  $R^2 =$   
22  $0.193$ ,  $P = 0.050$ ) (Fig. C1, appendix).

23 The percentage of the OBL plants was significantly higher in the monocots than in the  
24 dicots (63.9% and 47.2%, respectively,  $P = 0.001$ ) and the regression analysis showed a strong,  
25 positive relationships of the WI/LF categories with the % of monocots (adjusted  $R^2 = 0.844$ ,  
26  $P = 0.01$ ) (Fig. 7d). A significant positive relationship was also found between the WI/LF  
27 categories and the % of perennial species (adjusted  $R^2 = 0.927$ ,  $P < 0.0001$ ) (Fig. 7e), which  
28 has been shown to increase as the plant adaption to aquatic environments increased. On the  
29 other hand, no significant relationships were found between the HC categories and either the  
30 OBL % (adjusted  $R^2 = 0.277$ ,  $P = 0.280$ ) or the mean WI/LF categories (adjusted  $R^2 = 0.292$ ,  
31  $P = 0.096$ ) (Fig. 7f). DSE colonization was relatively high for the facultative and obligate-  
32 emergent plants and low for the real obligate aquatic plants (Fig. C2, appendix).

33

### 34 *3.5. Analyses of the families*

1 When all the families were considered, 38.0% were classified as AM, and this % fell to  
2 25.0% when the families with only 3 or more species were considered.

3 When considering the families with at least 3 species, the AM species exceeded 80% in  
4 the dicotyledonous Asteraceae, Campanulaceae, Balsaminaceae, Fabaceae, Lamiaceae,  
5 Linderniaceae, Lytraceae and Rosaceae. In comparison, the monocot families were colonized  
6 less frequently, with the highest values being around 70% (Poaceae). The Potamogetonaceae  
7 and the Sparganiaceae families were NM, and the dicots with the lowest % of AM species  
8 were the Brassicaceae and Nymphaeaceae (28.6 and 16.7, respectively) (Fig. 8). We  
9 classified most of the families as AM-NM. However, the above mentioned dicotyledonous  
10 well-colonized families were classified as AM, while the Callitrichaceae, Nymphaeaceae,  
11 Potamogetonaceae and Sparganiaceae families were classified as NM (Fig. 8).

12 The correlation analysis showed that the variables related to AMF colonization were  
13 strictly correlated to those related to the WI-LF category (Table 1). The HCs were correlated  
14 to all the AMF and WI-LF variables and the % of perennials was positively correlated to  
15 those of the WI/LF categories (Table 2). The highest correlations were found between the  
16 HCs, the OBL % and the mean AMF colonization class of the families.

17 The regression analysis, which was conducted considering these parameters two by two,  
18 highlighted similar trends for the monocots and dicots, but a different statistical significance.  
19 The regression lines of the HCs by the mean AMF colonization class showed a negative  
20 trend and was highly significant for the dicots (adjusted  $R^2 = 0.403$ ,  $P = 0.000$ ), but not  
21 significant for the monocots (adjusted  $R^2 = 0.268$ ,  $P = 0.059$ ) (Fig. 9a and b). The regression  
22 of the OBL % by the mean AMF colonization class was significant for both plant classes,  
23 with a higher significance for the monocots (dicots: adjusted  $R^2 = 0.187$ ,  $P = 0.018$ ;  
24 monocots: adjusted  $R^2 = 0.679$ ,  $P = 0.001$ ) (Fig. 9c and d). These graphs highlighted a low  
25 colonization level for the monocotyledonous families, as none of them had a higher mean  
26 colonization class than 2 (this corresponds to a colonization of between 20 and 40%). The  
27 regression lines between the mean HC and the OBL% showed a positive trend, and the  
28 regression was highly significant for the dicots (adjusted  $R^2 = 0.430$ ,  $P = 0.000$ ), but not  
29 significant for the monocots (adjusted  $R^2 = 0.220$ ,  $P = 0.083$ ) (Fig. 9e and f).

30 In the PCA analysis, which was run on the plant families, two axes, which accounted  
31 together for 79.2% of the variance, were designed; the scatterplot is shown in Fig. 10. The  
32 first component (PC1) and the second one (PC2) explained 59% and 20.2% of the total  
33 variation, respectively. Families with both positive and negative values were scattered along  
34 the two main axes.

1 Among the original variables explaining most of the variation for positive values of the  
2 first component (PC1) (right part of the PCA plot) were the percentage of class 0, with the  
3 highest loading on this component (0.430), and this was followed by the percentage of OBL  
4 plants (component loading 0.422), the HCs (0.393) and mean WI-LF category (0.356). For  
5 negative values of the PC1 (left part of the PCA plot), the 4+5 classes (-0.355) and the  
6 average of the AM colonization classes (-0.436) were the variables that showed statistical  
7 importance.

8 The percentage of perennials (component loading 0.592), the mean WI-LF category  
9 (0.461) and the 4+5 classes (0.426) contributed significantly to the positive values of the  
10 second component (PC2). The only significant contributors to the negative values of the PC2  
11 were the HCs and class 0, which showed a component loading of -0.141 and -0.188,  
12 respectively

13 Accordingly, plant families characterized by a low mean class of colonization ( $< 1$ ) and a  
14 high mean WI-LF category ( $> 4$ ), a high % of perennial plants ( $> 80\%$ ) and high HC value  
15 (around 3 or higher) grouped in the upper right part of the PCA scatterplot (Fig. 10). These  
16 plants belonged to seven monocotyledonous and three dicotyledonous families that were  
17 almost exclusively OBL, with the exception of Araceae. The Potamogetonaceae,  
18 Sparganiaceae, Callitrichaceae and Nymphaeaceae families were the only ones that we  
19 classified as NM, and most of the FL/S species families belonged to this group.

20 The plants that cluster in the left of the PCA scatterplot belonged to different dicot  
21 families and to Poaceae. They were characterized by a mean class of colonization of between  
22 about 2 and 3.5, with a low percentage of the 0 class, a mean  $HC \leq 3$  and a mean WI-LF  
23 category of between 2.5 and 3.0, except for Lytracaceae and the Campanulaceae. The latter  
24 family was distinct as it had a high % of heavily colonized and OBL-S species, so it lies in  
25 the uppermost part of the PCA scatterplot, and shows the highest score (3.39) for the positive  
26 values of PC2.

27 The remaining families formed a large central group, and were mainly scattered along the  
28 vertical axis. Apiaceae (specific score  $\geq 1$ ) and Ranunculaceae, with positive PC2 values,  
29 were clustered with the families that were less affected by the variables considered in this  
30 study and which are positioned in the centre of the scatterplot and with Elatinaceae and  
31 Phrymaceae, which are located in the lower right quadrant. These families, although very  
32 heterogeneous in relation to the variables that were considered, were grouped together by a  
33 relatively high mean WI/LF category (3.4 - 4.4) and % of OBL plants ( $>54\%$ ).

1 The second subgroup of families, with negative PC2 values, were clustered with  
2 Solanaceae and Commelinaceae, and positioned on the left, while Brassicaceae was  
3 positioned on the right. These plants showed low values in relation to the colonization class  
4 (0.4 - 1.7), to the mean WI/LF category ( $< 2.8$ ) and to the % of OBL plants ( $< 40\%$ ; equal to  
5 zero for Solanaceae and Commelinaceae).

6

#### 7 **4. Discussion**

8

9 Our results have shown a relatively low attitude to AMF colonization of plants that grow  
10 in wetland/aquatic habitats, as has been observed by several authors. The overall percentage  
11 of AM plants that were analysed was around 55% and 25% at the species and family levels,  
12 respectively. These values, especially at the family level, were much lower than those  
13 reported by Brundrett (2009) and by Wang and Qiu (2006) who, unlike in our case, analyzed  
14 data from most of the habitats and geographic regions throughout the world.

15 The frequency distribution has shown that the most frequent class of colonization is the 0  
16 class (0% of colonization), which corresponds to almost 40% of the species, while about 21%  
17 of the species have a % of AMF colonization that does not exceed 20% of the root length.  
18 Only 3.4% of the remaining plants, mainly dicots, have a colonization level that exceeds 80%  
19 of the root length. Because the level of root colonization is frequently related to the impact of  
20 AM associations on plant nutrition and growth (Smith and Read, 2008; Jansa et al., 2008),  
21 the occurrence of these low levels of colonization renders the role of symbiosis questionable  
22 (see Lekberg et al., 2015).

23 In plants that are not tolerant to a prolonged aquatic habitat, the absence of/reduction in  
24 colonization may be related to a shortage of oxygen and a depletion of carbohydrates  
25 (Mommer and Visser, 2005) that make the plant unable to support a functional AMF  
26 colonization (see, for example, Smith and Read, 2008). On the contrary, variations in the  
27 intensity of AMF colonization in adapted and thus non-stressed plants (Otte, 2001) point to  
28 the likely coexistence of plant species that differ in their dependency or responsiveness to  
29 AMF fungi. Literature data show that, as in terrestrial environments, many plants grow better  
30 when colonized by AMF, even under wetland/aquatic conditions (Wu et al., 2013; Fougnyes  
31 et al., 2007; Andersen and Andersen, 2006; Neto et al., 2006; Fraser and Feinstein, 2005;  
32 Jayachandran et al., 2003; Miller and Sharitz, 2000; Solaiman and Hirata, 1997) and that a  
33 high root AMF colonization is associated with a high P concentration in the plant tissues  
34 (García and Mendoza, 2008; Wolfe et al., 2006; Miller and Sharitz, 2000). This, and the fact

1 that AMF colonization may provide other benefits to the plants, for example, by improving  
2 the water uptake capacity during flooding (Calvo-Polanco et al., 2014) or the osmotic  
3 adjustment of plant tissues (Neto et al., 2006), indicates that AMF colonization, at least in  
4 certain plant-HC combinations, may increase plants fitness.

5 However, colonization is probably less important in these aquatic habitats, and may even  
6 be depressed, because flooding has been shown to mobilize phosphorus (P) in relation to  
7 aerobic soils, and to increase the P availability to plants (Maranguit et al., 2017; García et al.,  
8 2008). P is, in fact, immobilized on iron and aluminium oxides in most soils and is released  
9 under flooding or waterlogging conditions through microbially-mediated reductive  
10 dissolution of these compounds (Maranguit et al., 2017). Moreover, the development of  
11 extensive aerenchyma, which is a major trait that promotes plant tolerance to waterlogging  
12 (Tanentzap and Lee, 2017), may increase the availability of rhizospheric mineral nutrients to  
13 plants; oxygen leakage, in fact, may stimulate aerobic decomposition by saprotrophs (see  
14 Cornwell et al., 2001).

15 In addition, the rapid accumulation of the gaseous hormone ethylene, which occurs inside  
16 plant organs under flooding (Ravanbakhsh et al., 2017; Voeselek and Sasidharan, 2013),  
17 might depress root colonization in some plant species or varieties. Ethylene, in fact, is  
18 suspected of being a negative regulator of mycorrhizal intensity, by inhibiting AMF entry  
19 into the root and intraradical fungal diffusion (Foo et al., 2016).

20 For all these reasons, it is possible to hypothesise that both morphological/anatomical  
21 adaptations, including aerenchyma, and AMF colonization are alternative or synergistic  
22 strategies in the roots of aquatic plants to overcome the stress caused by water. However, the  
23 coexistence of colonized and non-colonized individuals in the same plant species points to  
24 the relative importance of environmental filtering, which conditions the occurrence and  
25 intensity of AMF colonization in aquatic habitats.

#### 26 27 *4.1. Influence of the environmental conditions and DSEs on AMF root colonization*

28 Colonization frequency distribution and regression analyses have shown that colonization  
29 decreased from the terrestrial to the most aquatic habitats. This was especially true for the  
30 dicots, where almost all the species were colonized in wet or water-saturated soils, while  
31 the % of the 0 class rose to about 65% of the plant species in streams. The same result was  
32 also evident from the distribution of the plant families in the PCA, where the “HC” and  
33 “mean colonization” variables showed opposite trends. Although many other physico-  
34 chemical factors, apart from the HCs, can manipulate the mycorrhization state in a given site,



1 we were not able to explore their importance in detail in the present work, due to the scarcity  
2 and heterogeneity of the data available from the selected papers. The temperature of the sites,  
3 which has recently been recognized as an important regulator of AMF colonization at a  
4 global scale (Soudzilovskaia et al., 2015), and the illumination intensities, which have been  
5 shown to influence the root colonization intensity and AMF community inside the roots (Shi  
6 et al., 2014), were rarely reported. We could only find the relationships of the intensity of  
7 AMF colonization with the P concentration and the pH in the dicots. However, both variables  
8 are in part related to the HCs, because they have been shown to be influenced by flooding  
9 (Maranguit et al., 2017; Dolinar and Gaberščik, 2010; García et al., 2008).

10 The dependence of AM colonization on the hydrological features of the sites has been  
11 found by some authors in both field and controlled conditions (Stevens et al., 2011; Sraj-  
12 Krzic et al., 2006; Miller, 2000; Miller and Sharitz, 2000; Miller et al., 1999; Rickerl et al.,  
13 1994), but not by others (Boherer et al., 2004; Bauer et al., 2003; Wetzels and van der Walk,  
14 1996). The reason for these discrepancies in part depends on the fact that AMF colonization  
15 is linked to the plant responses to changes in water regimes, which are very complex and are  
16 influenced by multiple factors (Sorrell et al., 2000). This is clearly shown in a recent paper  
17 by Wang et al. (2016), in which *Polygonum hydropiper*, an emergent aquatic plant, and  
18 *Panicum repens*, a semi-aquatic one, were analysed under three different flooding intensities.  
19 The % of colonization was higher in *P. hydropiper* under moderate/intensive flooding. On  
20 the other hand, *P. repens* had the highest colonization when the flooding was mild, and its  
21 colonization fell to zero under intensive flooding. This reflected the greater adaptive ability  
22 of *P. hydropiper*, whose number of adventitious roots increased to counteract hypoxia and  
23 the photosynthetic rate intensified, thus increasing the organic carbon that supports AMF  
24 symbiosis (Wang et al., 2016). This example shows that the variability of responses of  
25 species to a wetland/aquatic habitat may have profound implications on determining the  
26 intensity of root colonization by AMF.

27 The different phenological stages of a plant throughout the year makes the interpretation  
28 of plant responses to mycorrhization even more complex. For example, the growth rates of  
29 the plant and root and the reproductive stages, vary from species to species and influence  
30 AMF colonization with a seasonal trend which is largely independent of the HCs (García and  
31 Mendoza, 2008; Boherer et al., 2004; Miller, 2000). This may lead to confusion, especially  
32 when analyses have been conducted in only one period of the year.

33 Moreover, AM fungal species may show different degrees of adaptation to a  
34 wetland/aquatic habitat. For example, some fungal phylotypes are more competitive than

1 others under hypoxic conditions (Orchard et al., 2016; Maček et al., 2011), and the  
2 hydrological conditions of a site might act as the main determinant of AMF community  
3 composition and diversity (Moora et al., 2016; Deepika and Kothamasi, 2015; Kohout et al.,  
4 2012; García and Mendoza, 2008). Numerous studies have shown that, although AMF spores  
5 may survive for even long periods in waterlogged soils, spore germination and the growth of  
6 extraradical mycelium are inhibited or reduced by flooding (Stevens et al., 2010; García and  
7 Mendoza, 2009; García et al., 2008; Miller and Shariz, 2000).

8 The effect of flooding on the AMF association seems to depend largely on the extent of  
9 colonization at the onset of flooding (Miller and Sharitz, 2000). However, when AMF  
10 colonization is well established, the activity and functionality of AMF do not seem to be  
11 inhibited by flooding (Miller and Shariz, 2000). This has been demonstrated for rice, where  
12 similar expression profiles of two fungal transporter genes, *GintPT* and *GintAMT2*, and the  
13 presence of viable arbuscules were demonstrated under both dry and flooded conditions  
14 (Vallino et al., 2014). These data are in agreement with our results on arbuscule colonization;  
15 arbuscules occurred in most of the colonized species, and their % tended to increase with  
16 increasing AMF colonization. Since arbuscules are the main sites of plant/fungus nutrient  
17 exchange (Smith and Read, 2008), our data indirectly indicate that, when present, AMF  
18 colonization is also generally active in natural wetland/aquatic habitats.

19 As far as the possible influence of DSE on AMF colonization is concerned, our data do  
20 not support the idea of a possible competition between the two types of fungi (Kandalepas et  
21 al., 2010; Weishampel and Bedford, 2006), in agreement with De Marins et al. (2009). Both  
22 fungal types showed similar habitat preferences, although DSE seemed to be less tolerant to  
23 flooding. In fact, their presence in lakes and streams, as well as in FL/S plants, was very low.  
24 Hence, this result is in agreement with the suggested synergistic activity of DSE and AMF in  
25 P plant nutrition, with DSE increasing the pool of available P in the rhizosphere and AMF  
26 enhancing the plant uptake (Della Monica et al., 2015). The possibility of these two fungal  
27 categories also playing a complementary action in aquatic environments deserves more  
28 attention in specific future studies.

#### 29 30 4.2. Relationship between *WI/LF* categories and AMF root colonization

31 Because the mycorrhizal status of a plant is determined by the interaction of its anatomy  
32 and physiology with the aquatic environment, we deepened our analysis considering the  
33 wetland categories, which classify plant species on the basis of the typical habitat they live in,  
34 along with the life forms (emergent, floating or submerged) of obligate wetland plants.

1 Our analyses has in fact shown a decrease in the mean AMF colonization class with  
2 increasing levels of the mean WI/LF category, that is, with plants becoming more adapted to  
3 the aquatic environment. As expected, most of the species that were considered were found  
4 to belong to the OBL category. The percent frequency of the OBL plants was high, especially  
5 for the non-colonized (0 class) plants, decreased with increasing colonization and was  
6 positively or negatively correlated closely to all the parameters related to AMF colonization.  
7 As the OBL percent frequency was also positively correlated with the % of monocots, these  
8 data, as a whole, could indicate a low dependency of the OBL plants on AMF colonization,  
9 especially for monocotyledons.

10 However, it is important to point out that, although most OBL species are not- or are just  
11 slightly colonized, there are numerous exceptions, thus confirming the existence of different  
12 types of nutritional strategies that either involve or do not involve AMF colonization in  
13 aquatic plants. Some OBL emergent plants have been found heavily colonized, especially,  
14 but not exclusively, among the dicots. Some examples are *Ranunculus rivularis*, *Solidago*  
15 *patula*, *Hydrocotyle americana* and *Lycopus americanus* (Weishampel and Bedford, 2006;  
16 Cornwell et al., 2001; Clayton and Bagyaraj, 1984), which showed a higher colonization than  
17 80%. Similar levels of colonization were found in submerged plants, such as *Lobelia*  
18 *dortmanna* and *Hydrilla verticillata* (Nielsen et al., 2004; Beck-Nielsen and Madsen, 2001;  
19 Ragupathy et al., 1990; Farmer, 1985). Interestingly, the latter are two very different plants  
20 from each other. *Hydrilla verticillata* has very thin leaves to maximize the carbon influx and  
21 may use bicarbonate or C4-like photosynthesis to enhance its internal carbon concentration.  
22 *Lobelia dortmanna* is instead a plant with small, thick and impermeable leaves which, during  
23 the vegetative stage, uses the CO<sub>2</sub> that has entered, via the roots, from the sediments and,  
24 presumably, carries out a C3 photosynthesis process (Yin et al., 2017; Møller and Sand-  
25 Jensen, 2011; Maberly and Madsen, 2002; Richardson et al., 1984).

26 OBL species are characterized by a distinct combination of traits which reflect their  
27 adaptation to frequent inundations (McCoy-Sulentic et al., 2016). Large root aerenchyma  
28 volumes, for example, have been shown conserved in the OBL wetland species, where they  
29 may enhance plant performances during prolonged flooding (Tanentzap and Lee, 2017).

30 Šraj-Kržič et al. (2006) found no relationships between AMF colonization and  
31 aerenchyma, while Cornwell et al. (2001) reported a low level of colonization in the plants  
32 characterized by a well-developed aerenchyma, mainly in monocots. Moreover, according to  
33 Vallino et al. (2014), aerenchyma development may contribute to a decrease in root  
34 colonization in rice through the reduction of the arbuscule-hosting cortical cells. On the other

1 hand, through a loss of radial oxygen, aerenchyma more or less intensely increases the  
2 oxygenation of the soils and sediments, depending on the species and environmental  
3 conditions (Sorrell et al., 2000; Visser et al., 2000), and thus indirectly favours the  
4 colonization of nearby plants, as suggested by Zhang et al. (2014).

5 Adaptation to the aquatic environment is also linked to the life-cycle duration of the  
6 plants. A spectrum of life-histories has been shown to be associated with the permanency of  
7 the occupied aquatic habitat. These life-histories range from annual species, which occur  
8 mostly in temporarily inundated environments, such as seasonal pools or ditches, to long-  
9 lived perennial taxa, which can show either outcrossing or clonal reproduction, and prevail in  
10 permanent wetlands, large rivers and lake systems (Eckert et al., 2016). Our results have in  
11 fact shown that most of the analysed plants are perennials, and that their % increases in plant  
12 species that are more adapted to the aquatic habitat, with about 90% of perennials in the FL/S  
13 plant species.

14 However, the relationships between AMF colonization and the WI categories of the plant  
15 species have rarely been studied and are controversial. Among the papers we selected,  
16 Stevens et al. (2010) and Turner et al. (2000) did not find any relationship by studying a  
17 bottomland forest and some prairie fens, respectively. It is possible that, due to the above  
18 mentioned complexity of the interactions that determine AMF root colonization, only a large  
19 dataset from different environments would allow significant results to be obtained.

20 Finally, it should be pointed out that, although the mean HCs tended to increase as the  
21 WI-LF categories increased, no significant relationship was found between these two  
22 parameters when cumulative species data were used. This inconsistency probably arose from  
23 the observed overlap of habitats occupied by plant species of different wetland categories,  
24 along with the fact that these habitats were characterized by a continuum of HCs which made  
25 their precise classification unfeasible.

26

#### 27 *4.3. AMF colonization in the monocots- and dicots*

28 As previously discussed, the dicotyledonous species showed a higher attitude  
29 towards/dependence on AMF colonization than the monocots, a result that is in agreement  
30 with many of the papers that we analysed (Weishampel and Bedford, 2006, Cornwell et al.,  
31 2001). Moreover, arbuscules were more abundant in the dicots, in relation to the AMF  
32 colonization intensity, than in the monocots, thus possibly pointing to a greater functionality  
33 of the symbiosis in the former.

1        However, the number of species per family was found to be extremely variable in our  
2 survey, with the highest numbers in Poaceae and Cyperaceae. Assuming that the species  
3 within a family are homogeneous to a certain degree, the largest families would have exerted  
4 a stronger influence on the examined parameters, and this could have caused a bias when AM  
5 colonization between dicots and monocots was compared. To overcome this risk, we carried  
6 out an analysis at the family-level. In general, the results of the correlation analysis were  
7 coherent with those obtained from cumulative data in which individual species were taken  
8 into account. In addition, a significant correlation was found between the HCs and the  
9 parameters related to the WI-LF categories, possibly as a result of homogeneity in the  
10 adaptations and environmental preferences within families. The regression analysis also  
11 showed significant differences between the monocots and dicots. The distribution in the PCA  
12 scatterplot confirmed the different behaviour of the two classes of plants. The monocot  
13 families were mainly concentrated in the upper right quadrant, due to low levels of  
14 colonization and the high % of the OBL plants, and the dicots were scattered throughout the  
15 graph, thus pointing to a large range of adaptation and colonization intensities, although there  
16 were exceptions to this general pattern in the monocots, as in the case of Poaceae.

17        There is currently no explanation for the different behaviour of the two plant classes,  
18 unless it is related to the different evolutionary histories of these plants. Monocots are  
19 preponderant in aquatic habitats, as exemplified by the present dominance of sedges, rushes  
20 and reeds in wetlands and swamps throughout the world, and it has been hypothesised that  
21 they were primitively aquatic, or at least associated with wet habitats (Chase, 2004). As  
22 much as 33% of all monocotyledonous families have been classified as aquatic, compared  
23 with only 3% of dicots. The simplified structure of monocots and their reliance on  
24 adventitious root systems have long been regarded as an ancestral response of certain groups  
25 of land plants to readapt to an aquatic or semi-amphibious habitat (Crawford, 1992). The  
26 aquatic environment would then have induced the monocots to develop a greater adaptive  
27 plasticity in order to withstand the stresses of such a variable environment, and this  
28 adaptability may have led, among other factors, to a lower nutritional dependence on  
29 mycorrhizal associations.

30        Molecular data have shown differences between monocots and dicots that could be linked  
31 to their different colonization behaviour. Researches on the carotenogenesis of roots have  
32 highlighted a new *PSY3* class of phytoene synthase genes in dicots, a gene class that is  
33 lacking in monocots and in certain dicot lineages, such as in Brassicaceae (Walter et al.,  
34 2015). Some members of this gene class are regulated during nutrient stress responses and,

1 although the evidence is only circumstantial, their expression is involved in the formation of  
2 a precursor for strigolactones (Walter et al., 2015), which are signalling molecules of the  
3 establishment of AMF symbiosis (Smith and Read, 2008). Differences in signalling could in  
4 fact explain low AMF colonization (Lekberg et al., 2015). However, among the monocots,  
5 only the Poaceae family, which includes many well-colonized species has been studied so far  
6 (Walter et al., 2015), and thus the reason for the lack of gene copy is unclear. Nevertheless,  
7 these findings can be considered a promising starting point to understand the genetic origin  
8 of the different attitudes of monocots and dicots, but also of families or even genera, to  
9 colonization.

10 It is generally accepted that the loss of the AM condition has occurred several times  
11 independently during the evolution of land plants (Smith and Read, 2008), and it was caused  
12 by the loss of the genes required for the establishment and maintenance of symbiosis (Delaux  
13 et al., 2014). This mechanism is associated with the emergence of new traits that allow an  
14 efficient nutrient uptake (Delaux et al., 2014). However, species that have alternative  
15 strategies for the absorption of nutrients also exist (Delaux et al., 2014), and, according to our  
16 results, this condition seems to be common in aquatic environments. Mono- and  
17 dicotyledonous species that develop aerenchyma (see Seago et al., 2005), for example, may  
18 be both mycorrhizal and non-mycorrhizal. Moreover, in the *Carex* genus (Cyperaceae), root  
19 traits that may contribute to nutrient acquisition (i. e. different types of root hairs, dauciform  
20 roots and DSE colonization) have been shown to co-occur independently of each other and of  
21 AMF colonization in single species (Konoplenko et al., 2017).

22 Our results have confirmed that most families are AM-NM, including some families that  
23 are generally considered non-mycorrhizal (Brundrett et al., 2009), such as Brassicaceae,  
24 Cyperaceae, Juncaceae and Polygonaceae. Variations between the AM and NM conditions  
25 were also high within single species. In fact, around 35% of the considered species resulted  
26 to be AM-NM, when all the colonization data available in scientific articles and on the web  
27 were considered (not shown). Therefore, it is likely that, in aquatic ecosystems, which are  
28 extremely variable and dynamic, maintaining different survival and nutrition strategies could  
29 be advantageous and favoured by the selective pressure.

30

### 31 **Conclusions**

32 Our analysis has demonstrated: (1) a low tendency towards AMF colonization in  
33 wetland-aquatic habitats; (2) the role of hydrology in controlling the frequency and intensity  
34 of colonization, which steadily decreases as HCs become more selective; (3) the correlation

1 between the WI-LF categories and AMF colonization, the latter tends to be low in the  
2 obligate wetland plants; (4) the greater tendency towards intense and functional AMF  
3 colonization in dicots than in monocots in the wetland/aquatic habitat.

4 These findings agree with the suggestion that the HCs in wetland/aquatic habitats  
5 influence the competitive interactions of plants, through filtering species, on the basis of their  
6 fitness, and are thus important shapers of the community composition of plants (Miller, 2000;  
7 Casanova and Brock, 2000).

8 AMF colonization also adds a level of complexity to this framework, because of its effect  
9 on community composition in the wetland/aquatic habitats. Zhang et al. (2014), in a  
10 marshland plant community of mycorrhizal dicots, found positive neighbour effects of AMF  
11 on the subdominant species and negative/null effects on the dominant ones, with a  
12 consequent increase in plant diversity. Moreover, the AMF effect on the plant community  
13 may change in relation to the HCs. Wolfe et al. (2006), studying mesocosms consisting of  
14 dominant non-mycorrhizal and subordinated mycorrhizal species, found that plant diversity  
15 was unaffected by AMF colonization under a low water table treatment but decreased  
16 significantly under a high water table treatment.

17 These and other examples (Zhou et al. 2018), apart from highlighting the complex  
18 interactions between AMF colonization, HCs and plant communities, point to the fact that  
19 mycorrhizal interactions are not always a functionally advantageous trait that confers  
20 tolerance to aquatic habitat (Khan and Belik, 1995) and, depending on the plant species and  
21 the environmental conditions, they can be replaced by or occur along with other traits.

22 Despite this, AMF colonization in wetlands is widespread, although the level of  
23 colonization is frequently low. The plant AM status thus seems to reflect a variegated picture  
24 where the continuum of strategies, ranging from non-tolerant stressed plants, which are  
25 unable to sustain any fungal colonization, to highly tolerant plants, which can rely or not on  
26 AMF colonization, is influenced by the environmental conditions and the taxonomic identity  
27 of the partners. In our survey, colonized and non-colonized species have in fact been found in  
28 the same habitat, under the same HCs, and intense colonization of very specialized  
29 hydrophytes has been found in mycorrhizal-suppressive habitats.

30 A striking example of this is that of *Lobelia dortmanna*, an isoëtoid plant that lives  
31 submerged in oligotrophic lakes in the temperate European and North American areas and  
32 relies on AMF partners for its nutrient uptake (Moora et al., 2016; Møller and Sand-Jensen,  
33 2011). Its root colonization tends to correlate positively with the low nutrient concentrations  
34 and negatively with the high organic material found in lake sediments (Møller et al., 2013).

1 In recent years, isoëtoid communities have declined dramatically in response to  
2 disturbance and eutrophication (Moora et al., 2016) and the case of *L. dortmanna* highlights  
3 the importance of mycorrhizas for the survival of some endemic species. The growing  
4 interest in wetlands and other aquatic habitats will prompt further studies aimed at assessing  
5 the levels of AMF colonization in hydrophytes. The results of these investigations will  
6 facilitate the use of AM mycorrhizae as growth enhancers and aids for the restoration of plant  
7 communities in wetlands, as is already being done in terrestrial systems. Sorting out the  
8 effects of mycorrhizae on community dynamics in aquatic plants and understanding the  
9 dependence of endangered plant species on AMF colonization in these environments are key  
10 steps in decision-making processes for biodiversity conservation.

11

12 **Appendix A, B and C. Supplementary data.** Supplementary data associated with this  
13 article can be found in the online version.

14

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16 species. *Front Plant Sci.* 8: 2253. doi: 10.3389/fpls.2017.02253.



## 1 **Legends**

2

3 Fig. 1. Sampled sites in the USA (7, 8, 10, 13, 19, 21, 22, 23, 27, 28, 29), Canada (24, 26),  
4 South America (9, 14, 16), Europe (6, 11, 15, 17, 18, 25, 31, 34), India (3, 5, 20, 30, 33), China  
5 (1, 2, 4, 12) and New Zealand (32). The number of species analysed in each paper is indicated  
6 by different symbols which are shown at the bottom of the figure on the left (for the  
7 correspondence between numbers and papers see Reference list A1, appendix)

8

9 Fig. 2. Pie graphs showing the dicot (a) and monocot (b) orders and their relative proportions.  
10 See Table B1, appendix for the list of orders, families and species.

11

12 Fig. 3. Pie graphs showing the proportion of mycorrhizal, variable mycorrhizal (AM-NM) and  
13 non-mycorrhizal species in the dicots (a) and monocots (b). The mycorrhizal and non-  
14 mycorrhizal species include species that were analyzed only once and species analyzed twice  
15 or more times.

16

17 Fig. 4. AMF and arbuscule colonization. (a) Percentages of species belonging to each class of  
18 colonization in the dicots and monocots. The 0 class includes non-mycorrhizal plants. The  
19 remaining five classes had width 20 each (class 1 = > 0-20% AMF; class 2 = > 20-40% AMF;  
20 and so on up to class 5); different letters indicate significant differences. (b) Regression  
21 analysis between the % of monocots and the AMF colonization class. (c, d) Regression  
22 analyses of the % of AMF root colonization and the % of arbuscules; a highly significant  
23 relationship was found for both the monocots and the dicots, with a higher arbuscular-to-  
24 mycorrhizal colonization ratio for the dicots; the c and d graphs refer to 8 papers (see Table A1,  
25 appendix); (c), dicots, (d), monocots. (a-c) The dashed inner curves correspond to the 95%  
26 confidence interval for the population mean of the dependent variable (Y), while the  
27 continuous outer curves refer to the 95% prediction interval for a single value of Y.

28

29 Fig. 5. Relationships between the hydrological conditions (HCs) and AMF colonization; the  
30 HC categories have been defined as follows: 1, saturated to wet soils; 2, areas periodically  
31 flooded, but dry in summer, and wetland with low water levels; 3, area permanently under  
32 flooding, marshes, swamps and ponds; 4, permanent freshwater lakes; 5, rivers and streams.  
33 Fens and bogs were included in different classes, according to the water features. (a)  
34 Regression analyses between the HCs and the mean class of AMF colonization. (c, d)

1 Histograms showing the distribution of the six classes of colonization in relation to the  
2 different categories of HCs; (c), dicots; (d) monocots.

3  
4 Fig. 6. AMF and DSE colonization. (a) Histogram showing, per each category of HCs, the  
5 percentages of totally non-colonized ( $AMF^-DSE^-$ ), those colonized exclusively by AMF  
6 ( $AMF^+DSE^-$ ), those colonized exclusively by DSEs ( $AMF^-DSE^+$ ) and those colonized by both  
7 DSEs and by AMF ( $AMF^+DSE^+$ ) species. (b, c) Pie graphs showing the proportion of the non-  
8 colonized plants and the different types of colonization in the dicots (b) and the monocots (c).

9  
10 Fig. 7. (a-c) Relationships between the wetland indicator/life form (WI-LF) categories and  
11 AMF colonization. (a) Regression analysis showing the decrease in the mean WI-LF category  
12 with the increase in the mean AMF colonization class; (b, c) Histograms showing the  
13 percentage distribution of the different wetland categories over the six AMF root colonization  
14 classes; the rooted and free floating/submerged plants were considered together because of the  
15 low number of the free species; the same was done for the FACU and UPL categories. The  
16 OBL class (black-grey) has been subdivided according to the life forms of the species. The  
17 species for which the wetland class was not found have not been considered; (b) dicots (c)  
18 monocots. (d-f) Regression analyses showing the positive relationships of the mean WI-LF  
19 category with the percentages of monocots (d), the percentage of perennials (e) and the mean  
20 hydrological conditions (d). All the relationships, except the latter, were significant.

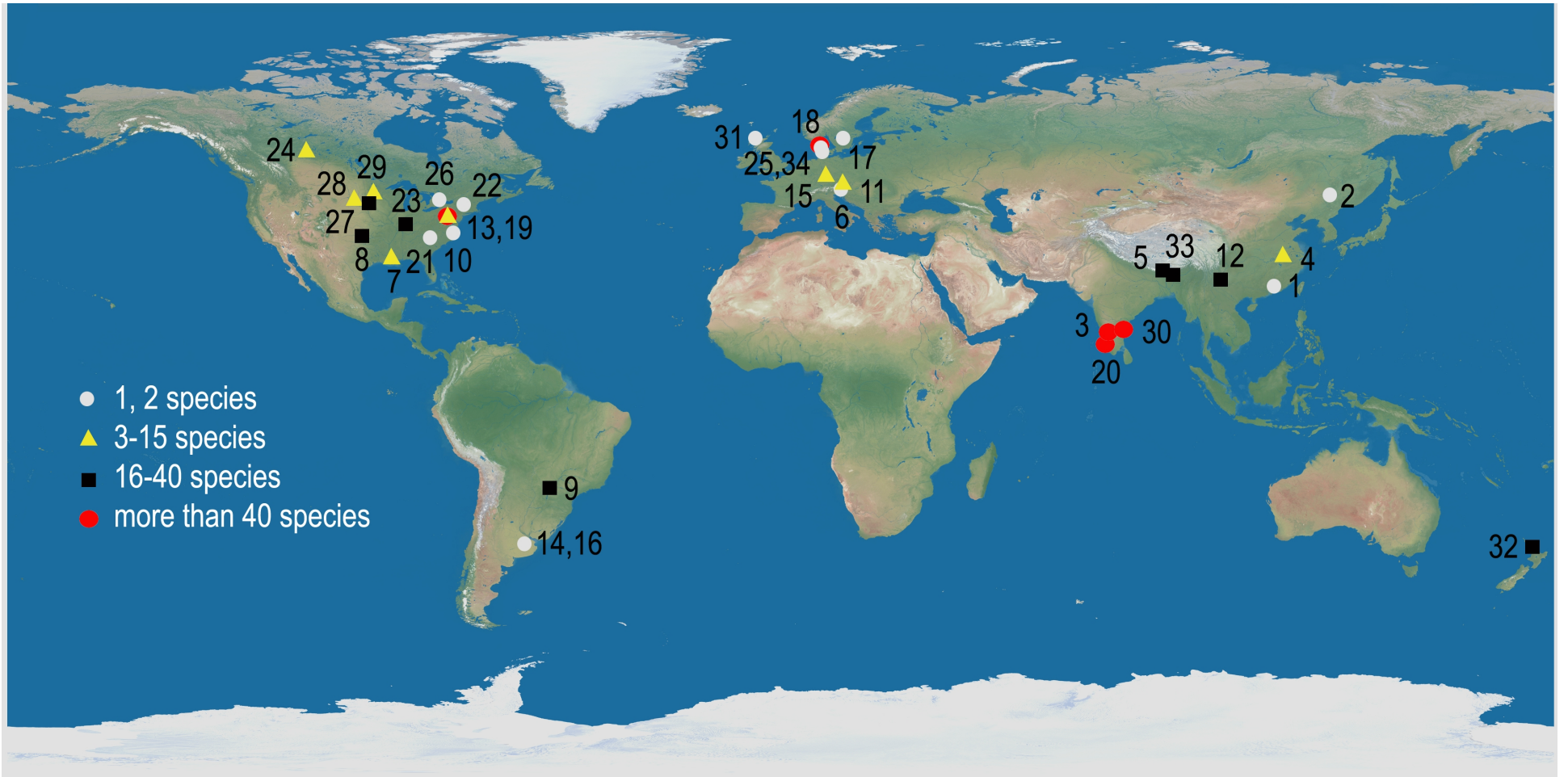
21  
22 Fig. 8. AMF colonization of the monocot and dicot families consisting of at least three species.  
23 The number of retrieved species and the assignment of the families to the AM, AM-NM or NM  
24 categories are indicated for each family. The percentages of mycorrhizal (AM), variable  
25 mycorrhizal (AM-NM) and non-mycorrhizal (NM) species are shown in the heat map (black,  
26 >75-100%; dark grey, >50-57%; light grey, >25-50%; white, 0-25%). The AM and NM  
27 species included species that were analyzed only once, twice or more times. The box plots on  
28 the right of the figure represent the distribution of the root colonization % for each plant  
29 family; the box range spans the first quartile to the third quartile; a segment inside the rectangle  
30 shows the median, while the mean corresponds to the open square; the "whiskers" above and  
31 below the box show the locations of the 10-90th percentiles, while the segments outside the  
32 box are the minimum and maximum.

33

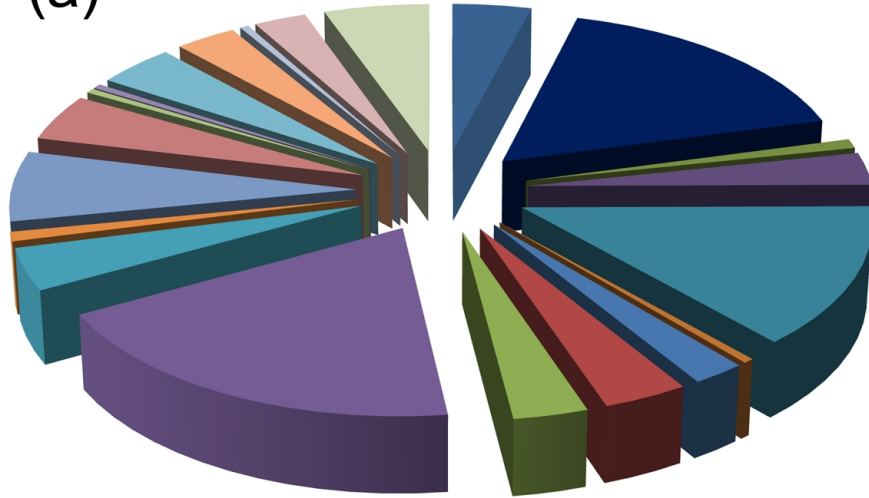
1 Fig. 9. Regression analysis on the dicotyledonous and monocotyledonous families.  
2 Relationships of the mean hydrological conditions (HC) (a and b) and of the % of obligate  
3 wetland plants (OBL) (c and d) by the mean AMF colonization class, and of the mean HCs by  
4 the OBL % (e and f); (a, c, e) dicots, in blue, and (b, d, f) monocots, in orange. Only families  
5 with at least 3 species have been considered. All regressions are statistically significant except  
6 for those shown in figure (b) and (f), which are related to the monocotyledonous families. It  
7 should be noted that the mean AMF colonization class was lower in the monocots than in the  
8 dicots, with 1.9 (Poaceae) and 3.5 (Campanulaceae) being the highest values in the two classes,  
9 respectively, as shown in (c) and (f). The dashed inner curves correspond to the confidence  
10 interval for the population mean of the dependent variable (Y), while the continuous outer  
11 curves refer to the prediction interval for a single value of Y.

12

13 Fig. 10. Principal component analysis (PCA) scatterplot run on the dicot (blue) and monocot  
14 (orange) families. The NM families and most of the families with floating and submerged  
15 species are grouped in the upper right part of the PCA scatterplot. These plants include most of  
16 the monocot families. The dicots are scattered throughout the plot, thus pointing to a large  
17 adaptation and colonization status range; WI-LF, wetland indicator-life form categories; OBL,  
18 obligate wetland plants. Only families with at least 3 species were considered. Key to families:  
19 1, Apiaceae (Apiales); 2, Asteraceae; 3, Campanulaceae; 4, Menyanthaceae; 5, Brassicaceae  
20 (Brassicales); 6, Amaranthaceae; 7, Polygonaceae; 8, Balsaminaceae (Ericales); 9, Fabaceae  
21 (Fabales); 10, Rubiaceae (Gentianales); 11, Acanthaceae; 12, Lamiaceae; 13, Linderniaceae;  
22 14, Phrymaceae; 15, Plantaginaceae; 16, Elatinaceae (Malpighiales); 17, Lythraceae; 18,  
23 Onagraceae; 19, Callitrichaceae; 20, Nymphaeaceae; 21, Ranunculaceae (Ranunculales); 22,  
24 Rosaceae (Rosales); 23, Haloragaceae (Saxifragales); 24, Convolvulaceae; 25, Solanaceae; 26,  
25 Alismataceae; 27, Araceae; 28, Hydrocharitaceae; 29, Potamogetonaceae; 30, Commelinaceae;  
26 31, Pontederiaceae; 32, Cyperaceae; 33, Juncaceae; 34, Poaceae; 35, Sparganiaceae; 36,  
27 Typhaceae.

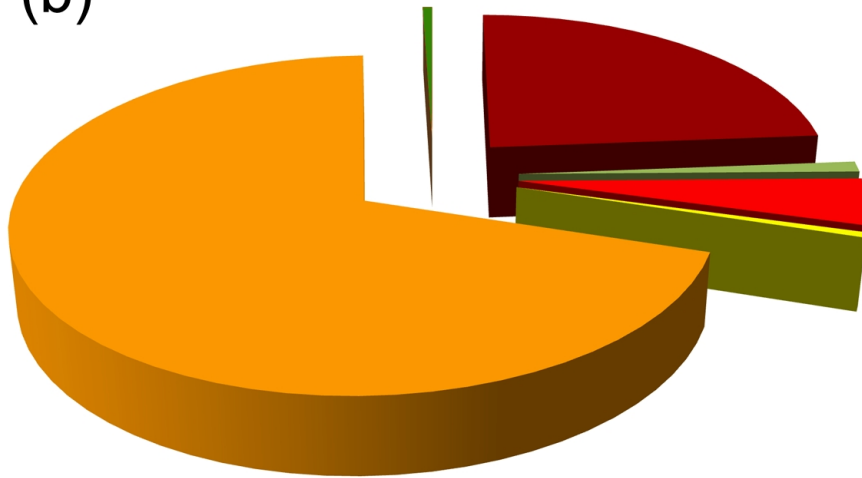


(a)



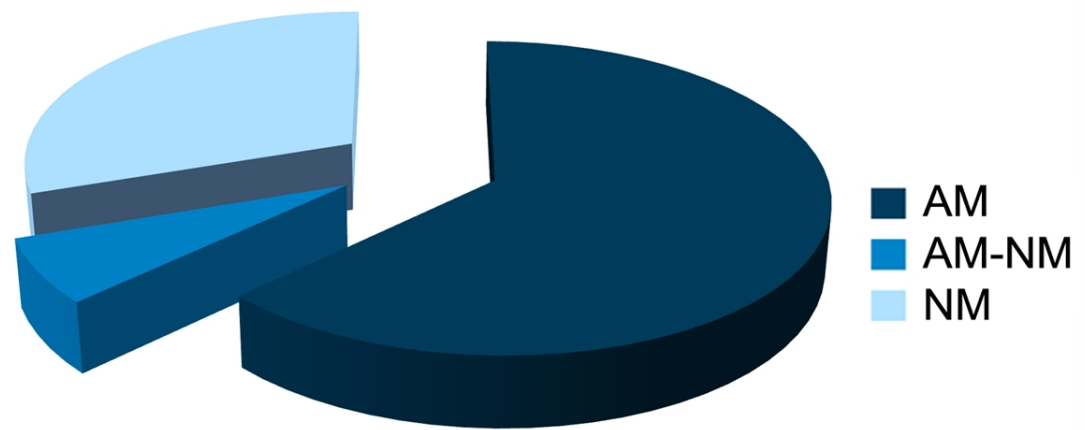
- Apiales
- Asterales
- Boraginales
- Brassicales
- Caryophyllales
- Cucurbitales
- Ericales
- Fabales
- Gentianales
- Lamiales
- Malpighiales
- Malvales
- Myrtales
- Nymphaeales
- Piperales
- Proteales
- Ranunculales
- Rosales
- Sapindales
- Saxifragales
- Solanales

(b)

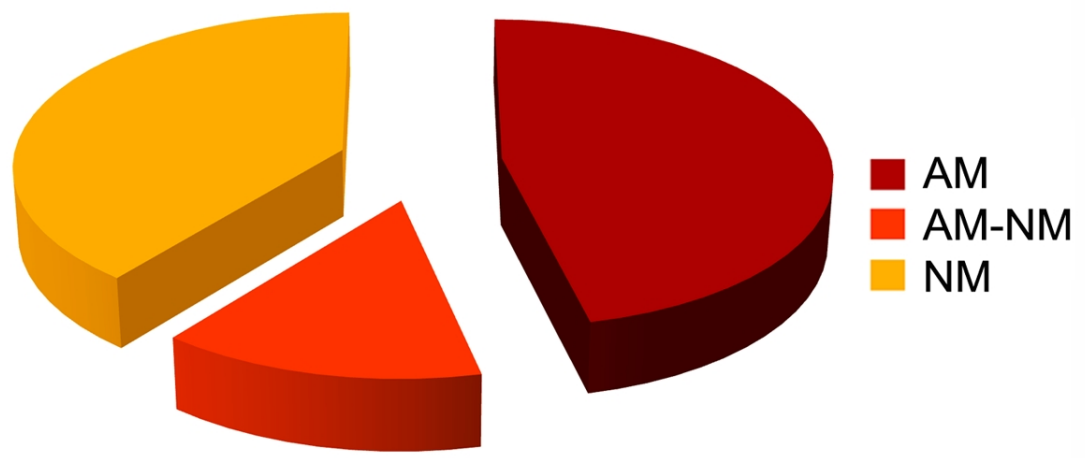


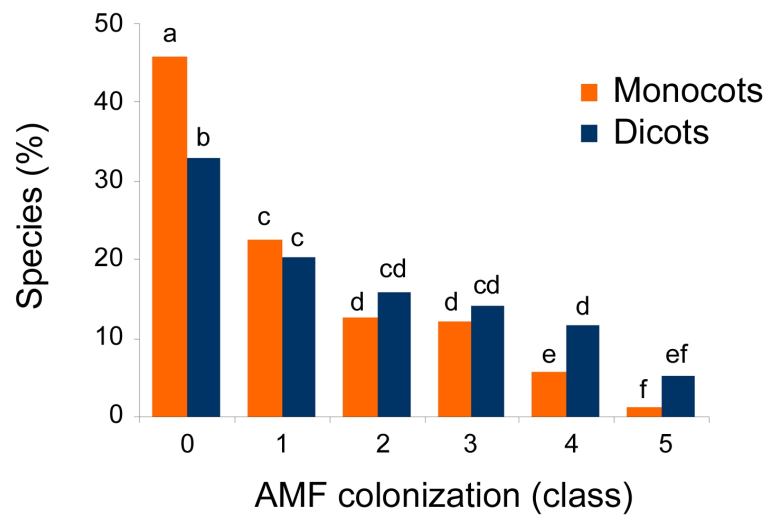
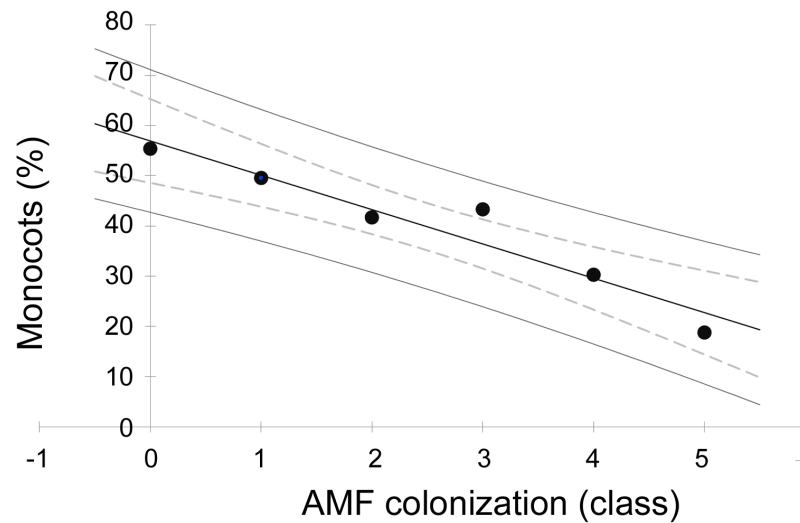
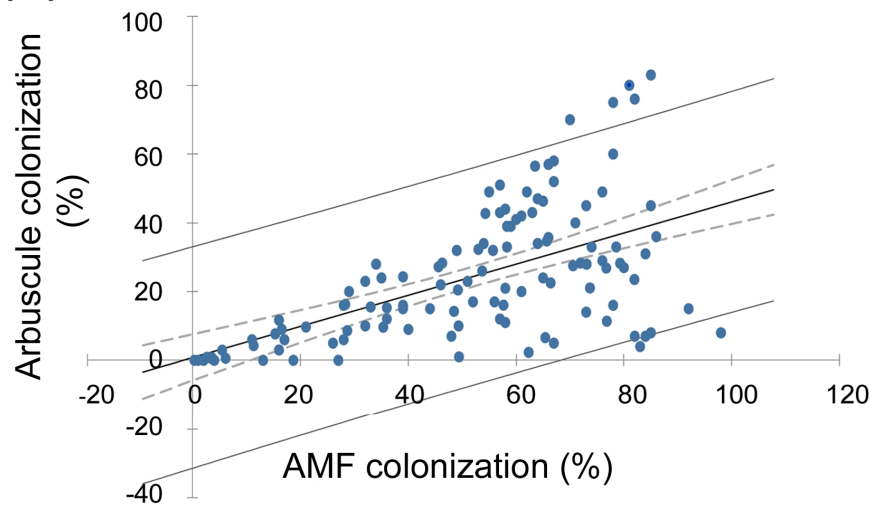
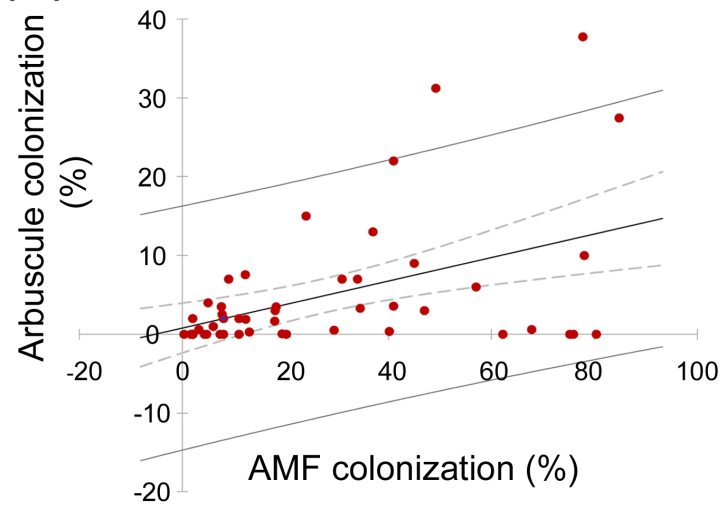
- Alismatales
- Asparagales
- Commelinales
- Liliales
- Poales
- Zingiberales

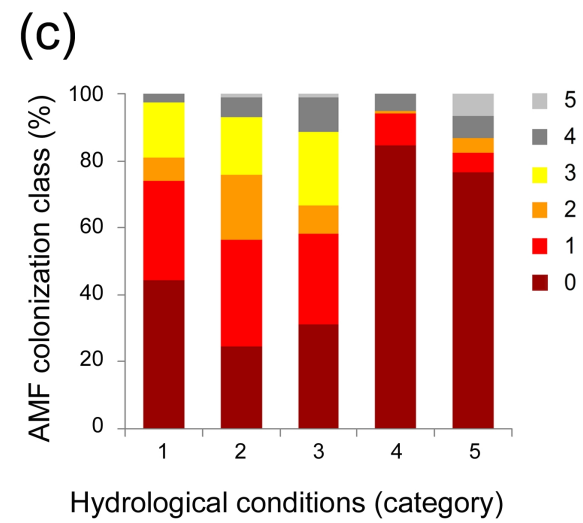
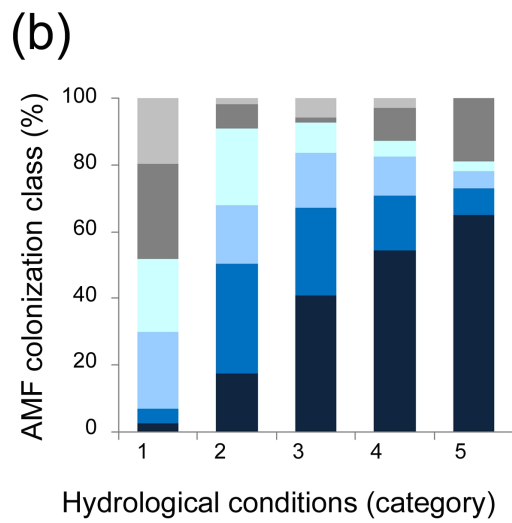
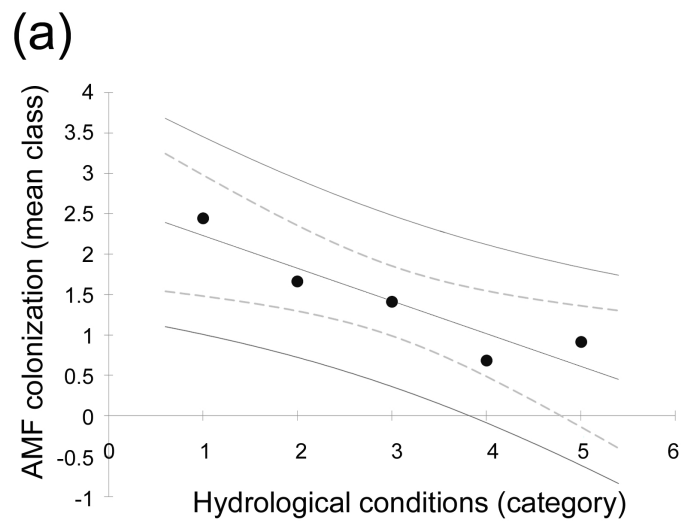
(a) Dicots



(b) Monocots

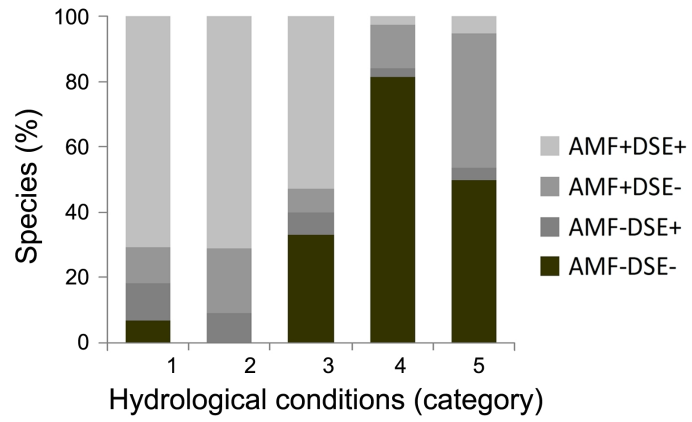


**(a)****(b)****(c)****(d)**

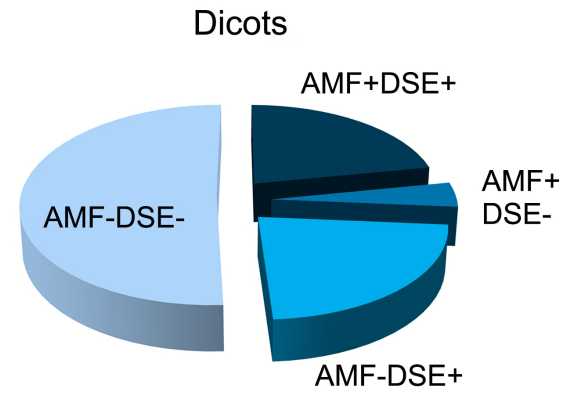




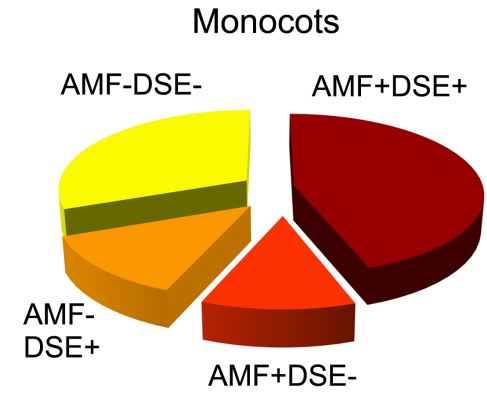
(a)

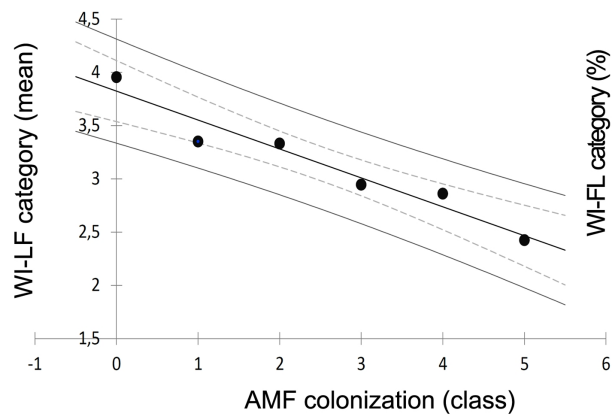
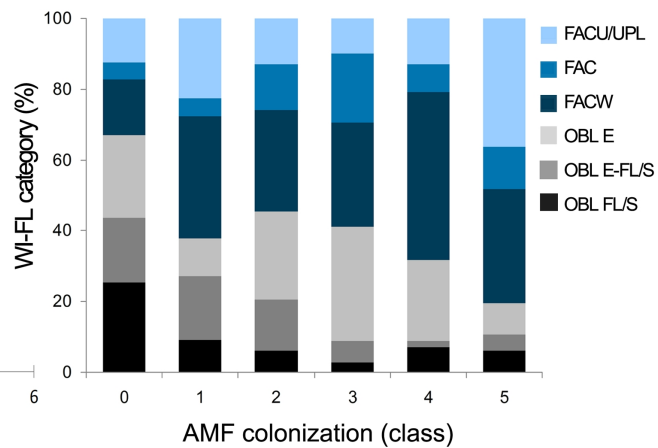
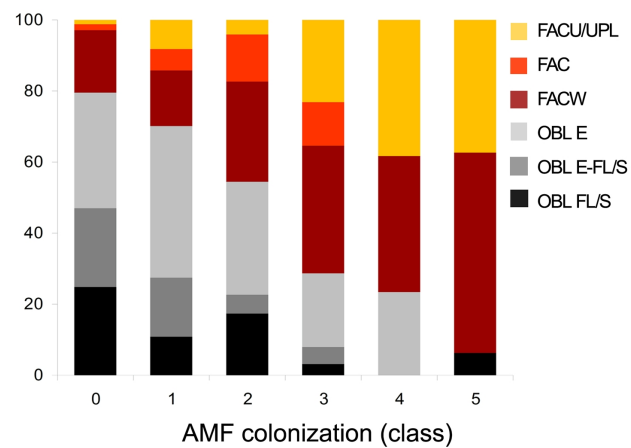
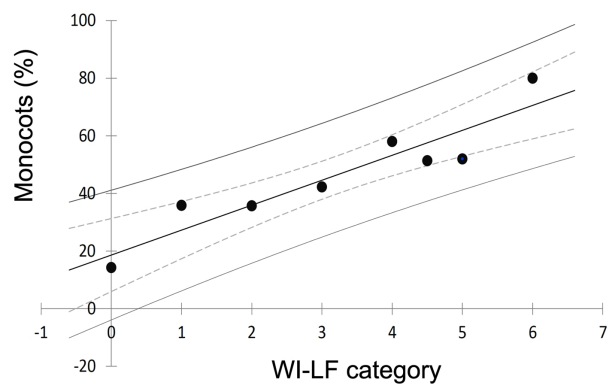
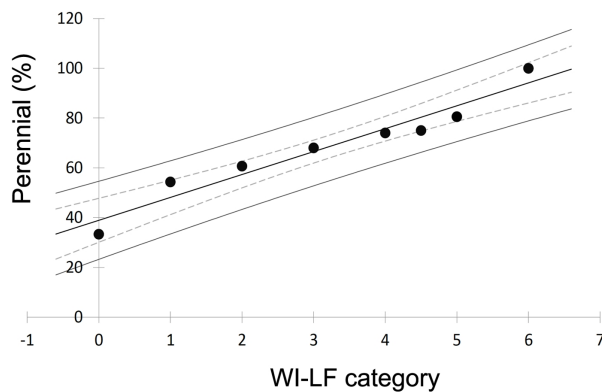
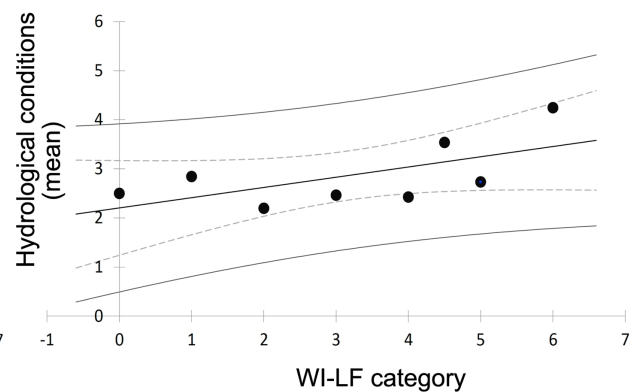


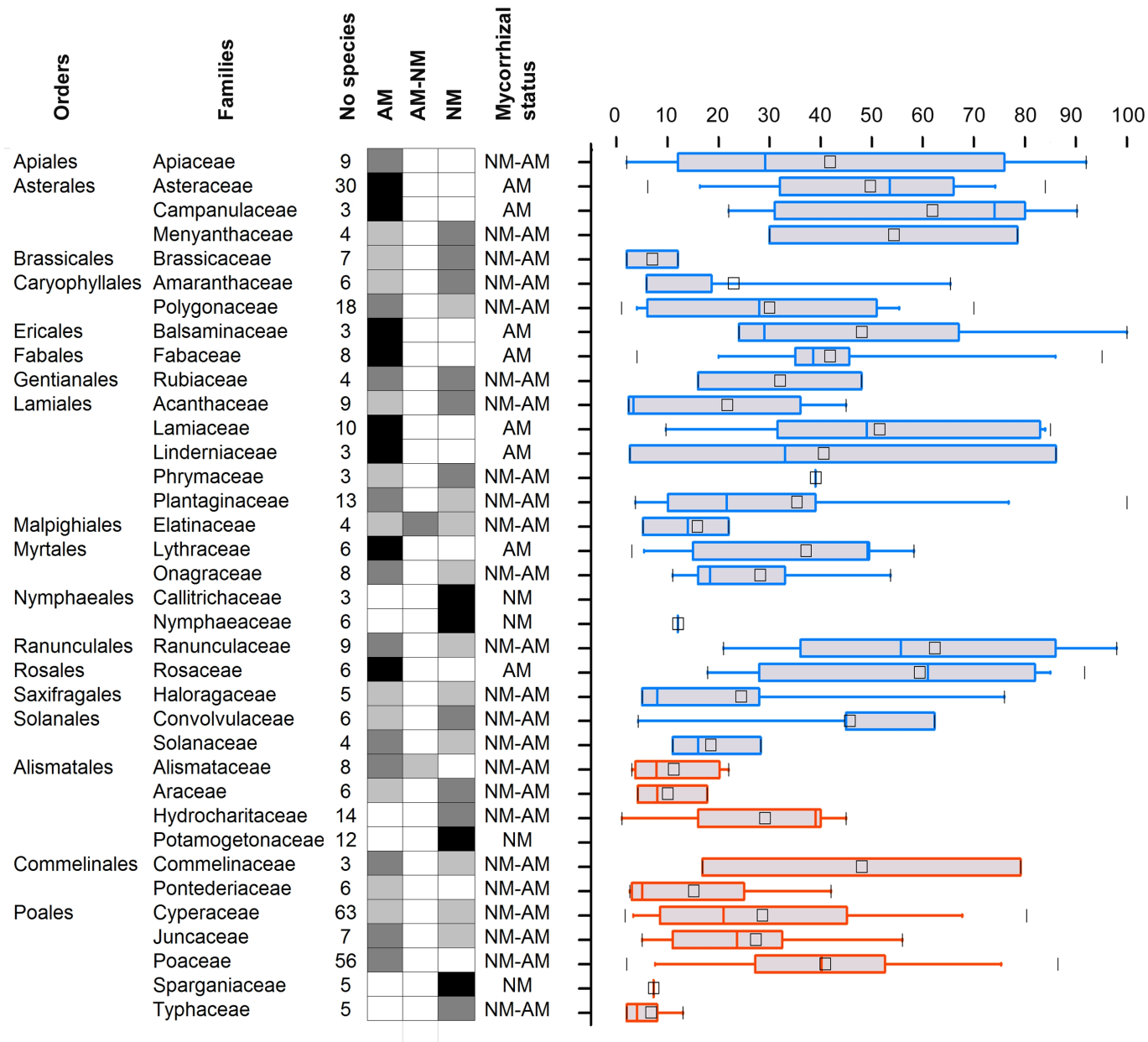
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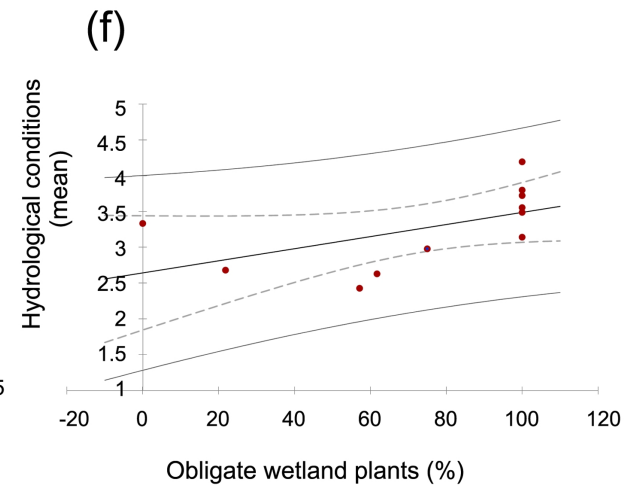
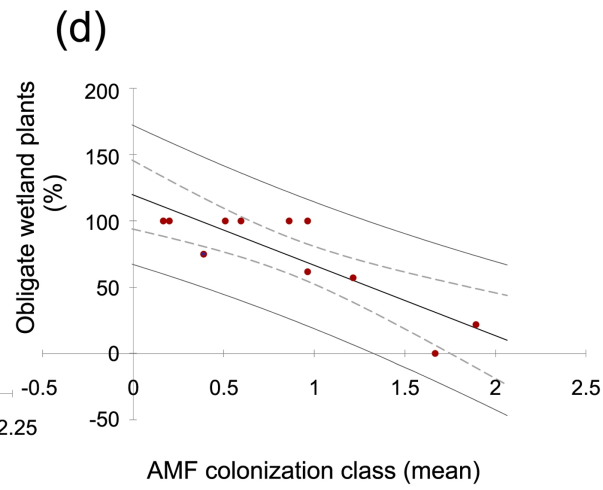
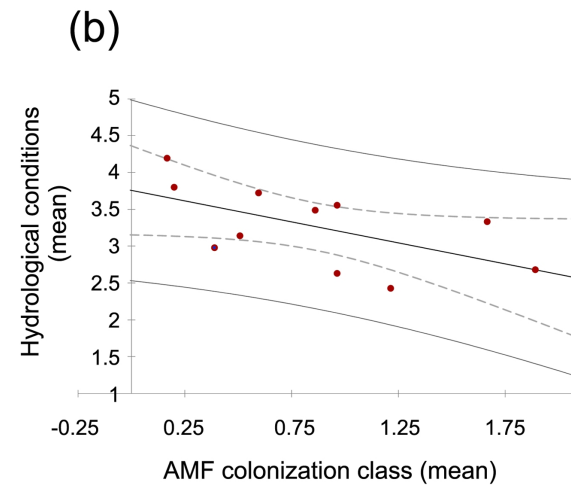
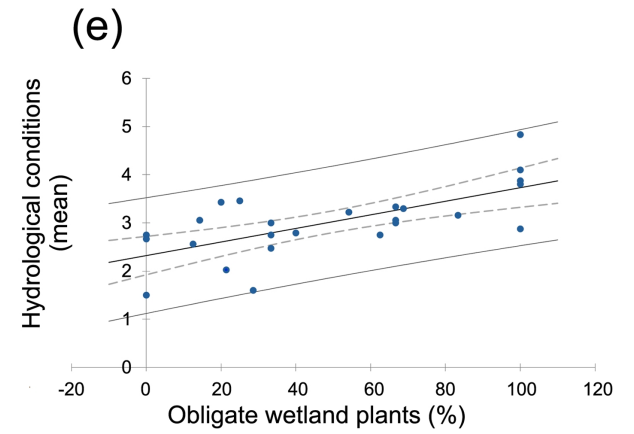
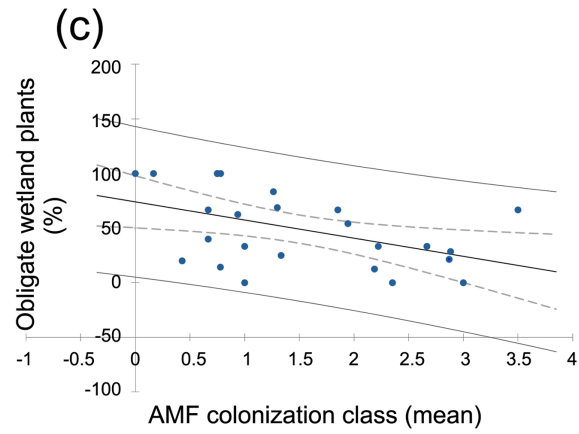
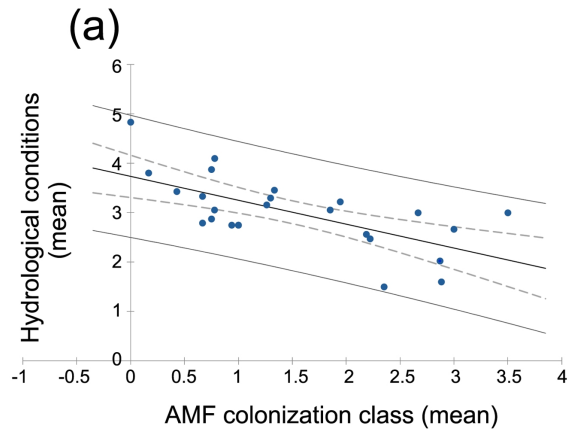


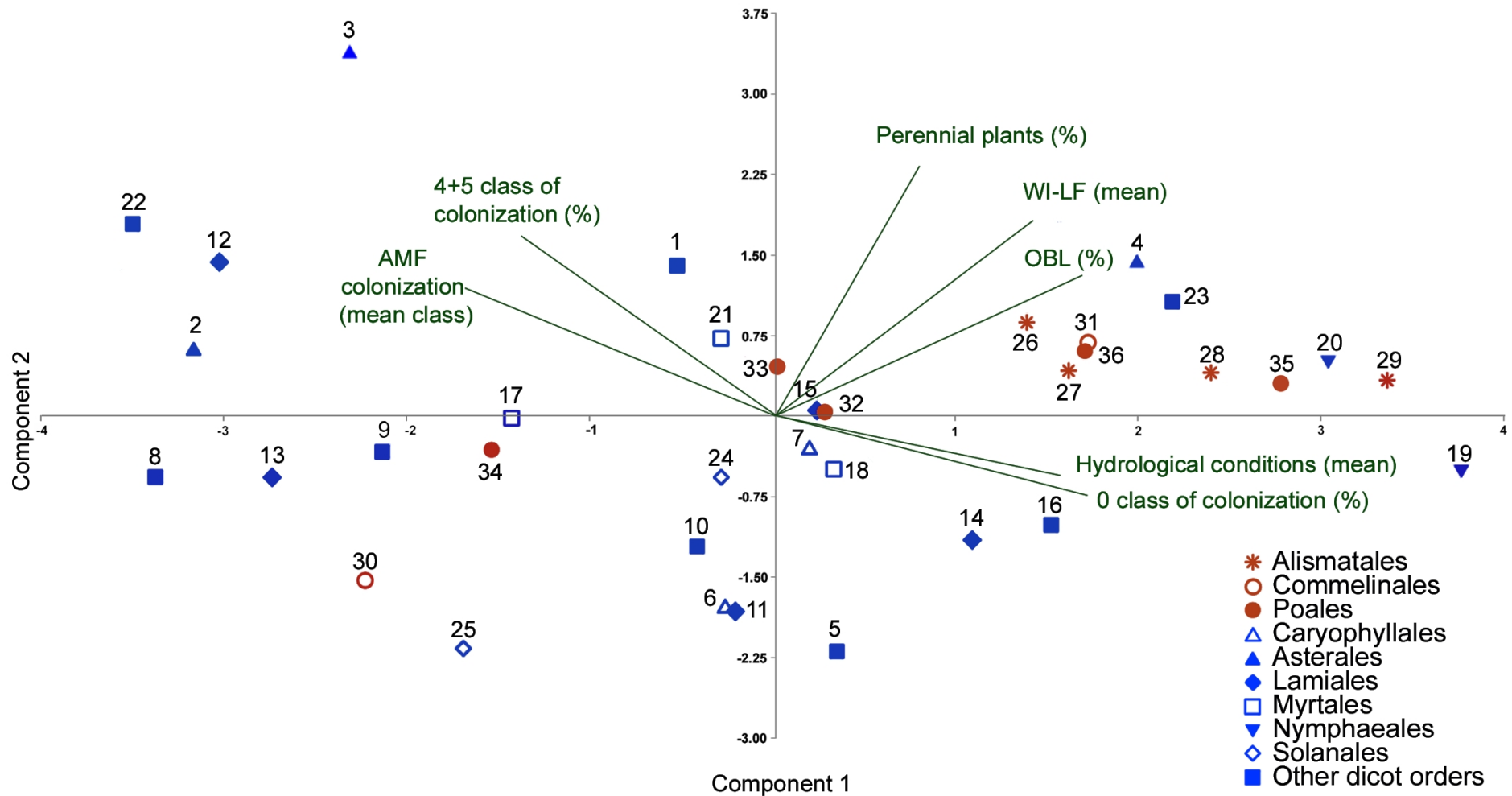
(c)



**(a)****(b)****(c)****(d)****(e)****(f)**

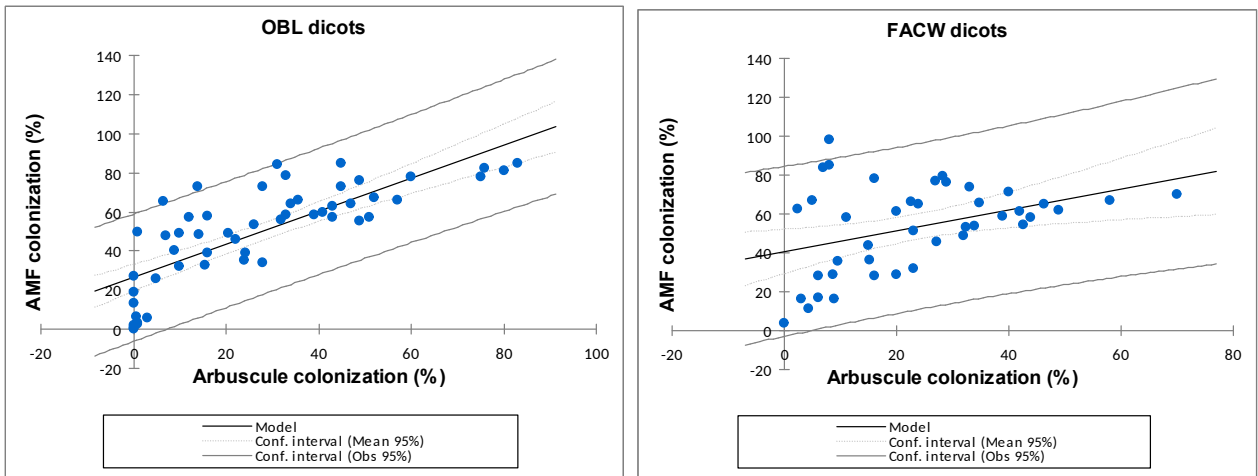




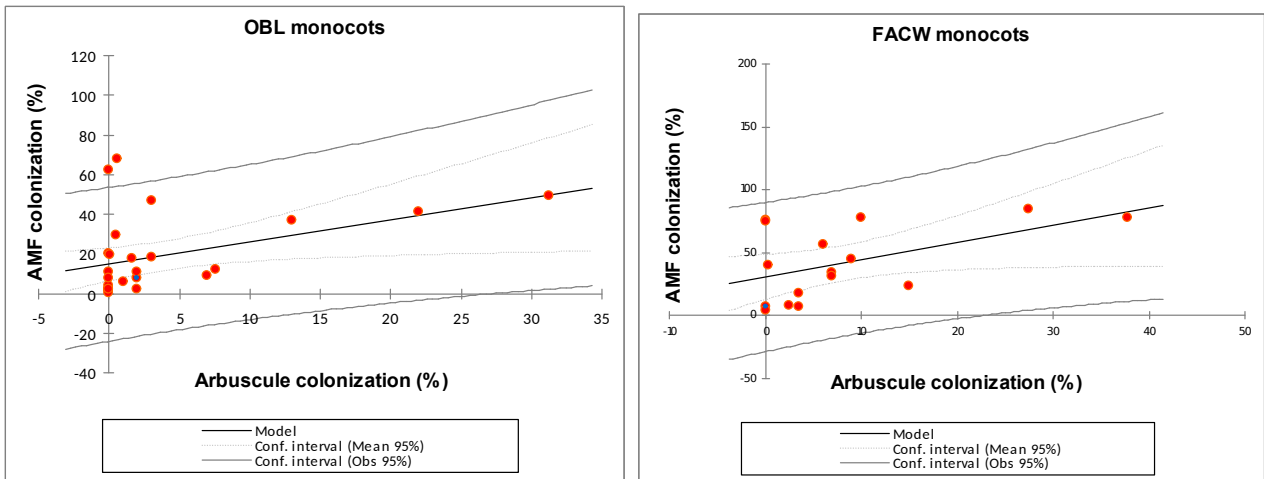


## Appendix C

**Fig. C1.** Regression analysis between AMF and arbuscule colonization in the OBL and FACW plants

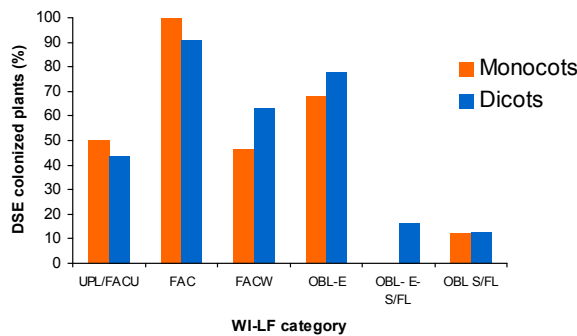


Regression between arbuscule and AMF colonization in the dicotyledonous OBL and FACW plants (adjusted  $R^2 = 0.608$ ,  $P < 0.0001$  and adjusted  $R^2 = 0.135$ ,  $P = 0.010$ , respectively).



Regression between arbuscule and AMF colonization in the monocotyledonous OBL and FACW plants (adjusted  $R^2 = 0.146$ ,  $P = 0.031$  and adjusted  $R^2 = 0.193$ ,  $P = 0.050$ , respectively).

**Fig. C2.** Percentage of species colonized by DSE in relation to the WI-LF categories



The histogram show the percentage of plants colonized by DSE in the different WI-LF categories. It is based on six papers. DSE colonization is relatively high within the facultative and obligate-emergent plants and low in the real obligate aquatic plants.

**Table 1. Correlation analysis of the families.** Relationships between the parameters related to AMF root colonization and those related to the wetland indicators and life forms (WI-LF) (OBL, obligate wetland plants; FL/S, floating and submerged plants).

	WI-LF (mean)	p	OBL (%)	p	FL/S (%)	p
Class of AMF colonization (mean)	<b>-0.364</b>	0.002	<b>-0.477</b>	0.000	<b>-0.296</b>	0.025
0 class (%)	<b>0.336</b>	0.004	<b>0.392</b>	0.001	<b>0.330</b>	0.012
4+5 class (%)	<b>-0.248</b>	0.045	<b>-0.334</b>	0.009	-0.081	0.562

Significant correlations are marked in bold.

**Table 2. Correlation analysis of the families.** Relationships between the parameters related to AMF root colonization and wetland indicators /life forms (WI-LF) with the mean hydrological conditions (HCs) and the % of perennial plants (OBL, obligate wetland plants; FL/S, floating and submerged plants).

	HCs	p	Perennial (%)	p
Class of AMF colonization (mean)	<b>-0.490</b>	0.000	-0.149	0.218
0 class (%)	<b>0.463</b>	0.000	0.192	0.114
4+5 class (%)	<b>-0.318</b>	0.010	-0.017	0.896
WI-LF (mean)	<b>0.393</b>	0.001	<b>0.345</b>	0.005
OBL (%)	<b>0.502</b>	0.000	<b>0.395</b>	0.002
FL/S (%)	<b>0.395</b>	0.003	<b>-0.437</b>	0.001

Significant correlations are marked in bold.

## Appendix A

### A1. List of the selected papers

- (01) Wang, Y., Li, Y., Bao, X., Björn, L.O., Li, S., Olsson, P.A. 2016. Response differences of arbuscular mycorrhizal fungi communities in the roots of an aquatic and a semiaquatic species to various flooding regimes. *Plant and Soil* 403: 361–373. doi: 10.1007/s11104-016-2811-7
- (02) Wang, L., Wu, J., Ma, F., Yang, J., Li, S., Li, Z., Zhang, X. 2015. Response of arbuscular mycorrhizal fungi to hydrologic gradients in the rhizosphere of *Phragmites australis* (Cav.) Trin ex. Steudel growing in the sun island wetland. *BioMed Research International* 2015: Article ID 810124, 9 pages doi: 10.1155/2015/810124
- (03) Seerangan, K., Thangavelu, M. 2014. Arbuscular mycorrhizal and dark septate endophyte fungal associations in south indian aquatic and wetland macrophytes. *Journal of Botany* 2014: Article ID 173125, 14 pages. doi: 10.1155/2014/173125.
- (04) Zhang, Q., Sun, Q., Koide, R.T., Peng, Z., Zhou, J., Gu, X., Gao, W., Yu, M. 2014. Arbuscular mycorrhizal fungal mediation of plant-plant interactions in a marshland plant community. *The Scientific World Journal* 2014, Article ID 923610, 10 pages. doi: 10.1155/2014/923610.
- (05) Choudhury, B., Kalita, M.C., Azad, P. 2010. Distribution of arbuscular mycorrhizal fungi in marshy and shoreline vegetation of Deepar Beel Ramsar Site of Assam, India. *World Journal of Microbiology & Biotechnology* 26:1965–1971. doi: 10.1007/s11274-010-0377-8
- (06) Dolinar, N., Gaberšček, A. 2010. Mycorrhizal colonization and growth of *Phragmites australis* in an intermittent wetland. *Aquatic Botany* 93: 93–98. doi:10.1016/j.aquabot.2010.03.012
- (07) Kandalepas D., Stevens K.J., Shaffer G.P., Platt W.J. 2010. How abundant are root-colonizing fungi in southeastern Louisiana's degraded marshes? *Wetlands* 30:189–199. doi: 10.1007/s13157-010-0017-y
- (08) Stevens, KJ, Wellner, MR, Acevedo, MF. 2010. Dark septate endophyte and arbuscular mycorrhizal status of vegetation colonizing a bottomland hardwood forest after a 100 year flood. *Aquatic Botany* 92: 105–111. doi:10.1016/j.aquabot.2009.10.013
- (09) de Marins, J.F., Carrenho, R., Thomaz, S.M. 2009. Occurrence and coexistence of arbuscular mycorrhizal fungi and dark septate fungi in aquatic macrophytes in a tropical river–floodplain system. *Aquatic Botany* 91: 13–19. doi:10.1016/j.aquabot.2009.01.001
- (10) Ray A.M., Inouye R.S. 2006. Effects of water-level fluctuations on the arbuscular mycorrhizal colonization of *Typha latifolia* L. *Aquatic Botany* 84: 210–216. doi:10.1016/j.aquabot.2005.10.005
- (11) Šraj-Kržič, N., Pongrac, P., Klemenc, M., Kladnik, A., Regvar, M., Gaberšček, A. 2006. Mycorrhizal colonisation in plants from intermittent aquatic habitats. *Aquatic Botany* 85: 331–336. doi:10.1016/j.aquabot.2006.07.001
- (12) Wang, K., Zhao, Z. 2006. Occurrence of arbuscular mycorrhizas and dark septate endophytes in hydrophytes from lakes and streams in southwest China. *International Review of Hydrobiology* 91: 29–37. doi: 10.1002/iroh.200510827
- (13) Weishampel, P.A., Bedford, B.L. 2006. Wetland dicots and monocots differ in colonization by arbuscular mycorrhizal fungi and dark septate endophytes. *Mycorrhiza* 16: 495–502. doi: 10.1007/s00572-006-0064-7
- (14) Escudero, V., Mendoza, R. 2005. Seasonal variation of arbuscular mycorrhizal fungi in temperate grasslands along a wide hydrologic gradient. *Mycorrhiza* 15: 291–299. doi: 10.1007/s00572-004-0332-3



- (15) Fuchs, B, Haselwandter, K. 2004. Red list plants: colonization by arbuscular mycorrhizal fungi and dark septate endophytes. *Mycorrhiza* 14: 277–281. doi: 10.1007/s00572-004-0314-5
- (16) Grigera, G., Oesterheld, M. 2004. Mycorrhizal Colonization Patterns under Contrasting Grazing and Topographic Conditions in the Flooding Pampa (Argentina). *Journal of Range Management* 57:601–605. doi: 10.2307/4004015
- (17) Nielsen, K.B., Kjølter, R., Olsson, A., Schweiger, P.F., Andersen, F.Ø., Rosendahl, S. 2004. Colonisation and molecular diversity of arbuscular mycorrhizal fungi in the aquatic plants *Littorella uniflora* and *Lobelia dortmanna* in southern Sweden. *Mycological Research* 108: 616–625. doi: 10.1017/S0953756204000073
- (18) Beck-Nielsen, D., Madsen, T.V. 2001. Occurrence of vesicular–arbuscular mycorrhiza in aquatic macrophytes from lakes and streams. *Aquatic Botany* 71: 141–148. doi: 10.1016/S0304-3770(01)00180-2
- (19) Cornwell, W.K., Bedford, B.L., Chapin, C.T. 2001. Occurrence of arbuscular mycorrhizal fungi in a phosphorus-poor wetland and mycorrhizal response to phosphorus fertilization. *American Journal of Botany* 88:1824–1829. doi: 10.2307/3558359
- (20) Harikumar, V.S. 2001. Arbuscular mycorrhizal synthesis in some wetland plants in Kerala. *Mycorrhiza News* 12: 14–15.
- (21) Miller, S.P. 2000. Arbuscular mycorrhizal colonization of semi-aquatic grasses along a wide hydrologic gradient. *New Phytologist* 145, 145–155: doi: 10.1046/j.1469-8137.2000.00566.x
- (22) Van Hoewyk, D., Wigand, C., Groffman, P.M. 2001. Endomycorrhizal colonization of *Dasiphora floribunda*, a native plant species of calcareous wetlands in eastern New York State, USA. *New Phytologist* 145: 145–155. doi: 10.1046/j.1469-8137.2000.00566.x
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**Table A1.** Information on the selected papers.

<b>Paper number</b>	<b>Locality</b>	<b>Geographic area</b>	<b>Latitude</b>	<b>Longitude</b>	<b>No of species</b>	<b>Authors</b>	<b>Arbuscule colonization</b>	<b>DSE colonization</b>	<b>pH</b>
1	Yangliao Lake, Zhuhai	China	22.33	113.56	2	Wang et al. 2016	yes		yes
2	Sun Island	China	45.72	126.56	1	Wang et al 2015	yes		yes
3	Tamilnadu	India	10.94	76.69	54	Seerangan and Thangavelu 2014	yes	yes	yes
4	Anqing city, Anhui province	China	30.47	116.99	5	Zhang et al 2014			
5	Deeper Beel, Assam	India	26.11	90.64	22	Choudhury et al. 2010			
6	Lake Cerknica, Slovenia	Europe	45.75	14.37	1	Dolinar and Gaberščik 2010			
7	Lousiana (Turtle Cove Environmental Research Station)	USA	30.30	-90.34	15	Kandalepas et al. 2010	yes	yes	
8	Gree belt Trinity River (Texas)	USA	33.45	-97.08	34	Stevens et al. 2010	yes	yes	
9	Upper Paraná (Brazil)	South America	-22.75	-53.31	18	De Marins et al. 2009			
10	Fairview Constr. Wetland, Aberdeen	USA	39.47	-76.14	1	Ray and Inohuye 2006			
11	Slovenia	Europe	45.97	14.47	8	Šraj-Kržič et al. 2006			
12	Yunnan province, SW	China	24.83	103.18	33	Wang and Zhao 2006			
13	Ithaca, New York	USA	42.00	-76.00	62	Weishampel and Bedford 2006	yes	yes	yes
14	Buenos Aires Province, Argentina (site 2)	South America	-36.25	-58.83	1	Escudero and Mendoza 2005			yes
15	County of Salzburg, Austria	Europe	47.77	13.00	4	Fuchs and Haselwandter 2004			yes
16	Las Chicas Ranch, Argentina	Sud America	-36.50	-58.50	1	Grigera and Oosterheld 2004			
17	Southern Sweden	Europe	56.57	14.10	2	Nielsen et al. 2004	yes		
18	Mid-Jutland Danish	Europe	56.32	9.28	45	Beck-Nielsen and Vindbæk Madsen 2001			
19	Belle School Fen, New York	USA	42.00	-76.00	12	Cornwell et al. 2001			yes
20	Alappuzha, Kerala	India	9.49	76.49	42	Harikumar 2001			yes
21	Carolina bays, South Carolina	USA	33.55	-81.72	2	Miller 2001			yes
22	Eastern New York	USA	42.57	-73.77	1	Van Hoewyk et al. 2001			
23	Greene County, Ohio	USA	39.68	-83.92	19	Turner et al. 2000			yes
24	Alberta	Canada	54.68	-113.37	14	Thormann et al. 1999			yes
25	Jutland, Denmark	Europe	56.02	9.45	1	Wigand et al. 1998			
26	Mercer's Glenn, Ontario	Canada	43.32	79.80	1	Stevens and Peterson 1996			
27	Iowa/North Dacota	USA	42.69	-94.29	22	Wetzel and van der Valk 1995			yes
28	Lake County, South Dakota	USA	43.95	-97.18	4	Rickerl et al. 1994	yes		
29	Lake Owasso, Minnesota	USA	45.04	-93.13	3	Stenlund and Charvat 1994			
30	Tamil Nadu	India	13.08	80.27	63	Ragupathy et al. 1990			
31	Loch na Ula- Sutherland, Scotland	Europe	58.41	-5.01	2	Farmer 1985			yes
32	Lakes	New Zealand	-38.00	176.00	15	Clayton and Bagyaraj 1984			
33	Shillong	India	25.57	91.93	30	Chaubal et al. 1982			
34	Jutland, Denmark	Europe	56.32	9.32	2	Søndergaard and Laegaard 1977			

## Appendix B

**Table B1.** List of the species considered, their mycorrhizal status and WI-LF categories.

Order	Family	Species	AMF status <sup>(1)</sup>	WI category <sup>(2)</sup>	LF category <sup>(3)</sup>	Author(s)
<b>DICOTILEDONS</b>						
<b>Apiales</b>	<b>Apiaceae</b>	<i>Berula erecta</i>	AM-NM	OBL	S-E	Beck-Nielsen and Vindbæk Madsen 2001
		<i>Centella asiatica (Hydrocotyle asiatica)</i>	AM	FAC		Kumar and Muthukumar 2014; Harikumar 2001
		<i>Hydrocotyle americana</i>	AM	OBL	E	Weishampel and Bedford 2006; Cornwell et al. 2001
		<i>Hydrocotyle sibthorpioides</i>	NM(1)	FAC		Chaubal et al. 1982
		<i>Lilaeopsis lacustris</i>	AM	OBL	S	Clayton and Bagyaraj 1984
		<i>Oenanthe decumbens</i>	NM(1)	OBL	E	Wang and Zhao 2006
		<i>Oenanthe fistulosa</i>	AM(1)	OBL	E	Šraj-Kržič et al. 2006
		<i>Sium latifolium</i>	AM(1)	OBL	FL-E	Šraj-Kržič et al. 2006
		<i>Zizia aurea</i>	AM(1)	FAC		Weishampel and Bedford 2006
<b>Asterales</b>	<b>Asteraceae</b>	<i>Acanthospermum hyspidum</i>	AM(1)	UPL		Harikumar 2001
		<i>Ageratum conyzoides</i>	AM(1)	FACU		Kumar and Muthukumar 2014
		<i>Aster praealtus</i>	AM(1)	FACW		Stevens et al. 2010
		<i>Bidens frondosa</i>	AM(1)	FACW		Stevens et al. 2010
		<i>Cirsium vulgare</i>	AM(1)	FACU		Wetzel and van der Valk 1995
		<i>Conyza canadensis</i>	AM(1)	FACU		Zhang et al. 2014
		<i>Doellingeria umbellata</i>	AM(1)	FACW		Weishampel and Bedford 2006
		<i>Eclipta alba (E. prostrata)</i>	AM	FACW		Kumar and Muthukumar 2014; Choudhury et al. 2010; Stevens et al. 2010; Harikumar 2001; Ragupathy et al. 1990.
		<i>Eupatorium coelestinum</i>	AM	FACW		Stevens et al. 2010
		<i>Eupatorium maculatum</i>	AM	FACW		Weishampel and Bedford 2006, Cornwell et al. 2001
		<i>Eupatorium perfoliatum</i>	AM	FACW		Weishampel and Bedford 2006
		<i>Eupatorium serotinum</i>	AM(1)	FAC		Turner et al. 2000

		<i>Euthamia graminifolia</i>	AM	FAC		Weishampel and Bedford 2006
		<i>Iva frutescens</i>	AM(1)	FACW		Kandalepas et al. 2010
		<i>Ixeris polycephala</i>	AM(1)	nf		Zhang et al. 2014
		<i>Packera aurea (Senecio aureus)</i>	AM	FACW		Weishampel and Bedford 2006, Cornwell et al. 2001
		<i>Petasites frigidus var. sagittatus</i>	NM(1)	FACW		Thormann et al. 1999
		<i>Pluchea odorata</i>	AM(1)	OBL	E-T	Stevens et al. 2010
		<i>Serratula tinctoria</i>	AM(1)	FAC		Fuchs and Haselwandter 2004
		<i>Solidago canadensis</i>	AM	FACU		Wetzel and van der Valk 1995
		<i>Solidago patula</i>	AM	OBL	E	Weishampel and Bedford 2006; Cornwell et al. 2001
		<i>Solidago rugosa</i>	AM(1)	FAC		Weishampel and Bedford 2006
		<i>Solidago uliginosa</i>	AM(1)	OBL	E	Weishampel and Bedford 2006
		<i>Spilanthes calva</i>	AM(1)	nf		Kumar and Muthukumar 2014
		<i>Spilanthes uliginosa</i>	AM(1)	FACW		Kumar and Muthukumar 2014
		<i>Symphyotrichum boreale</i>	AM(1)	OBL	E	Weishampel and Bedford 2006
		<i>Symphyotrichum puniceum</i>	AM	OBL	E	Weishampel and Bedford 2006
		<i>Symphyotrichum subulatum</i>	AM(1)	OBL	E	Kandalepas et al. 2010
		<i>Synedrella nodiflora</i>	AM(1)	FACU		Kumar and Muthukumar 2014
		<i>Xanthium strumarium</i>	AM(1)	FAC		Stevens et al. 2010
	<b>Campanulaceae</b>	<i>Lobelia siphilitica</i>	AM(1)	FACW		Weishampel and Bedford 2006
		<i>Lobelia dortmanna</i>	AM	OBL	S	Nielsen et al. 2004; Beck-Nielsen and Vindbæk Madsen 2001; Farmer 1985; Søndergaard and Laegaard 1977
		<i>Pratia perpusilla</i>	AM	OBL	S	Clayton and Bagyaraj 1984
	<b>Menyanthaceae</b>	<i>Menyanthes trifoliata</i>	NM(1)	OBL	E	Thormann et al. 1999
		<i>Nymphoides hydrophylla</i>	AM	OBL	FL	Kumar and Muthukumar 2014; Ragupathy et al. 1990
		<i>Nymphoides peltata</i>	NM(1)	OBL	FL	Wang and Zhao 2006
		<i>Limnanthemum indicum</i>	NM(1)	OBL	FL	Harikumar 2001
<b>Boraginales</b>	<b>Boraginaceae</b>	<i>Heliotropium indicum L.</i>	AM(1)	FACW		Stevens et al. 2010
		<i>Myosotis palustris (M. scorpioides)</i>	AM-NM	FACW		Sraj-Krzic et al. 2006; Beck-Nielsen and Vindbæk Madsen 2001
<b>Brassicales</b>	<b>Brassicaceae</b>	<i>Brassica juncea</i>	AM(1)	UPL		Chaubal et al. 1982
		<i>Cardamine hirsuta</i>	NM(1)	FACU		Chaubal et al. 1982
		<i>Cardamine macrophylla</i>	NM(1)	nf		Chaubal et al. 1982
		<i>Cardamine multijuga</i>	AM(1)	nf		Wang and Zhao 2006
		<i>Nasturtium indicum</i>	NM(1)	FACW		Chaubal et al. 1982

		<i>Rorippa amphibia</i>	NM(1)	FACW		Beck-Nielsen and Vindbæk Madsen 2001
		<i>Rorippa sessiliflora</i>	NM(1)	OBL	E	Stevens et al. 2010
<b>Caryophyllales</b>	<b>Amaranthaceae</b>	<i>Alternanthera philoxeroides</i>	AM-NM	OBL	E	Kandalepas et al. 2010; Chaubal et al. 1982
		<i>Alternanthera sessilis</i>	NM	FACW		Kumar and Muthukumar 2014
		<i>Alternanthera triandra</i>	AM(1)	FAC		Harikumar 2001
		<i>Amaranthus australis</i>	AM(1)	OBL	E	Kandalepas et al. 2010
		<i>Celosia argentea</i>	NM(1)	FACU		Harikumar 2001
		<i>Digera muricata</i>	NM(1)	nf		Harikumar 2001
	<b>Caryophyllaceae</b>	<i>Drymaria cordata</i>	AM(1)	FAC		Chaubal et al. 1982
	<b>Ceratophyllaceae</b>	<i>Ceratophyllum demersum</i>	NM	OBL	S	Wang and Zhao 2006; Ragupathy et al. 1990
	<b>Droseraceae</b>	<i>Drosera intermedia</i>	AM(1)	OBL	E	Fuchs and Haselwandter 2004
		<i>Drosera rotundifolia</i>	AM-NM	OBL	E	Weishampel and Bedford 2006; Thormann et al. 1999
	<b>Phytolaccaceae</b>	<i>Rivina humilis</i>	NM(1)	FACU		Stevens et al. 2010
	<b>Polygonaceae</b>	<i>Polygonum acuminatum</i>	AM(1)	OBL	E	De Marins et al. 2009
		<i>Polygonum amphibium</i>	AM-NM	OBL	FL-E	Beck-Nielsen and Vindbæk Madsen 2001; Wetzel and van der Valk 1995; Rickerl et al. 1994
		<i>Polygonum capitatum</i>	AM(1)	FACU		Chaubal et al. 1982
		<i>Polygonum chinense</i>	NM(1)	nf		Kumar and Muthukumar 2014
		<i>Polygonum ferrugineum</i>	AM(1)	OBL	E	De Marins et al. 2009
		<i>Polygonum glabrum</i>	NM	OBL	E	Ragupathy et al. 1990; Kumar and Muthukumar 2014
		<i>Polygonum hydropiper</i>	AM-NM	OBL	E	Wang et al. 2016; Kumar and Muthukumar 2014; Wang and Zhao 2006; Chaubal et al. 1982
		<i>Polygonum hydropiperoides</i>	NM(1)	OBL	E	Stevens et al. 2010
		<i>Polygonum lapathifolium var. salicifolium</i>	AM(1)	FACW		Wang and Zhao 2006
		<i>Polygonum persicaria</i>	AM(1)	FACW		Wetzel and van der Valk 1995
		<i>Polygonum pubescens</i>	AM(1)	OBL	E	Zhang et al. 2014
		<i>Polygonum pulchrum</i>	NM(1)	OBL	E	Ragupathy et al. 1990
		<i>Polygonum punctatum</i>	AM-NM	OBL	E	Kandalepas et al. 2010; De Marins et al. 2009
		<i>Polygonum stelligerum</i>	AM(1)	nf		De Marins et al. 2009
		<i>Polygonum tomentosum</i>	AM(1)	FACW		Harikumar 2001
		<i>Rumex crispus</i>	AM(1)	FACW		Stevens et al. 2010
		<i>Rumex hydrolapathum</i>	NM(1)	OBL	E	Beck-Nielsen and Vindbæk Madsen 2001
		<i>Rumex nepalensis</i>	AM(1)	nf		Chaubal et al. 1982

<b>Cucurbitales</b>	<b>Cucurbitaceae</b>	<i>Melothria pendula</i>	AM(1)	FAC		Stevens et al. 2010
<b>Ericales</b>	<b>Balsaminaceae</b>	<i>Impatiens aquatilis</i>	AM(1)	nf		Wang and Zhao 2006
		<i>Impatiens capensis</i>	AM	FACW		Weishampel and Bedford 2006
		<i>Impatiens chinensis</i>	AM	nf		Chaubal et al. 1982; Harikumar 2001
	<b>Primulaceae</b>	<i>Lysimachia ciliata</i>	AM(1)	FACW		Weishampel and Bedford 2006
		<i>Lysimachia thyrsoiflora</i>	NM(1)	OBL	E	Beck-Nielsen and Vindbæk Madsen 2001
<b>Fabales</b>	<b>Fabaceae</b>	<i>Aeschynomene aspera</i>	AM	FACW		Ragupathy et al. 1990; Harikumar 2001
		<i>Aeschynomene indica</i>	AM(1)	FACW		Ragupathy et al. 1990
		<i>Crotalaria quinquefolia</i>	AM(1)	FAC		Ragupathy et al. 1990
		<i>Kummerowia striata</i>	AM(1)	FACU		Zhang et al. 2014
		<i>Lotus glaber</i>	AM	FACU		Escudero and Mendoza 2005
		<i>Neptunia oleracea</i>	NM(1)	OBL	FF	Ragupathy et al. 1990
		<i>Sesbania herbacea</i>	AM(1)	FACW		Kandalepas et al. 2010
		<i>Vigna luteola</i>	AM(1)	FACW		Kandalepas et al. 2010
<b>Gentianales</b>	<b>Asclepiadaceae</b>	<i>Asclepias curassavica</i>	NM(1)	FACU		Kumar and Muthukumar 2014
		<i>Asclepias incarnata</i>	AM(1)	OBL	E-T	Weishampel and Bedford 2006
	<b>Loganiaceae</b>	<i>Mitreola petiolata</i>	AM(1)	FACW		Stevens et al. 2010
	<b>Rubiaceae</b>	<i>Galium labrodoricum</i>	AM(1)	OBL	nf	Weishampel and Bedford 2006
		<i>Galium rotundifolium</i>	AM(1)	FACU		Chaubal et al. 1982
		<i>Hedyotis auricularia</i>	NM(1)	nf		Kumar and Muthukumar 2014
		<i>Oldenlandia corymbosa</i>	NM(1)	FACU		Harikumar 2001
<b>Lamiales</b>	<b>Acanthaceae</b>	<i>Barleria cristata</i>	NM(1)	UPL		Kumar and Muthukumar 2014
		<i>Dicliptera brachiata</i>	AM(1)	FACW		Stevens et al. 2010
		<i>Hygrophila auriculata (Asteracantha longifolia)</i>	NM	FACW		Kumar and Muthukumar 2014; Harikumar 2001; Ragupathy et al. 1990
		<i>Hygrophila spinosa</i>	AM(1)	FACW		Harikumar 2001
		<i>Hygrophila balsamica</i>	NM(1)	FACW		Ragupathy et al. 1990
		<i>Hygrophila polysperma</i>	AM(1)	OBL	S-E-T	Harikumar 2001
		<i>Hygrophila cf. costata</i>	AM(1)	FACW		De Marins et al. 2009
		<i>Justicia betonica</i>	NM(1)	nf		Kumar and Muthukumar 2014
		<i>Justicia simplex</i>	NM(1)	nf		Harikumar 2001

<b>Lamiaceae</b>	<i>Betonica officinalis</i>	AM(1)	nf		Fuchs and Haselwandter 2004
	<i>Leonurus artemisia</i>	AM(1)	nf		Zhang et al. 2014
	<i>Lycopus americanus</i>	AM	OBL	E	Weishampel and Bedford 2006
	<i>Lycopus uniflorus</i>	AM	OBL	E	Weishampel and Bedford 2006; Cornwell et al. 2001
	<i>Mentha ×piperita</i>	AM(1)	FACW		Weishampel and Bedford 2006
	<i>Mentha aquatica</i>	AM(1)	FACW		Šraj-Kržič et al. 2006
	<i>Prunella vulgaris</i>	AM(1)	FACU		Weishampel and Bedford 2006
	<i>Pycnanthemum tenuifolium</i>	AM(1)	FACW		Turner et al. 2000
	<i>Teucrium canadense</i>	AM(1)	FACW		Stevens et al. 2010
	<i>Teucrium scordium</i>	NM(1)	nf		Šraj-Kržič et al. 2006
	<b>Linderniaceae</b>	<i>Lindernia crustacea</i>	AM(1)	FACU	
<i>Lindernia dubia</i>		AM(1)	OBL	E	Stevens et al. 2010
<i>Lindernia parviflora</i>		AM(1)	FACW?		Kumar and Muthukumar 2014
<b>Martyniaceae</b>	<i>Proboscidea louisianica</i>	AM(1)	FAC		Stevens et al. 2010
<b>Orobanchaceae</b>	<i>Centranthera hispida</i>	NM(1)	FAC		Ragupathy et al. 1990
	<i>Striga asiatica</i>	NM(1)	nf		Ragupathy et al. 1990
<b>Phrymaceae</b>	<i>Mimulus alatus</i>	AM(1)	OBL	S-E	Stevens et al. 2010
	<i>Mimulus guttatus</i>	NM(1)	OBL	E	Beck-Nielsen and Vindbæk Madsen 2001
	<i>Peplidium maritimum</i>	NM(1)	FACW		Ragupathy et al. 1990
<b>Plantaginaceae</b>	<i>Bacopa monnieri</i>	AM-NM	OBL	S-E	Kumar and Muthukumar 2014; Ragupathy et al. 1990
	<i>Chelone glabra</i>	AM	OBL	E	Weishampel and Bedford 2006
	<i>Dopatrium junceum</i>	NM(1)	OBL	E	Harikumar 2001
	<i>Dopatrium nudicaule</i>	NM(1)	OBL	S-E	Ragupathy et al. 1990
	<i>Gratiola officinalis</i>	AM(1)	nf		Šraj-Kržič et al. 2006
	<i>Limnophila gratissima</i>	AM(1)	OBL	E	Harikumar 2001
	<i>Limnophila heterophylla</i>	AM(1)	OBL	S-E	Harikumar 2001
	<i>Limnophila indica</i>	NM(1)	OBL	S-E	Ragupathy et al. 1990
	<i>Littorella uniflora</i>	AM	OBL	S-E	Nielsen et al. 2004; Beck-Nielsen and Vindbæk Madsen 2001; Wigand et al. 1998; Farmer 1985; Søndergaard and Laegaard 1977
	<i>Plantago major</i>	AM(1)	FACU		Chaubal et al. 1982
	<i>Scoparia dulcis</i>	AM(1)	FACU		Kumar and Muthukumar 2014
	<i>Veronica anagallis-aquatica</i>	AM-NM	OBL	S-E	Beck-Nielsen and Vindbæk Madsen 2001
	<i>Veronica beccabunga</i>	NM(1)	OBL	E	Beck-Nielsen and Vindbæk Madsen 2001
<b>Verbenaceae</b>	<i>Lippia nodiflora (Phyla nodiflora)</i>	AM	FACW		Kumar and Muthukumar 2014; Stevens et al. 2010; Ragupathy et al. 1990



<b>Malpighiales</b>	<b>Clusiaceae</b>	<i>Triadenum virginicum</i>	AM(1)	OBL	E	Weishampel and Bedford 2006
	<b>Elatinaceae</b>	<i>Elatine ambigua</i>	NM(1)	OBL	S-E	Wang and Zhao 2006
		<i>Elatine hexandra</i>	AM(1)	OBL	S-E	Beck-Nielsen and Vindbæk Madsen 2001
		<i>Bergia capensis</i>	AM-NM	OBL	E	Harikumar 2001; Ragupathy et al. 1990
		<i>Elatine gratioloides</i>	AM-NM	OBL	S-E	Clayton and Bagyaraj 1984
		<i>Acalypha ostryifolia</i>	AM(1)	nf		Stevens et al. 2010
	<b>Euphorbiaceae</b>	<i>Chamaesyce serpens</i>	AM(1)	UPL		Stevens et al. 2010
		<b>Violaceae</b>	<i>Viola pubescens</i>	AM(1)	FACU	
	<i>Viola cucullata</i>		AM	FACW		Weishampel and Bedford 2006
	<b>Malvales</b>	<b>Tiliaceae</b>	<i>Corchorus aestuans</i>	AM	FACU	
<b>Malvaceae</b>		<i>Hibiscus laevis</i>	AM	OBL	E	Stevens et al. 2010
<b>Myrtales</b>	<b>Lythraceae</b>	<i>Ammannia auriculata</i>	AM(1)	OBL	E	Stevens et al. 2010
		<i>Ammannia baccifera</i>	AM(1)	FACW		Ragupathy et al. 1990
		<i>Ammannia robusta</i>	AM(1)	OBL	E	Stevens et al. 2010
		<i>Lythrum alatum</i>	AM(1)	FACW		Turner et al. 2000
		<i>Lytrum salicaria</i>	AM	OBL	S-E	Stevens and Peterson 1996
	<b>Onagraceae</b>	<i>Rotala rotundifolia</i>	AM-NM	OBL	S-E	Wang and Zhao 2006; Chaubal et al. 1982
		<i>Epilobium coloratum</i>	AM(1)	FACW		Weishampel and Bedford 2006
		<i>Epilobium hirsutum</i>	AM-NM	FACW		Beck-Nielsen and Vindbæk Madsen 2001
		<i>Jussiaea repens</i>	NM(1)	OBL	FL-E	Harikumar 2001
		<i>Ludwigia adscendens</i>	AM(1)	OBL	FL-E	Ragupathy et al. 1990
		<i>Ludwigia decurrens</i>	AM(1)	OBL	E	Stevens et al. 2010
		<i>Ludwigia hyssopifolia</i>	NM(1)	FACW		Ragupathy et al. 1990
		<i>Ludwigia perennis</i>	NM	OBL	S-E	Kumar and Muthukumar 2014; Ragupathy et al. 1990
		<i>Ludwigia parviflora</i>	AM(1)	OBL	S-E	Harikumar 2001
	<b>Trapaceae</b>	<i>Trapa quadrispinosa</i>	NM(1)	OBL	FL	Wang and Zhao 2006
	<b>Nymphaeales</b>	<b>Cabombaceae</b>	<i>Cabomba furcata</i>	NM(1)	OBL	S
<b>Callitrichaceae</b>		<i>Callitriche cophocarpa</i>	NM(1)	OBL	S-FL	Beck-Nielsen and Vindbæk Madsen 2001
		<i>Callitriche hamulata</i>	NM	OBL	S-FL	Beck-Nielsen and Vindbæk Madsen 2001
		<i>Callitriche stagnalis</i>	NM(1)	OBL	S-F-E	Beck-Nielsen and Vindbæk Madsen 2001

	<b>Nymphaeaceae</b>	<i>Nuphar lutea</i>	NM(1)	OBL	FL	Beck-Nielsen and Vindbæk Madsen 2001
		<i>Nymphaea alba</i>	AM(1)	OBL	FL	Chaubal et al. 1982
		<i>Nymphaea amazonum</i>	NM(1)	OBL	FL	De Marins et al. 2009
		<i>Nymphaea nouchali (N. stellata)</i>	NM	OBL	FL	Harikumar 2001; Ragupathy et al. 1990
		<i>Nymphaea pubescens</i>	NM(1)	OBL	FL	Kumar and Muthukumar 2014
		<i>Nymphaea tetragona</i>	NM(1)	OBL	FL	Wang and Zhao 2006
<b>Piperales</b>	<b>Piperaceae</b>	<i>Peperomia pellucida</i>	NM(1)	FACU		Kumar and Muthukumar 2014
<b>Proteales</b>	<b>Nelumbonaceae</b>	<i>Nelumbo nucifera</i>	NM	OBL	FL-E	Kumar and Muthukumar 2014; Wang and Zhao 2006; Ragupathy et al. 1990
<b>Ranunculales</b>	<b>Ranunculaceae</b>	<i>Anemone rivularis</i>	NM(1)	nf		Chaubal et al. 1982
		<i>Batrachium circinatum</i>	NM(1)	OBL	S-E	Beck-Nielsen and Vindbæk Madsen 2001
		<i>Batrachium peltatum</i>	NM(1)	OBL	FL	Beck-Nielsen and Vindbæk Madsen 2001
		<i>Caltha palustris</i>	NM(1)	OBL	E	Beck-Nielsen and Vindbæk Madsen 2001
		<i>Clematis virginiana</i>	AM	FAC		Weishampel and Bedford 2006; Cornwell et al. 2001
		<i>Ranunculus flammula</i>	AM(1)	FACW		Beck-Nielsen and Vindbæk Madsen 2001
		<i>Ranunculus rivularis</i>	AM	OBL?	E	Clayton and Bagyaraj 1984
		<i>Ranunculus sceleratus</i>	AM(1)	OBL	E	Stevens et al. 2010
		<i>Thalictrum pubescens</i>	AM(1)	FACW		Weishampel and Bedford 2006
<b>Rosales</b>	<b>Rosaceae</b>	<i>Dasiphora floribunda (D.fruticosa)</i>	AM	FACW		Weishampel and Bedford 2006; Van Hoewyk et al. 2001
		<i>Fragaria virginiana</i>	AM(1)	FACU		Weishampel and Bedford 2006
		<i>Geum rivale</i>	AM(1)	FACW		Weishampel and Bedford 2006
		<i>Potentilla anserina</i>	AM(1)	FACW		Wetzel and van der Valk 1995
		<i>Rubus chamaemorus</i>	NM(1)	FACW		Thormann et al. 1999
		<i>Rubus pubescens</i>	AM	FACW		Weishampel and Bedford 2006
	<b>Urticaceae</b>	<i>Pilea pumila</i>	AM(1)	FACW		Weishampel and Bedford 2006
<b>Sapindales</b>	<b>Sapindaceae</b>	<i>Cardiospermum halicacabum</i>	AM(1)	FAC		Stevens et al. 2010
<b>Saxifragales</b>	<b>Grossulariaceae</b>	<i>Ribes hirtellum</i>	AM(1)	FAC		Weishampel and Bedford 2006
	<b>Haloragaceae</b>	<i>Myriophyllum alterniflorum</i>	NM(1)	OBL	S	Beck-Nielsen and Vindbæk Madsen 2001
		<i>Myriophyllum brasiliense</i>	AM(1)	OBL	S	De Marins et al. 2009

		<i>Myriophyllum propinquum</i>	AM	OBL	S	Clayton and Bagyaraj 1984
		<i>Myriophyllum spicatum</i>	NM	OBL	S	Wang and Zhao 2006; Beck-Nielsen and Vindbæk Madsen 2001
		<i>Myriophyllum triphyllum</i>	AM-NM	OBL	S	Clayton and Bagyaraj 1984
<b>Solanales</b>	<b>Convolvulaceae</b>	<i>Ipomoea aquatica (I. reptans)</i>	AM-NM	OBL	E	Kumar and Muthukumar 2014; Harikumar 2001; Ragupathy et al. 1990
		<i>Ipomoea cairica</i>	NM(1)	FACU		Kumar and Muthukumar 2014
		<i>Ipomoea carnea</i>	AM(1)	FACU		Ragupathy et al. 1990
		<i>Ipomoea eriocarpa</i>	NM(1)	nf		Kumar and Muthukumar 2014
		<i>Ipomoea sagittata</i>	AM(1)	FACW		Kandalepas et al. 2010
		<i>Merremia tridentata</i>	NM(1)	nf		Kumar and Muthukumar 2014
	<b>Solanaceae</b>	<i>Physalis longifolia</i>	AM(1)	UPL		Stevens et al. 2010
		<i>Physalis turbinata</i>	AM(1)	UPL		Stevens et al. 2010
		<i>Solanum ptycanthum</i>	AM(1)	FACU		Stevens et al. 2010
		<i>Solanum dulcamara</i>	NM(1)	FAC		Beck-Nielsen and Vindbæk Madsen 2001
	<b>Hydroleaceae</b>	<i>Hydrolea zeylanica</i>	AM(1)	FACW		Ragupathy et al. 1990
	<b>Sphenocleaceae</b>	<i>Sphenoclea zeylanica</i>	AM(1)	OBL	S-E	Ragupathy et al. 1990

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## MONOCOTILEDONS

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<b>Alismatales</b>	<b>Alismataceae</b>	<i>Alisma plantago-aquatica</i>	AM-NM	OBL	S-E	Šraj-Kržič et al. 2006; Wang and Zhao 2006; Beck-Nielsen and Vindbæk Madsen 2001
		<i>Alisma subcordatum</i>	AM(1)	OBL	S-E	Wetzel and van der Valk 1995
		<i>Sagittaria lancifolia</i>	AM(1)	OBL	E	Kandalepas et al. 2010
		<i>Sagittaria latifolia</i>	AM(1)	OBL	S-E	Wetzel and van der Valk 1995
		<i>Sagittaria montevidensis</i>	NM(1)	OBL	S-E	De Marins et al. 2009
		<i>Sagittaria sagittifolia</i>	AM(1)	OBL	S-E	Wang and Zhao 2006
		<i>Sagittaria trifolia</i>	AM-NM	OBL	S-E	Wang and Zhao 2006
		<i>Limnocharis flava</i>	AM(1)	OBL	S-E	Harikumar 2001
	<b>Aponogetonaceae</b>	<i>Aponogeton natans</i>	AM(1)	OBL	FL	Ragupathy et al. 1990
	<b>Araceae</b>	<i>Acorus calamus</i>	AM(1)	OBL	S-E	Harikumar 2001
		<i>Colocasia esculenta (C. antiquorum)</i>	AM-NM	FACW	E	Kumar and Muthukumar 2014; Harikumar 2001; Ragupathy et al. 1990
		<i>Lasia spinosa</i>	NM(1)	nf	E	Chaubal et al. 1982
		<i>Pistia stratiotes</i>	NM	OBL	FF	Kumar and Muthukumar 2014; De Marins et al. 2009; Ragupathy et al. 1990

		<i>Stuednera colocasioides</i>	NM(1)	nf		Chaubal et al. 1982
		<i>Symplocarpus foetidus</i>	AM(1)	OBL	S-E	Weishampel and Bedford 2006
<b>Hydrocharitaceae</b>		<i>Blyxa aubertii</i>	NM(1)	OBL	S	Harikumar 2001
		<i>Blyxa octandra</i>	AM(1)	OBL	S	Ragupathy et al. 1990
		<i>Egeria densa</i>	NM(1)	OBL	S	Clayton and Bagyaraj 1984
		<i>Egeria najas</i>	NM(1)	OBL	S	De Marins et al. 2009
		<i>Elodea canadensis</i>	NM	OBL	S-FL	Beck-Nielsen and Vindbæk Madsen 2001
		<i>Hydrilla verticillata</i>	AM-NM	OBL	S	Kumar and Muthukumar 2014; Wang and Zhao 2006; Ragupathy et al. 1990; Chaubal et al. 1982
		<i>Hydrocharis dubia</i>	NM(1)	OBL	S-E	Wang and Zhao 2006
		<i>Limnobium variegatum</i>	NM(1)	OBL	nf	De Marins et al. 2009
		<i>Nechamandra alternifolia</i>	AM(1)	OBL	S	Ragupathy et al. 1990
		<i>Ottelia alismoides</i>	AM-NM	OBL	S-FL	Kumar and Muthukumar 2014; Ragupathy et al. 1990
		<i>Ottelia ovalifolia</i>	NM(1)	OBL		Clayton and Bagyaraj 1984
		<i>Vallisneria natans</i>	AM-NM	OBL	S	Wang and Zhao 2006; Ragupathy et al. 1990
		<i>Vallisneria spiralis</i>	AM(1)	OBL	S	Harikumar 2001
		<i>Vallisneria gigantea</i>	NM(1)	OBL		Clayton and Bagyaraj 1984
<b>Lemnaceae</b>		<i>Spirodela polyrrhiza</i>	AM(1)	OBL	FF	Ragupathy et al. 1990
		<i>Lemna gibba</i>	NM(1)	OBL	FF	Ragupathy et al. 1990
<b>Najadaceae</b>		<i>Najas graminea</i>	AM(1)	OBL	S	Ragupathy et al. 1990
<b>Potamogetonaceae</b>		<i>Potamogeton cheesemanii</i>	AM-NM	OBL	S-FL	Clayton and Bagyaraj 1984
		<i>Potamogeton crispus</i>	NM(1)	OBL	S	Beck-Nielsen and Vindbæk Madsen 2001
		<i>Potamogeton gramineus</i>	NM(1)	OBL	S-E	Beck-Nielsen and Vindbæk Madsen 2001
		<i>Potamogeton lucens</i>	NM	OBL	S	Wang and Zhao 2006; Beck-Nielsen and Vindbæk Madsen 2001
		<i>Potamogeton malaianus</i>	NM	OBL	E-FL	Wang and Zhao 2006; Ragupathy et al. 1990
		<i>Potamogeton natans</i>	NM(1)	OBL	FL	Beck-Nielsen and Vindbæk Madsen 2001
		<i>Potamogeton ochreatus</i>	NM(1)	OBL	s	Clayton and Bagyaraj 1984
		<i>Potamogeton oxyphyllus</i>	NM(1)	OBL	S	Wang and Zhao 2006
		<i>Potamogeton pectinatus</i>	AM-NM	OBL	S	Wang and Zhao 2006; Clayton and Bagyaraj 1984
		<i>Potamogeton perfoliatus</i>	NM	OBL	S	Wang and Zhao 2006; Beck-Nielsen and Vindbæk Madsen 2001
		<i>Potamogeton praelongus</i>	NM(1)	OBL	S	Beck-Nielsen and Vindbæk Madsen 2001
		<i>Potamogeton tepperi</i>	NM(1)	OBL	S-FL	Wang and Zhao 2006
<b>Ruppiaaceae</b>		<i>Ruppia polycarpa</i>	AM-NM	OBL	S	Clayton and Bagyaraj 1984
<b>Asparagales</b>	<b>Iridaceae</b>	<i>Gladiolus x gandavensis</i>	NM(1)	nf		Wang and Zhao 2006

		<i>Iris versicolor</i>	AM(1)	OBL	E	Weishampel and Bedford 2006
<b>Commelinales</b>	<b>Commelinaceae</b>	<i>Commelina benghalensis</i>	NM	FACU		Kumar and Muthukumar 2014; Harikumar 2001
		<i>Cyanotis axillaris</i>	AM(1)	nf		Harikumar 2001
		<i>Pollia secundiflora</i>	AM(1)	nf		Kumar and Muthukumar 2014
	<b>Pontederiaceae</b>	<i>Eichhornia azurea</i>	NM(1)	OBL	FL	De Marins et al. 2009
		<i>Eichhornia crassipes</i>	AM-NM	OBL	FF(FL)	Kumar and Muthukumar 2014; De Marins et al. 2009; Harikumar 2001; Ragupathy et al. 1990
		<i>Monochoria hastata</i>	AM-NM	OBL	S	Harikumar 2001; Chaubal et al. 1982
		<i>Monochoria hastifolia</i>	AM(1)	OBL	S	Ragupathy et al. 1990
		<i>Monochoria vaginalis</i>	AM-NM	OBL	S-E	Kumar and Muthukumar 2014; Harikumar 2001; Ragupathy et al. 1990
		<i>Pontederia cordata L.</i>	AM(1)	OBL	E	De Marins et al. 2009
<b>Liliales</b>	<b>Liliaceae</b>	<i>Smilacina trifolia</i>	NM	OBL	S-E	Thormann et al. 1999
<b>Poales</b>	<b>Cyperaceae</b>	<i>Carex acuta</i>	NM(1)	FACW		Beck-Nielsen and Vindbæk Madsen 2001
		<i>Carex aquatilis</i>	NM	OBL	E	Thormann et al. 1999
		<i>Carex atherodes</i>	AM(1)	OBL	E	Wetzel and van der Valk 1995
		<i>Carex flava</i>	AM-NM	OBL	E	Weishampel and Bedford 2006; Cornwell et al. 2001
		<i>Carex granularis</i>	AM(1)	FACW		Turner et al. 2000
		<i>Carex hystericina</i>	AM-NM	OBL	E	Weishampel and Bedford 2006; Cornwell et al. 2001
		<i>Carex lanuginosa</i>	NM(1)	OBL	?	Turner et al. 2000
		<i>Carex lasiocarpa</i>	NM	OBL	E	Weishampel and Bedford 2006; Cornwell et al. 2001; Thormann et al. 1999; Wetzel and van der Valk 1995
		<i>Carex leptalea</i>	NM	OBL	E	Weishampel and Bedford 2006
		<i>Carex prairea</i>	NM(1)	FACW		Weishampel and Bedford 2006
		<i>Carex rostrata</i>	NM(1)	OBL	E	Thormann et al. 1999
		<i>Carex sterilis</i>	AM-NM	OBL	E	Weishampel and Bedford 2006; Cornwell et al. 2001
		<i>Carex stricta Lam.</i>	AM(1)	OBL	E	Wetzel and van der Valk 1995
		<i>Carex trichocarpa</i>	AM(1)	FACW		Turner et al. 2000
		<i>Carex utriculata</i>	NM(1)	OBL	E	Thormann et al. 1999
		<i>Carex vesicaria</i>	AM(1)	OBL	E	Wetzel and van der Valk 1995
		<i>Cyperus articulatus</i>	AM-NM	OBL	E	Kumar and Muthukumar 2014; Ragupathy et al. 1990
		<i>Cyperus brevifolius</i>	AM(1)	FACW		Choudhury et al. 2010
		<i>Cyperus cephalotes</i>	NM(1)	nf		Kumar and Muthukumar 2014

<i>Cyperus difformis</i>	AM(1)	OBL	E	Harikumar 2001
<i>Cyperus distans</i>	AM-NM	OBL	E	Choudhury et al. 2010; Chaubal et al. 1982
<i>Cyperus erythrorhizos</i>	AM(1)	OBL	E	Stevens et al. 2010
<i>Cyperus exaltatus</i>	NM	FACW		Kumar and Muthukumar 2014; Ragupathy et al. 1990
<i>Cyperus flavescens</i>	AM(1)	OBL	E	Turner et al. 2000
<i>Cyperus giganteus</i>	NM(1)	OBL	E	De Marins et al. 2009
<i>Cyperus imbricatus</i>	AM(1)	OBL	E	Choudhury et al. 2010
<i>Cyperus iria</i>	AM	FACW		Kumar and Muthukumar 2014; Harikumar 2001
<i>Cyperus javanicus</i>	NM(1)	FACW		Ragupathy et al. 1990
<i>Cyperus pangorei</i>	NM(1)	nf		Kumar and Muthukumar 2014
<i>Cyperus rotundus</i>	AM(1)	FACU		Choudhury et al. 2010
<i>Cyperus strigosus</i>	AM(1)	FACW		Turner et al. 2000
<i>Cyperus tenuispica</i>	NM(1)	FACW		Ragupathy et al. 1990
<i>Eleocharis cellulosa</i>	AM(1)	OBL	E	Kandalepas et al. 2010
<i>Eleocharis congesta</i>	NM	OBL	E	Chaubal et al. 1982
<i>Eleocharis elliptica</i>	NM	OBL	E	Weishampel and Bedford 2006
<i>Eleocharis erythropoda</i>	NM(1)	OBL	E	Turner et al. 2000
<i>Eleocharis montevidensis</i>	AM(1)	FACW		Kandalepas et al. 2010
<i>Eleocharis palustris</i>	NM(1)	OBL	E	Beck-Nielsen and Vindbæk Madsen 2001
<i>Eleocharis tenuis</i>	NM(1)	FACW		Cornwell et al. 2001
<i>Eriophorum vaginatum</i>	NM	OBL	E	Thormann et al. 1999
<i>Eriophorum viridicarinatum</i>	AM(1)	OBL	E	Weishampel and Bedford 2006
<i>Fimbristylis argentea</i>	NM(1)	FACW		Kumar and Muthukumar 2014
<i>Fimbristylis consanguinea</i>	NM(1)	FACW		Kumar and Muthukumar 2014
<i>Fimbristylis dichotoma</i>	AM(1)	FACW		Choudhury et al. 2010
<i>Fimbristylis falcata</i>	AM(1)	FACW		Kumar and Muthukumar 2014
<i>Fimbristylis miliacea</i>	NM(1)	OBL	E	Ragupathy et al. 1990
<i>Fimbristylis vahlii</i>	AM(1)	FACW		Stevens et al. 2010
<i>Kyllinga nemoralis</i>	AM(1)	FACU		Kumar and Muthukumar 2014
<i>Oxycaryum cubense</i>	NM(1)	OBL	E-FL	De Marins et al. 2009
<i>Pycneus polystachyos</i>	NM(1)	FACW		Ragupathy et al. 1990
<i>Schoenoplectus acutus (Scirpus acutus)</i>	AM-NM	OBL	E	Weishampel and Bedford 2006; Wetzel and van der Valk 1995
<i>Schoenoplectus americanus</i>	AM(1)	OBL	E	Kandalepas et al. 2010
<i>Schoenoplectus robustus</i>	AM(1)	OBL	E	Kandalepas et al. 2010

	<i>Schoenoplectus tabernaemontani</i> ( <i>Scirpus tabernaemontani</i> )	AM-NM	OBL	E	Kandalepas et al. 2010; Turner et al. 2000
	<i>Scirpus articulatus</i>	NM(1)	FACW		Chaubal et al. 1982
	<i>Scirpus atrovirens</i>	AM-NM	OBL	E	Weishampel and Bedford 2006; Wetzel and van der Valk 1995; Turner et al. 2000
	<i>Scirpus cespitosus</i>	NM(1)	OBL	E	Thormann et al. 1999
	<i>Scirpus fluviatilis</i>	AM-NM	OBL	E	Rickerl et al. 1994
	<i>Scirpus juncooides</i>	NM(1)	OBL	E	Chaubal et al. 1982
	<i>Scirpus lateriflorus</i>	NM(1)	OBL	E	Choudhury et al. 2010
	<i>Scirpus maritimus</i>	AM(1)	OBL	E	Wetzel and van der Valk 1995
	<i>Scirpus pendulus</i>	AM(1)	OBL	E	Turner et al. 2000
	<i>Scirpus pungens</i>	AM(1)	OBL	E	Turner et al. 2000
<b>Eriocaulaceae</b>	<i>Eriocaulon quinquangulare</i>	NM	nf		Kumar and Muthukumar 2014; Harikumar 2001
	<i>Eriocaulon cinereum</i>	AM(1)	OBL	E	Ragupathy et al. 1990
<b>Juncaceae</b>	<i>Juncus brachycephalus</i>	AM-NM	OBL	E	Weishampel and Bedford 2006
	<i>Juncus bulbosus</i>	NM(1)	OBL	S-E	Beck-Nielsen and Vindbæk Madsen 2001
	<i>Juncus dudleyi</i>	AM(1)	FACW		Turner et al. 2000
	<i>Juncus effusus</i>	NM(1)	OBL	E	Beck-Nielsen and Vindbæk Madsen 2001
	<i>Juncus nodosus</i>	AM(1)	OBL	E	Turner et al. 2000
	<i>Juncus tenuis</i>	AM(1)	FAC		Weishampel and Bedford 2006
	<i>Juncus torreyi</i>	AM(1)	FACW		Turner et al. 2000
<b>Poaceae</b>	<i>Aeluropus lagopoides</i>	NM(1)	FAC		Ragupathy et al. 1990
	<i>Agrostis stolonifera</i>	AM(1)	FACW		Weishampel and Bedford 2006
	<i>Andropogon aciculatus</i>	AM(1)	FAC		Choudhury et al. 2010
	<i>Axonopus compressus</i>	AM	FACW		Kumar and Muthukumar 2014; Choudhury et al. 2010
	<i>Bromus ciliatus</i>	AM	FACW		Weishampel and Bedford 2006
	<i>Calamagrostis canadensis</i>	AM-NM	FACW		Weishampel and Bedford 2006; Thormann et al. 1999; Wetzel and van der Valk 1995
	<i>Cynodon dactylon</i>	AM	FACU		Choudhury et al. 2010; Ragupathy et al. 1990
	<i>Digitaria adscendens</i>	AM(1)	FACU		Choudhury et al. 2010
	<i>Digitaria stricta</i>	AM(1)	nf		Choudhury et al. 2010
	<i>Distichlis stricta</i>	AM(1)	FACW		Wetzel and van der Valk 1995
	<i>Echinochloa colona</i>	NM	FACW		Harikumar 2001; Ragupathy et al. 1990
	<i>Echinochloa frumentacea</i>	AM(1)	FAC		Ragupathy et al. 1990
	<i>Echinochloa picta</i>	NM(1)	FACW		Ragupathy et al. 1990
	<i>Eleusine indica</i>	AM(1)	FACU		Choudhury et al. 2010

<i>Eragrostis gangetica</i>	NM(1)	nf		Kumar and Muthukumar 2014
<i>Eragrostis secunda</i>	AM(1)	UPL		Choudhury et al. 2010
<i>Glyceria fluitans</i>	NM(1)	OBL	S-E	Šraj-Kržič et al. 2006
<i>Glyceria maxima</i>	NM(1)	OBL	S-E	Beck-Nielsen and Vindbæk Madsen 2001
<i>Glyceria striata</i>	AM	OBL	E	Weishampel and Bedford 2006
<i>Hierochloe odorata</i>	AM(1)	FACW		Turner et al. 2000
<i>Hordeum jubatum</i>	AM(1)	FAC		Wetzel and van der Valk 1995
<i>Imperata cylindrica</i>	AM(1)	FACU		Choudhury et al. 2010
<i>Ischaemum indicum</i>	NM(1)	nf		Harikumar 2001
<i>Jansenella griffithiana</i>	NM(1)	nf		Kumar and Muthukumar 2014
<i>Leersia hexandra</i>	AM	OBL	E	Miller 2001
<i>Leersia oryzoides</i>	NM(1)	OBL	E	Weishampel and Bedford 2006
<i>Molinia caerulea</i>	AM	FACU		Fuchs and Haselwandter 2004
<i>Oryza sativa</i>	AM	OBL	E	Kumar and Muthukumar 2014; Ragupathy et al. 1990
<i>Oryza sativa var. fatua</i>	AM(1)	OBL	E	Harikumar 2001
<i>Panicum brevifolium</i>	AM(1)	FACU		Chaubal et al. 1982
<i>Panicum hemitomon</i>	AM	FACW		Miller 2001
<i>Panicum indicum</i>	AM(1)	FACU		Choudhury et al. 2010
<i>Panicum psilopodium</i>	AM(1)	FAC		Ragupathy et al. 1990
<i>Panicum repens</i>	AM-NM	FAC		Wang et al. 2016
<i>Panicum virgatum</i>	AM(1)	FACU		Wetzel and van der Valk 1995
<i>Paspalidium geminatum</i>	NM(1)	OBL	E-FL	Ragupathy et al. 1990
<i>Paspalum dilatatum</i>	AM	FAC		Grigera and Oosterheld 2004; Chaubal et al. 1982
<i>Paspalum paspaloides</i>	AM(1)	FACW		Choudhury et al. 2010
<i>Paspalum repens</i>	AM(1)	OBL	E-FL	De Marins et al. 2009
<i>Paspalum scrobiculatum</i>	AM(1)	FACW		Ragupathy et al. 1990
<i>Phalaris arundinacea</i>	AM-NM	FACW		Beck-Nielsen and Vindbæk Madsen 2001; Rickerl et al. 1994
<i>Phragmites australis (P. communis)</i>	AM-NM	FACW		Wang et al. 2015; Dolinar and Gaberščik 2010; Wang and Zhao 2006; Beck-Nielsen and Vindbæk Madsen 2001
<i>Phragmites karka</i>	AM(1)	FACW		Choudhury et al. 2010
<i>Poa pratensis</i>	AM	FACU		Wetzel and van der Valk 1995
<i>Pogonatherum crinitum</i>	AM(1)	nf		Choudhury et al. 2010
<i>Pseudoraphis spinescens</i>	NM(1)	OBL	E-FL	Ragupathy et al. 1990
<i>Puccinellia nuttalliana</i>	AM(1)	FACW		Wetzel and van der Valk 1995
<i>Saccharum officinarum</i>	AM(1)	FACU		Choudhury et al. 2010



		<i>Sacciolepis interrupta</i>	AM(1)	OBL	E-FL	Ragupathy et al. 1990
		<i>Setaria glauca</i>	AM(1)	FAC		Choudhury et al. 2010
		<i>Sorghum halepense</i>	AM(1)	FACU		Stevens et al. 2010
		<i>Spartina pectinata</i>	AM	FACW		Wetzel and van der Valk 1995
		<i>Sphenopholis obtusata</i>	AM(1)	FAC		Turner et al. 2000
		<i>Sporobolus wallichii</i>	AM(1)	nf		Kumar and Muthukumar 2014
		<i>Vetiveria zizanioides</i>	AM(1)	FACW		Choudhury et al. 2010
		<i>Zizania caduciflora</i>	NM	OBL	E	Wang and Zhao 2006
	<b>Sparganiaceae</b>	<i>Sparganium angustifolium</i>	NM(1)	OBL	E-FL	Beck-Nielsen and Vindbæk Madsen 2001
		<i>Sparganium emersum</i>	NM(1)	OBL	E-FL	Beck-Nielsen and Vindbæk Madsen 2001
		<i>Sparganium erectum</i>	NM(1)	OBL	E-FL	Beck-Nielsen and Vindbæk Madsen 2001
		<i>Sparganium eurycarpum</i>	AM(1)	OBL	E	Wetzel and van der Valk 1995
		<i>Sparganium ramosum</i>	NM(1)	OBL	E	Chaubal et al. 1982
	<b>Typhaceae</b>	<i>Typha angustata (T. domingensis)</i>	NM	OBL	E	Kandalepas et al. 2010; Kumar and Muthukumar 2014; Ragupathy et al. 1990
		<i>Typha angustifolia</i>	NM	OBL	E	Weishampel and Bedford 2006; Beck-Nielsen and Vindbæk Madsen 2001; Stenlund and Charvat 1994
		<i>Typha latifolia</i>	AM-NM	OBL	E	Ray and Inohuye 2006; Weishampel and Bedford 2006; Beck-Nielsen and Vindbæk Madsen 2001; Cornwell et al. 2001; Turner et al. 2000; Thormann et al. 1999; Stenlund and Charvat 1994
		<i>Typha orientalis</i>	NM	OBL	E	Wang and Zhao 2006
		<i>Typha x glauca</i>	AM	OBL	E	Rickerl et al. 1994; Stenlund and Charvat 1994
<b>Zingiberales</b>	<b>Cannaceae</b>	<i>Canna indica</i>	AM(1)	FACW		Kumar and Muthukumar 2014

<sup>(1)</sup> AM(1) and NM(1), mycorrhizal and non-mycorrhizal species, respectively, only found once in the selected papers; AM and NM, species resulted to be mostly mycorrhizal or non-mycorrhizal, respectively; AM-NM, species where approximately equivalent mycorrhizal and non-mycorrhizal reports were found.

<sup>(2)</sup> WI, wetland indicator category; OBL, obligate wetland, almost always occurring in wetlands; FACW, facultative wetland, usually occurring in wetlands, but may occur in non-wetlands; FAC, facultative, occurring in wetlands and non-wetlands; FACU, facultative upland, usually occurring in non-wetlands, but possibly occurring in wetlands; UPL, obligate upland, almost never occurring in wetlands; nf, not found.

<sup>(3)</sup> LF, life form; E, rooted emergent plants; FL or S, rooted plants with floating or submerged leaves; FF or FS, not anchored to the substrate, free floating and free submerged plants.

#### Author contributions

Both authors studied the design, performed data analysis and wrote the manuscript. AF collected and organized data. The article in its final form for submission was approved by both the Authors. The authors declare responsibility of the integrity of the work as a whole.