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Arbuscular mycorrhizas of plants growing in the Western Ghats region, Southern India

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Abstract A survey of the arbuscular mycorrhizal (AM) status of plants growing in the Western Ghats region of Southern India was undertaken. Root and soil samples of plants growing in the four vegetation types forest, grassland, scrub, and cultivated land or plantation were examined. Of the 329 species (representing 61 families) examined, 174 were mycorrhizal. AM association was recorded in 81 species for the first time, including species from several families assumed to be non-mycorrhizal, e.g. Amaranthaceae, Capparaceae, Commelinaceae, Cyperaceae and Portulacaceae. AM fungal spores of 35 species belonging to *Acaulospora, Gigaspora, Glomus, Sclerocystis* and *Scutellospora* were recorded. AM fungal species richness was found to be highest in scrub and lowest in agricultural and plantation soils. Mean colonization levels were dependent on plant life-form, life-cycle pattern and vegetation type.

Key words Arbuscular mycorrhizal fungi · Western Ghats · Life-cycle · Life-form · *Glomus* · *Acaulospora* · *Gigaspora* · *Scutellospora* · *Sclerocystis*

Introduction

The Western Ghats extend for about 1600 km from the Tapti River in the north down to the peninsular tip in the south. It is an ecologically rich region of India, comparable to the Himalayas in its biological diversity. Western Ghats harbors about 4000 species of flowering plants and is one of the 18 main concentrations of biodiversity in the world. In recent years, the natural vegetation of Western Ghats has declined due to deforestation, urbanization, logging, lopping of leaves, cattle grazing, cultivation, conversion of forests into plantations and dry-season fires (Tewari 1995).

Arbuscular mycorrhizal (AM) fungi are associated with about 80% of the plant families in the world (Giovannetti and Sbrana 1998). The fungi responsible for AM formation in plants in the majority of terrestrial ecosystems show great diversity. The conservation and efficient utilization of this diversity are of crucial importance for sustainable plant production systems (Giovannetti and Gianinazzi-Pearson 1994). Although most tropical plants have AM associations, it was thought that members of families such as Amaranthaceae, Caryophyllaceae Chenopodiaceae, Cruciferae, Cyperaceae, Juncaceae and Proteaceae rarely or never form an AM association (Peat and Fitter 1993). In addition, plant genera within a particular family may not only vary in the extent of their mycotrophy but some may be non-mycorrhizal (e.g. *Lupinus* in Fabaceae). The mycorrhizal status of the Indian flora is largely unknown. Records exist of the mycorrhizal status of aquatic and marshy plants (Ragupathy et al. 1990; Sengupta and Chaudhuri 1990) and of plants in the tropical plains (Ragupathy and Mahadevan 1993), tropical forests (Mohankumar and Mahadevan 1987), semi-arid soils (Neeraj et al. 1991; Rachel et al. 1991), sand dunes (Mohankumar et al. 1988) and mangroves (Mohankumar and Mahadevan 1986). However, little is known about the mycorrhizal status of plants in the Western Ghats (Appasamay and Ganapathi 1995; Muthukumar et al. 1996).

The aim of this study was to obtain information on the mycorrhizal status of plant species in the Western Ghats which may be of significance in explaining vegetation patterns and plant fluctuations. In addition, the data obtained were used to answer the following questions: (1) Does the intensity of AM colonization differ between ecological life-forms? (2) Does AM colonization vary between annual and perennial species? (3) Does vegetation influence AM colonization? (4) Does AM colonization of dicots differ from that of mono-

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cots? (5) Does vegetation influence AM fungal communities?

Materials and methods

Study sites

Root and soil samples were collected between January 1993 and December 1995 from six different areas and vegetation types in the Western Ghats region (Fig. 1). The site characteristics are presented in Table 1.

Sampling

Root and soil samples for each species were collected from five individuals at different stages of growth (vegetative and reproductive). Care was taken during collection that roots of shrubs and tree species could be positively identified. For this reason, samples of herbs were usually made by uprooting the plants. Roots were washed and stained within 24 h or preserved in formalin-acetic acid-alcohol upto 6 months before staining. Rhizosphere soil from roots and adjacent to plants was collected. Soil samples collected from different individuals of a species were mixed to form a composite sample. These composite soil samples were used for the isolation of AM fungal spores and for soil chemistry.

Determination of soil characters

Soil pH was determined in 1:1, soil:water soon after the soil samples were brought to the laboratory. The total nitrogen (N) and available phosphorus (P) were determined according to Jackson (1971) and exchangeable potassium (K) was determined after extraction with ammonium acetate (Jackson 1971). Soil organic matter was assessed according to Piper (1950).

Estimates of AM fungal colonization and isolation of AM fungal spores

Fixed roots were cleared in 2.5% KOH (Koske and Gemma 1989), acidified with 5 N HCl and stained with trypan blue (0.05% in lactophenol). Roots that remained dark after clearing were bleached with 3% H_2O_2 before staining. The roots were left overnight in trypan blue-lactophenol for staining. Soft or flimsy roots were just immersed in KOH for 24–48 h to effect clearing. This reduced root damage and cortex loss due to boiling in KOH.

The stained roots were examined with a compound microscope (×200–400) for AM fungal structures and the percentage root length colonization was estimated according to the magnified intersection method (McGonigle et al. 1990). In addition, the number of hyphae, arbuscule and vesicle intersections were noted. It was thus possible to quantify both the root length colonized by AM structures and total root length colonization. Only species in which arbuscules were found were considered to have arbuscular mycorrhizae.

AM fungal spores were isolated by a modification of the wet-sieving and decanting technique (Muthukumar et al. 1996). Aliquots (100 g) of each composite soil sample were dispersed in 1 l water and the suspension left undisturbed for 15 min to allow soil particles to settle. The suspension was then decanted through 710- and 38-μm sieves and the residues on the sieves were washed into beakers. After settlement of the heavier particles, the supernatant was filtered through gridded filter papers. Each filter paper was spread onto a glass plate and scanned under a dissection microscope at ×40 magnification. Intact AM fungal spores were transferred using a wet needle to polyvinylalcohol-lactophenol with or without Melzer's reagent on a glass slide for identification.

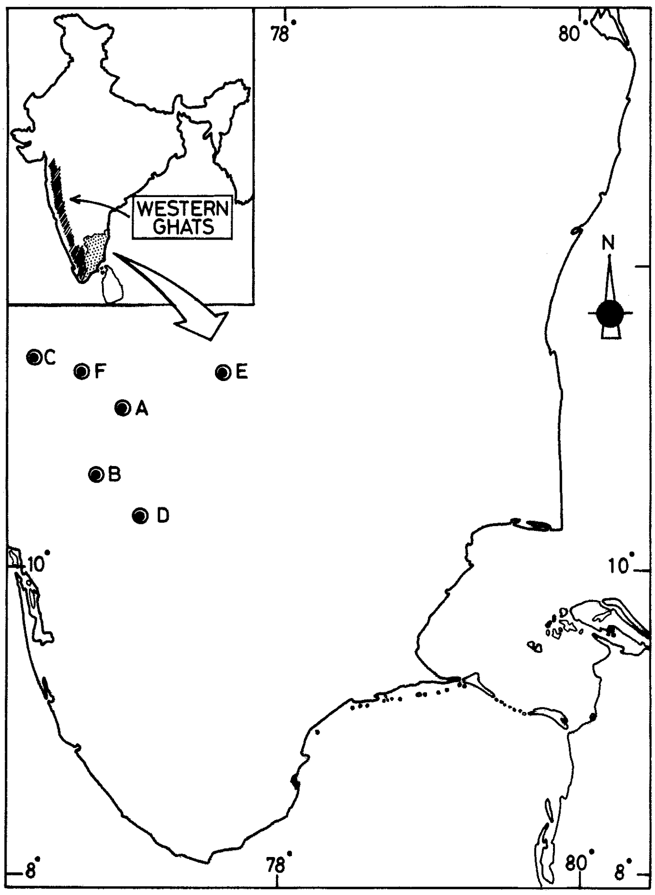


Fig. 1 Map showing study sites. *A* Coimbatore, *B* Siruvani, *C* Thaisolai, *D* Karumalai, *E* Satyamangalam, *F* Pykara

Identification of AM fungal spores

Intact and crushed spores in polyvinylalcohol-lactophenol and in Melzer's reagent were examined and identified according to Schenck and Perez (1990). Spore colour was examined under a dissection microscope on fresh specimens immersed in water. Classification, spore wall characters and the spelling of scientific names are as suggested by Morton and Benny (1990), Walker (1983, 1986) and Walker and Trappe (1993). Voucher specimens of AM fungi have been deposited in the Botany Department, Bharathiar University, Coimbatore.

Life-history attributes and plant nomenclature

Each plant species recorded during the survey was categorized for life-form and life-cycle attributes as determined from the literature (Parin 1981a,b; Toby and Hodd 1982; Nair and Henry 1983; Henry et al. 1987,1989) or field observations. Nomenclature and authorities are as used by Nair and Henry (1983) and Henry et al. (1987, 1989).

Data analysis

Kruskal-Wallis non-parametric Analysis of Variance (ANOVA) with tied ranks and Mann-Whitney non-parametric analysis were used to test whether plant species of different life-forms, vegetation types or life-cycles differ in extent of mycotrophy. When a plant species was sampled from more than one site, only one en-

Table 1 Study site characteristics

	Site					
	A Coimbatore	*B* Siruvani	*C* Thaisolai	*D* Karumalai	*E* Satyamangalam	*F* Pykara
Location	11°04′N & 76°93′E	10°58′N & 76°73′E	11°15′N & 76°35′E	10°32′N & 77°04′E	11°28′N & 77°59′E	11°28′N & 76°63′E
Altitude (m a.s.l.)	426–550	500	1850	1200	540	2073
Annual rainfall (mm)	500–700	800–1500	2800–3200	300–4500	360–600	1590–2152
Vegetation type[a]	Forest, scrub, grassland	Forest, grassland	Grassland	Forest	Plantation, cultivated land	Forest, grassland
Soil type	Sandy loam	Clay loam	Sandy clay loam	Clay	Red soil	Clay loam
pH	7.6 (0.11)[b]	7.8 (0.21)	8.0 (0.21)	7.5 (0.31)	7.6 (0.12)	6.9 (0.03)
Nitrogen (mg kg^{-1})	1.0 (0.01)	1.6 (0.10)	1.8 (0.04)	1.8 (0.10)	1.4 (0.18)	2.0 (0.08)
Phosphorus (mg kg^{-1})	1.0 (0.01)	1.0 (0.03)	0.9 (0.01)	0.9 (0.01)	1.1 (0.04)	1.2 (0.11)
Potassium (mg kg^{-1})	7.8 (0.15)	2.0 (0.40)	2.3 (0.15)	1.6 (0.12)	1.6 (0.82)	2.8 (0.51)
Organic matter (%)	2.8 (0.73)	2.66 (0.02)	4.12 (0.08)	4.87 (1.12)	3.96 (0.79)	7.6 (1.57)

[a] Monsoon vegetation
[b] Standard errors in parentheses

try (the average) was entered for life-cycle and life-form. One-way ANOVA was used to evaluate the effect of vegetation type (forest, grassland, scrub, cultivated land or plantation) on AM fungal species richness (mean number of species).

Results

The soil characteristics of the study sites as shown in Table 1. As in most areas of the tropics, soils were low in nutrients, especially available phosphorus. Of the 329 plant species examined (representing 61 families), mycorrhizas were present in 174 (Table 2). The mycorrhizal colonization was characterized by arbuscules, intraradical hyphae, intracellular hyphal coils with or without vesicles (Fig. 2). Vesicles and hyphae (but no arbuscules) were observed in 135 plant species. Mycorrhizas were most frequent in Papilionaceae, Caesalpiniaceae, Rubiaceae, Compositae, Boraginaceae, Convolvulaceae, Acanthaceae and Mimosaceae (Table 2). The mean AM colonization was highest in Papilionaceae. Among the plant families examined, 26% contained only mycorrhizal species, 36% had mycorrhizal and non-mycorrhizal species and 38% had only non-mycorrhizal species.

AM colonization was observed in several members of supposedly non-mycorrhizal families like Amaranthaceae (*Achyranthes aspera, Gompherena serrata*), Capparaceae (*Cadaba fruticosa*), Commelinaceae (*Commelina attenuata*, *C. diffusa*), Cyperaceae (*Bulbostylis barbata*, *Carex baccans, C. myosurus, Cyperus compressus, C. cyperinus, C. triceps, Fimbristylis ovata, Scleria lithosperma*) and Portulacaceae, (*Portulaca pilosa*). More than 50% of the non-mycorrhizal species observed were concentrated in Amaranthaceae, Euphorbiaceae, Commelinaceae, Cyperaceae and Poaceae. Of dicots, 58% (134 of 231) and of monocots 38% (40 of 98) were mycorrhizal. Mycorrhizal colonization levels in dicots were significantly greater than those of monocots ($Z_{(1)329}=18.55$; $P<0.001$). Mycorrhizal colonization levels among mycorrhizal plant species were influenced by life-form ($H_{C\ 3,174}=906948$; $P<0.001$) with herbs having the lowest levels (Fig. 3). However, this large difference between mycorrhizal life-forms disappeared when non-mycorrhizal species were included ($H_{C\ 3,329}$ = –0.00001; $P>0.05$). Annuals and biennials tended to be less mycotrophic than perennials ($Z_{(1)329}=6.76$; $P<0.001$) (Fig. 4). This was not due to a higher percentage of non-mycorrhizal species among annuals, since when non-mycorrhizal species were omitted from the analysis, typically annual and biennial species still had significantly lower colonization levels than perennial species ($Z_{(1)174}=16.90$; $P<0.001$). A mean mycorrhizal colonization level for each vegetation type was calculated by averaging mycorrhizal colonization of all species collected from each vegetation, ranging from 30% in scrub land to 25% in grasslands. Vegetation type had a significant effect on mean colonization level ($H_{C\ 3,358}=127.01$; $P<0.001$). Across all sites, a total of 35 AM fungal spore types, or morpho species (sensu Morton et al. 1992) belonging to *Acaulospora* (3 species), *Gigaspora* (2 species), *Glomus* (21 species) *Sclerocystis* (4 species) (Wu 1993) and *Scutellospora* (5 species) were observed (Fig. 5, Table 3). Numbers were assigned to five *Glomus* collections because the spore characteristics did not correspond to previously described species. Species richness (mean number of species) was highest in scrubs and lowest in cultivated and plantation soils, although the vegetation effect on species richness was not significant ($F_{3,7}=0.709$; $P>0.05$).

Discussion

Many records of AM colonization in this survey are the first published reports for these plant species. Until now, there has been a paucity of information on the mycorrhizal status of plants from the Western Ghats region; we are aware of literature on fewer than 50 species. The present study differs from other investigations on AM in the quantification of AM structures within roots. Most previous studies on mycorrhizas in wild plants have not distinguished between active and inactive mycorrhizas or between different internal AM structures. Such studies merely quantified total mycor-

Table 2 Life history attributes, incidence and extent of AM mycotrophy in angiosperms of the Western Ghats. Families are arranged in the Bentham & Hooker system (* First report, # hyphae and vesicles observed)

Plant species	Site[a]	Habitat[b]	Life-form[c]	Life-cycle[d]	AM colonization (%)[e]			
					HC	AC	VC	TC
Magnoliaceae								
# *Michelia champaca* L.	A	FO	T	P	–	–	–	–
Annonaceae								
# *Artabotrys hexapetalus* (L.F.) Bhandari	A	FO	CLS	P	–	–	–	–
# *Polyalthia longifolia* (Sonner.) Thw.	A	FO	T	P	–	–	–	–
Menispermaceae								
# *Cocculus hirsutus* (L.) Diels	A	GL	T	P	–	–	–	–
# *Pachygone ovata* (Poir.) Miers ex Hook f. & Thorns.	B	FO	S	P	–	–	–	–
Capparaceae								
Cadaba fruticosa (L.) Druce	A	SC	S	P	9.58 ± 2.88	4.84 ± 2.61	11.54 ± 3.21	25.96 ± 5.91
# *Capparis sepiaria* L.	A	SC	S	P	–	–	–	–
# *C. spinosa* L.	A	SC	S	P	–	–	–	–
# *C. zeylanica* L.	A	SC	S	P	–	–	–	–
Cleomaceae								
# *Cleome gynandra* L.	A	Gl	H	A	–	–	–	–
C. monophylla L.	A	GL	H	A	–	–	–	–
C. monophylla L.	B	FO			–	–	–	–
# *C. viscosa* L.	A	GL	H	A	–	–	–	–
C. viscosa L.	E	PL			–	–	–	–
Polygalaceae								
Polygala arvensis Willd.	A	GL	H	A	15.36 ± 2.31	7.72 ± 3.18	23.86 ± 6.41	46.94 ± 10.41
P. erioptera DC.	A	GL	H	A	9.59 ± 4.81	12.63 ± 4.14	4.90 ± 2.75	27.12 ± 8.63
Caryophyllaceae								
Polycarpaea corymbosa (L.) Lam.	A	GL	H	A	–	–	–	–
# *P. prostratum* (Forsk.) Asch. & Sehweinf.	A	GL	H	P	–	–	–	–
Portulacaceae								
Portulaca oleracea L.	A	SC	H	A	–	–	–	–
P. oleracea L.	B	FO			–	–	–	–
* *P. pilosa* L.	A	SC	H	P	31.46 ± 17.03	4.23 ± 1.73	20.46 ± 1.68	56.15 ± 9.76
Hypericaceae								
* *Hypericum japonicum* E Thunb. ex Murr.	F	GL	H	P	21.29 ± 8.93	9.31 ± 2.08	24.38 ± 7.76	54.98 ± 11.14
Malvaceae								
Abutilon indicum L. Sweet	A	GL	US	A	12.61 ± 3.25	13.57 ± 7.81	18.26 ± 8.75	44.44 ± 13.61
Gossypium hirsutum L.	E	CL	US	P	9.57 ± 2.36	18.21 ± 4.38	29.15 ± 10.09	56.93 ± 15.31
* *Pavonia zeylanica* (L.) Cav.	A	GL	US	P	23.81 ± 9.06	0.00 ± 0.00	24.67 ± 6.83	48.48 ± 12.14
Sida cordifolia L.	A	GL	US	P	14.01 ± 7.15	7.25 ± 3.16	33.11 ± 9.71	54.37 ± 8.61
# *S. rhombifolia* L.	A	SC	US	P	–	–	–	–
# *Thespesia populnea* (L.) Soland. ex Correa	A	SC	T	P	–	–	–	–
Sterculiceae								
* *Guazuma ulmifolia* Lam.	A	SC	T	P	18.36 ± 5.18	13.11 ± 4.38	8.91 ± 4.15	40.38 ± 11.09
# *Waltheria indica* L.	A	SC	US	P	–	–	–	–
# *W. indica* L.	B	FO			–	–	–	–
Tiliaceae								
Corchorus trilocularis L.	A	GL	H	A	0.84 ± 0.43	25.08 ± 3.84	16.51 ± 0.31	42.43 ± 4.75
C. trilocularis L.	E	PL			12.58 ± 7.87	20.15 ± 4.38	3.81 ± 1.05	36.54 ± 18.11
Oxalidaceae								
* *Biophytum sensitivum* (L.) DC	B	FO	H	P	18.57 ± 8.08	3.57 ± 2.52	1.67 ± 1.17	23.81 ± 6.73
B. sensitivum (L.) DC.	F	GL			12.11 ± 4.99	9.21 ± 3.81	8.52 ± 2.36	29.84 ± 12.64
* *Oxalis corniculata* L.	A	GL	H	P	4.77 ± 2.81	2.78 ± 1.31	11.49 ± 5.53	19.01 ± 6.99
O. corniculata L.	B	FO			9.87 ± 4.26	12.17 ± 5.18	15.96 ± 9.26	38.00 ± 10.28
O. corniculata L.	E	CL			10.21 ± 3.95	8.11 ± 6.71	20.18 ± 7.52	38.50 ± 9.81
* *O. corymbosa* DC.	A	GL	H	P	45.00 ± 13.54	9.00 ± 1.36	14.00 ± 8.31	68.00 ± 7.12

Table 2 (Continued)

Plant species	Site[a]	Habitat[b]	Life-form[c]	Life-cycle[d]	AM colonization (%)[e]			
					HC	AC	VC	TC
Rutaceae								
# *Atalantia monophylla* (L.) Correa	A	GL	T	P	–	–	–	–
Citrus aurantium L.	E	CL	T	P	18.06 ± 7.62	28.91 ± 7.06	38.24 ± 8.11	85.21 ± 9.88
# *Toddalia asiatica* (L.) Lam.	A	SC	S	P	–	–	–	–
Meliceae								
# *Azadirachta indica* A. Juss.	A	SC	T	P	–	–	–	–
# *Melia azedarach* L.	A	SC	T	P	–	–	–	–
Rhamnaceae								
# *Ziziphus mauritiana* Lam.	A	SC	S	P	–	–	–	–
Vitaceae								
Cayratia pedata (Lam.) Juss. ex Gagnep.	B	FO	S	P	–	–	–	–
# *Cissus quadrangularis* L.	A	SC	S	P	–	–	–	–
# *C. quadrangularis* L.	B	FO			–	–	–	–
Sapindaceae								
* *Cardiospermum halicacabum* L.	A	GL	H	A	24.89 ± 12.31	4.31 ± 1.89	20.51 ± 10.88	49.71 ± 11.06
C. halicacabum L.	B	FO			30.21 ± 3.26	8.10 ± 2.86	12.53 ± 4.21	50.84 ± 9.81
# *Dodonaea viscosa* (L.) Jacq.	A	SC	S	P	–	–	–	–
Papilionaceae								
Abrus precatorius L.	A	SC	S	P	60.26 ± 10.10	14.19 ± 3.56	15.12 ± 2.36	90.32 ± 5.36
Alysicarpus monilifer (L.) DC.	B	FO	H	A	21.03 ± 8.12	39.12 ± 5.16	30.21 ± 1.38	90.36 ± 12.17
Atylosia scarabaeoides (L.) Benth.	A	SC	S	P	15.12 ± 2.36	28.87 ± 5.86	42.16 ± 12.15	86.15 ± 15.12
Clitoria ternatea L.	A	FO	CLH	A/B	24.74 ± 3.87	20.26 ± 4.12	50.12 ± 1.56	95.12 ± 1.56
C. ternatea L.	B	GL			20.32 ± 8.36	14.31 ± 6.83	30.71 ± 14.36	65.34 ± 11.92
* *Crotalaria epunctata* Dalz.	A	GL	US	P	27.71 ± 2.56	52.17 ± 3.56	12.12 ± 1.58	92.00 ± 5.18
* *C. hirta* Willd.	A	GL	US	A	11.04 ± 2.86	45.12 ± 3.86	12.12 ± 3.58	68.28 ± 3.98
C. junceae L.	A	GL	S	P	15.17 ± 3.18	23.14 ± 2.54	19.86 ± 5.41	58.17 ± 1.89
* *C. mysorensis* Roth.	A	GL	H	A	30.15 ± 12.16	23.18 ± 1.56	32.17 ± 2.56	85.50 ± 9.13
* *C. prostrata* Rottl. ex Willd.	A	GL	H	P	3.32 ± 1.56	50.36 ± 1.25	29.16 ± 1.25	82.84 ± 4.83
C. retusa L.	A	SC	US	P	2779 ± 11.64	37.99 ± 8.42	22.54 ± 3.70	88.32 ± 3.38
C. verrucosa L.	A	GL	H	A	2.78 ± 0.28	18.14 ± 1.31	18.24 ± 3.57	39.16 ± 2.92
* *C. willdenowiana* DC.	A	GL	H	P	9.21 ± 3.85	29.86 ± 5.12	40.26 ± 3.18	79.33 ± 8.13
Desmodium triflorum (L.) DC.	A	GL	H	A	10.46 ± 3.97	12.16 ± 1.95	60.25 ± 12.81	82.90 ± 9.84
Eleiotis sororia DC.	A	SC	H	A	24.69 ± 9.68	24.74 ± 2.09	36.66 ± 2.98	86.09 ± 7.44
# *Galactia tenuiflora* (Klein ex Willd.) Wight & Arn.	A	SC	H	P	–	–	–	–
Indigofera colutea (Burn.f.) Merr.	A	SC	S	P	36.73 ± 11.29	22.13 ± 5.86	32.14 ± 2.18	91.00 ± 15.16
I. hirsuta L.	A	GL	H	A/B	28.30 ± 12.88	18.95 ± 1.54	35.49 ± 2.49	82.74 ± 1.85
* *I. linnaei* Ali	A	GL	H	A	13.22 ± 03.91	23.12 ± 1.56	18.17 ± 5.21	54.51 ± 12.36
* *I. parviflora* Heyne ex Wight & Arn.	A	SC	H	A	1.24 ± 0.87	12.19 ± 3.78	29.87 ± 9.86	43.30 ± 9.76
* *I. trita* L.f. subsp. *subulata* (Vahl ex Poir.) Ali	B	FO	US	P	16.45 ± 8.98	13.16 ± 5.62	29.92 ± 7.18	59.53 ± 6.22
* *I. trita* L.f. subsp. *trita* Wight	A	SC	US	P	17.54 ± 4.16	5.86 ± 1.32	68.91 ± 10.12	92.31 ± 12.11
* *I. Wightii* Graham ex Wight & Arn.	A	SC	S	P	14.89 ± 9.26	13.18 ± 5.12	30.19 ± 3.42	58.26 ± 4.65
* *Pongamia pinnata* (L.) Pierre	A	SC	T	P	18.29 ± 4.87	9.36 ± 1.86	60.32 ± 11.28	87.97 ± 12.18
* *Rynchosia cana* DC.	A	GL	CLH	A	14.21 ± 2.91	31.19 ± 12.56	18.76 ± 4.19	64.16 ± 8.12
* *R. viscosa* (Roth.) DC.	A	GL	CLH	A	8.37 ± 1.95	39.97 ± 2.26	23.58 ± 10.17	71.92 ± 15.95
R. viscosa (Roth.) DC.	B	FO			12.38 ± 4.91	43.81 ± 8.31	18.21 ± 8.31	74.40 ± 12.31
Sesbania bispinosa (Jacq.) W. F. Wight	A	GL	S	P	24.33 ± 12.36	20.97 ± 7.61	30.82 ± 9.86	76.12 ± 13.86
Tephrosia hookeniana Wight & Am.	A	SC	S	P	12.86 ± 3.71	20.12 ± 11.12	20.14 ± 9.72	53.12 ± 8.95
* *T. pumila* (Lam.) Pers.	A	SC	H	A	13.61 ± 5.21	22.37 ± 12.17	38.21 ± 11.56	74.19 ± 15.18
T. purpurea (L.) Pers.	A	GL	US	P	23.34 ± 8.36	34.18 ± 8.71	18.75 ± 1.21	76.27 ± 14.21
# * *Teramnus labialis* (L.f.) Spreng.	A	SC	H	A	–	–	–	–
* *Zornia gibbosa* Span.	A	GL	H	A	27.50 ± 9.42	29.66 ± 2.19	30.79 ± 4.46	87.95 ± 1.65
Caesalpiniaceae								
Bauhinia racemosa Lam.	B	FO	T	P	9.57 ± 3.84	8.32 ± 2.11	24.02 ± 12.16	41.91 ± 13.58
* *Cassia absus* L.	B	FO	H	A/B	14.14 ± 3.86	42.36 ± 12.12	10.21 ± 3.56	66.71 ± 8.53
C. auriculata L.	A	GL	S	P	31.89 ± 6.85	9.31 ± 4.18	23.81 ± 8.09	65.01 ± 14.10
C. fistula L.	A	SC	T	P	17.53 ± 8.97	0.00 ± 0.00	40.28 ± 13.12	57.81 ± 12.93
* *C. hirsuta* L.	B	FO	US	P	4.95 ± 1.36	20.31 ± 7.85	45.21 ± 14.96	70.47 ± 9.86
C. occidentalis L.	A	SC	US	P	4.90 ± 1.38	25.36 ± 10.12	60.21 ± 10.16	90.47 ± 3.86
C. occidentalis L.	B	FO			14.53 ± 3.97	13.29 ± 5.86	20.21 ± 3.16	48.03 ± 9.37

Table 2 (Continued)

Plant species	Site[a]	Habitat[b]	Life-form[c]	Life-cycle[d]	AM colonization (%)[e]			
					HC	AC	VC	TC
# *C. pumila* Lam.	B	FO	US	P	–	–	–	–
# *C. tora* L.	B	FO	H	A	–	–	–	–
* *Delonix regia* (Boj. ex Hock.) Rafin.	A	SC	T	P	35.12 ± 7.39	0.00 ± 0.00	20.49 ± 8.22	55.61 ± 12.58
Parkinsonia aculeata L.	A	SC	T	P	41.30 ± 6.03	13.85 ± 4.86	14.81 ± 9.74	69.96 ± 18.41
# *Tamarindus indica* L.	A	SC	T	P	–	–	–	–
Mimosaceae								
# *Acacia auriculiformis* A. Cunn. ex G. Don.	A	SC	T	P	–	–	–	–
A. dealbata Link	A	SC	T	P	23.86 ± 2.95	8.71 ± 2.02	42.61 ± 13.11	75.18 ± 9.73
A. eburnea (L.f.) Willd.	A	SC	T	P	8.55 ± 3.39	30.45 ± 2.36	28.12 ± 1.59	67.12 ± 12.15
A. farnesiana (L.) Willd	A	SC	T	P	18.31 ± 2.51	12.36 ± 1.58	49.31 ± 12.91	79.98 ± 13.86
A. leucophloea (Rab.) Willd.	A	SC	T	P	7.51 ± 2.11	10.12 ± 3.87	23.11 ± 5.38	40.74 ± 6.12
A. mearnsii Wilde	A	SC	T	P	12.12 ± 1.36	13.11 ± 5.81	41.01 ± 9.17	66.24 ± 8.50
A. nilotica (L.) Willd. ex Del	A				–	–	–	–
sub sp. *indica* (Benth.) Brenan	A	SC	T	P	6.58 ± 2.31	20.15 ± 3.15	31.81 ± 13.86	58.54 ± 11.01
# *Albizia lebbeck* (L.) Willd.	A	SC	T	P	–	–	–	–
Leucaena latisiliqua (L.) Gillis	A	SC	T	P	12.41 ± 3.25	18.51 ± 4.84	33.81 ± 4.11	64.73 ± 6.12
Mimosa pudica L.	A	GL	US	P	8.91 ± 1.98	10.15 ± 3.12	53.15 ± 12.61	72.21 ± 6.37
Pithecellobium dulce (Roxb.) Benth.	A	SC	T	P	18.61 ± 6.13	7.51 ± 5.81	20.89 ± 5.38	47.01 ± 9.31
Prosopis cineraria (L.) Druce	A	SC	T	P	12.82 ± 5.92	15.31 ± 3.22	30.11 ± 7.89	58.24 ± 8.36
Myrtaceae								
# *Eucalyptus globulus* Labill.	A	FO	T	P	–	–	–	–
Cucurbitaceae								
# *Coccinia grandis* (L.) Voigt	A	GL	CLH	P	–	–	–	–
Mukia leiosperma (Wight & Arn.) Wight	B	FO	CLH	P	–	–	–	–
Zehneria scabra (L.f.) Sond.	B	FO	CLH	P	–	–	–	–
Begoniaceae								
# *Begonia malabarica* Lam.	B	FO	S	P	–	–	–	–
Cactaceae								
Opuntia dillenii (Ker.-Gawl.) Haw.	A	SC	S	P	9.35 ± 2.08	4.81 ± 2.61	23.51 ± 4.61	37.67 ± 5.59
Aizoaceae								
* *Trianthema portulacastrum* L.	A	GL	H	A	27.68 ± 12.58	2.34 ± 0.05	14.12 ± 1.95	44.14 ± 7.36
Moulluginaceae								
Gisekia pharnaceoides L.	A	GL	H	A	–	–	–	–
Glinus oppositifolius (L.) A.DC.	B	GL	H	A	–	–	–	–
Moullugo nudicaulis Lam.	A	GL	H	A	–	–	–	–
M. pentaphylla L.	B	GL	H	A	–	–	–	–
Umbelliferae								
# *Centella asiatica* (L.) Urban	B	GL	H	P	–	–	–	–
Rubiaceae								
* *Hedyotis aspera* Heyne ex Roth	A	GL	H	A	11.00 ± 3.04	9.13 ± 1.37	0.00 ± 0.00	20.13 ± 3.45
H. corymbosa (L.) Lam.	A	GL	H	A	5.75 ± 2.11	3.62 ± 0.70	3.87 ± 1.92	13.24 ± 3.67
* *Pavetta indica* L.	A	SC	S	P	13.41 ± 6.41	12.83 ± 4.61	20.36 ± 11.58	46.60 ± 14.95
Spermacoce hispida L.	A	SC	H	A/B	8.66 ± 4.39	40.97 ± 2.87	0.00 ± 0.00	49.63 ± 5.68
# *Tarenna asiatica* (L.) Kuntze ex K. Schum.	B	FO	S	P	–	–	–	–
Compositae								
* *Anaphalis elliptica* DC.	F	GL	H	A	0.31 ± 0.15	3.21 ± 1.15	8.79 ± 3.75	12.31 ± 4.53
# *A. notoniana* (DC.) DC.	F	GL	H	A	–	–	–	–
# *Bidens pilosa* L. var. *minor* (Blume) Sherff	A	GL	H	A	–	–	–	–
* *Emilia sonchifolia* (L.) DC.	A	GL	H	A	27.49 ± 10.11	37.54 ± 4.83	3.97 ± 1.14	69.00 ± 10.06
* *Glossogyne bidens* (Retz.) Alston	A	GL	H	P	3.19 ± 1.09	44.21 ± 11.01	45.81 ± 7.94	93.21 ± 10.42
* *Gnaphalium polycaulon* Pers.	B	FO	H	A	2.41 ± 1.17	18.91 ± 2.33	41.39 ± 12.86	62.71 ± 14.33
# *Grangea maderaspatana* (L.) Poir.	B	FO	H	A	–	–	–	–
* *Lagascea mollis* Cav.	A	GL	H	A	1.97 ± 0.85	55.69 ± 4.78	5.66 ± 1.03	63.32 ± 5.75
Parthenium hysterophorus L.	A	GL	S	A	15.28 ± 4.92	29.81 ± 5.88	18.76 ± 7.45	63.85 ± 7.26
Tridax procumbens L.	A	GL	H	P	10.94 ± 5.21	67.97 ± 10.38	1.90 ± 1.55	80.81 ± 11.33
Vernonia cinerea (L.) Less.	A	SC	H	P	11.07 ± 4.73	22.87 ± 4.62	25.27 ± 9.55	59.21 ± 7.20
Vicoa indica (L.) DC.	A	GL	H	A	37.00 ± 10.15	24.55 ± 3.59	23.68 ± 0.61	85.23 ± 0.83
Plumbaginaceae								
Plumbago zeylanica L.	A	SC	H	P	18.91 ± 4.08	12.81 ± 6.31	23.51 ± 8.14	55.23 ± 12.81

Table 2 (Continued)

Plant species	Site[a]	Habitat[b]	Life-form[c]	Life-cycle[d]	AM colonization (%)[e] HC	AC	VC	TC
Sapotaceae								
# *Madhuca longifolia* (Koen.) Macbr.	A	FO	T	P	–	–	–	–
# *Mimusops elengi* L.	A	FO	T	P	–	–	–	–
Oleaceae								
Jasminum angustifolium (L.) Willd.	B	FO	S	P	23.11 ± 8.31	14.11 ± 3.97	21.81 ± 7.15	59.03 ± 8.99
Apocynaceae								
Carissa carandas L.	A	GL	S	P	–	–	–	–
Catharanthus pusillus (Murr.) G. Don.	A	SC	H	A	–	–	–	–
# *C. roseus* (L.) G. Don	A	GL	S	A	–	–	–	–
# *C. roseus* (L.) G. Don.	B	GL						
* *Rauwolfia serpentina* (L.) Benth. ex. Kurz	B	FO	US	P	18.69 ± 5.25	10.12 ± 3.58	3.86 ± 1.72	32.67 ± 11.15
Asclepiadaceae								
# *Asclepias curassavica* L.	B	FO	H	P	–	–	–	–
Calotropis gigantea (L.) R. Br.	A	SC	S	P	8.44 ± 3.88	2.37 ± 1.35	7.51 ± 2.18	18.32 ± 5.36
# *C. procera* (Ait.) R. Br.	A	SC	S	P	–	–	–	–
Caralluma adscendens (Roxb.) Haw var. *attenuata* (Wight) Grav. & Mayuranathan	A	SC	H	P	–	–	–	–
* *Leptadenia reticulata* (Retz.) Wight & Arn.	A	SC	S	P	1.21 ± 1.05	3.75 ± 1.39	3.36 ± 2.15	8.32 ± 2.97
# *Pentatropis capensis* (L.f.) Bullock	A	SC	CLH	P	–	–	–	–
# *Pergularia daemia* (Forssk.) Chiov.	A	SC	CLH	P	–	–	–	–
Tylophora indica (Burm.f.) Merr.	A	SC	CLH	P	–	–	–	–
Periplocaceae								
* *Cryptostegia grandiflora* R.Br.	B	FO	CLS	P	19.37 ± 6.41	5.36 ± 2.10	23.87 ± 6.21	48.60 ± 12.07
Hemidesmus indicus (L.) R.Br. var. *indicus* Wight	A	FO	CLH	P	2.71 ± 1.08	18.63 ± 5.63	43.81 ± 7.77	65.15 ± 13.38
Boraginaceae								
* *Heliotropium marifolium* Retz.	A	GL	H	A	6.47 ± 2.11	7.41 ± 0.85	1.48 ± 1.29	15.36 ± 1.10
H. ovalifolium Forssk.	A	GL	H	A	18.83 ± 4.37	12.86 ± 3.16	10.12 ± 4.37	41.81 ± 12.38
# *H. supinum* L.	A	SC	H	A	–	–	–	–
Trichodesma indicum (L.) R.Br.		FO	H	A	16.61 ± 8.73	8.11 ± 3.01	23.15 ± 12.17	47.87 ± 13.84
* *T. zeylanicum* (Burm.f.) R.Br.	A	FO	H	A	11.16 ± 5.61	5.12 ± 2.05	18.91 ± 6.08	35.19 ± 8.31
Convolvulaceae								
Evolvulus alsinoides (L.) L.	A	GL	H	P	6.44 ± 3.18	41.47 ± 6.83	18.23 ± 1.37	66.14 ± 5.74
# *Ipomoea asarifolia* (Desr.) Roem. & Schultes	B	GL	H	P	–	–	–	–
* *I. eriocarpa* R.Br.	A	FO	H	P	18.12 ± 9.15	6.81 ± 1.05	23.14 ± 9.15	48.07 ± 12.64
* *I. quamoclit* L.	A	FO	CLH	A	16.72 ± 5.32	23.41 ± 12.11	40.18 ± 8.79	80.31 ± 14.31
* *I. staphylina* Roem. & Schultes	A	GL	CLS	P	12.15 ± 4.56	18.95 ± 6.83	20.19 ± 4.82	51.29 ± 12.61
Merremia tridentata (L.) Hall.	A	GL	H	P	25.56 ± 12.76	16.89 ± 1.60	39.88 ± 1.12	82.33 ± 6.48
Solanaceae								
* *Datura metel* L.	A	GL	US	A/B	20.95 ± 8.36	8.36 ± 2.88	23.81 ± 9.72	53.12 ± 12.36
* *D. stramonium* L.	A	FO	US	A	15.88 ± 5.21	12.36 ± 5.31	14.95 ± 3.26	43.19 ± 8.05
# *Solanum anguivi* Lam.	A	FO	US	P	–	–	–	–
S. melongena L. var. *melongena* Wight	A	FO	H	A	24.54 ± 8.03	14.56 ± 3.58	30.21 ± 8.59	69.31 ± 10.52
# *S. nigrum* L.	A	FO	H	A	–	–	–	–
# *S. torvum* Sw.	A	SC	S	P	–	–	–	–
* *S. trilobactum* L.	A	SC	CLS	P	22.82 ± 7.63	14.36 ± 8.54	12.03 ± 4.11	49.21 ″ 3.86
Scrophulariaceae								
# *Scoparia dulcis* L.	B	FO	US	A	–	–	–	–
Sopubia delphiniifolia (L.) G. Don	B	FO	H	A	–	–	–	–
# *Striga asiatica* (L.) Kuntze	B	GL	H	A	–	–	–	–
S. asiatica (L.) Kuntze	A	GL			–	–	–	–
Lentibulariaceae								
Utricularia coerulea L.	F	GL	H	A	–	–	–	–
U. uliginosa Vahl.	F	GL	H	A	–	–	–	–
Bignoniaceae								
* *Crescentia cujete* L.	A	FO	T	P	19.56 ± 8.07	8.10 ± 5.12	27.51 ± 6.57	55.17 ± 8.71
Millingtonia hortensis L.f.	A	FO	T	P	5.97 ± 1.38	16.61 ± 2.51	38.50 ± 5.80	61.08 ± 12.95

Table 2 (Continued)

Plant species	Site[a]	Habi-tat[b]	Life-[c] form	Life-[d] cycle	AM colonization (%)[e]			
					HC	AC	VC	TC
Pedaliaceae								
Pedalium murex L.	A	GL	H	A	3.57 ± 1.81	29.13 ± 7.47	7.17 ± 3.20	39.87 ± 8.75
Acanthaceae								
* *Andrographis paniculata* (Burm.f.) Wall. ex Nees	A	FO	H	A	25.64 ± 12.15	4.31 ± 0.33	2.38 ± 1.50	32.33 ± 4.34
* *Barleria cristata* L.	B	FO	US	A	25.14 ± 6.99	5.21 ± 1.81	13.98 ± 6.12	44.33 ± 8.76
* *B. cuspidata* Heyene ex Nees	A	FO	S	A	16.32 ± 6.84	15.36 ± 4.93	8.53 ± 2.71	40.21 ± 7.58
B. noctiflora L.f.	A	GL	S	A	13.17 ± 6.72	18.21 ± 3.85	28.23 ± 9.98	59.61 ± 7.96
* *Crossandra infundibuliformis* (L.) Nees	B	FO	US	P	20.19 ± 5.31	9.87 ± 3.26	18.64 ± 6.32	48.70 ± 15.32
* *Justicia adhatoda* L.	A	GL	S	P	23.86 ± 9.73	12.52 ± 6.83	22.04 ± 4.16	58.42 ± 9.73
J. glauca Rottl.	A	GL	H	A	32.15 ± 10.17	8.11 ± 4.67	12.97 ± 3.63	53.23 ± 12.61
Rostellularia prostrata (Roxb. ex Clarke) Majumdar	A	SC	H	A	18.07 ± 6.85	19.23 ± 4.79	16.35 ± 2.53	53.65 ± 5.00
Verbenaceae								
# *Lantana camara* L.	B	SC	S	P	–	–	–	–
# *Priva cordifolia* (L.f.) Druce	A	GL	H	A	–	–	–	–
Tectona grandis L.f.	B	FO	T	P	8.58 ± 2.08	18.36 ± 6.21	35.21 ± 8.71	62.15 ± 8.31
Vitex negundo L.	A	FO	T	P	21.15 ± 7.92	32.21 ± 9.82	12.91 ± 4.81	66.27 ± 11.05
Labiatae								
Hyptis suaveolens (L.) Poit.	B	FO	H	A	12.39 ± 4.81	8.61 ± 2.33	33.27 ± 9.81	54.27 ± 8.61
Leucas aspera (Willd.) Link	A	GL	H	A	14.64 ± 6.68	53.13 ± 12.34	2.79 ± 2.33	70.56 ± 13.66
* *L. biflora* (Vahl) R.Br.	B	FO	H	A	18.91 ± 5.36	12.39 ± 4.33	28.15 ± 7.88	59.45 ± 12.74
# *Ocimum basilicum* L. var. *basilicum* Hook. f.	B	GL	H	A/B	–	–	–	–
* *O. basilicum* L. var. *pilosum* Benth.	A	GL	H	A	15.15 ± 15.19	8.81 ± 3.86	1.80 ± 1.47	25.76 ± 10.55
* *O. basilicum* L. var. *purpurascens* Benth.	A	GL	H	A	23.11 ± 5.89	11.09 ± 5.42	30.01 ± 9.88	64.21 ± 14.09
# *Orthosiphon thymiflorus* (Roth.) Sleensen	A	SC	H	A	–	–	–	–
# *O. thymiflorus* (Roth.) Slenesen	B	FO			–	–	–	–
# *Plectranthus vettiveroides* (Jacob) Singh & Sharma	B	FO	H	P	–	–	–	–
Nyctaginaceae								
# *Boerhaavia diffusa* L.	A	SC	H	P	–	–	–	–
# *Mirabilis jalapa* L.	A	GL	H	P	–	–	–	–
Amaranthaceae								
* *Achyranthes aspera* L.	A	SC	H	A	6.79 ± 3.94	2.44 ± 1.99	2.53 ± 1.15	11.76 ± 4.13
# *Aerva lanata* (L.) Juss. ex Schultes	A	SC	US	P	–	–	–	–
# *A. persica* (Burm.f.) Merr.	A	SC	H	A	–	–	–	–
Allmania nodiflora (L.) R.Br. ex Wight	A	SC	H	A	–	–	–	–
# *Alternanthera sessilis* (L.) R.Br. ex. DC.	A	GL	H	A	–	–	–	–
# *Amaranthus spinosus* L.	B	FO	H	A	–	–	–	–
# *A. tricolor* L.	A	GL	H	A	–	–	–	–
# *A. viridis* L.	A	GL	H	A	–	–	–	–
# *Celosia argentea* L.	A	GL	H	A	–	–	–	–
# *C. polygonoides* Retz.	A	GL	H	A	–	–	–	–
Digera muricata (L.) Mart. Beitr. Amar.	A	SC	H	A	–	–	–	–
* *Gomphrena serrata* L.	A	SC	H	P	31.19 ± 15.36	12.08 ± 7.46	15.62 ± 8.94	58.89 ± 14.05
Pupalia lappaceae (L.) Juss.	A	SC	S	P	–	–	–	–
Trichurus monsoniae (L.f.) Townsed	A	GL	H	P	–	–	–	–
Aristolochiaceae								
* *Aristolochia bracteata* Lam.	B	FO	H	P	14.91 ± 5.88	7.91 ± 2.51	20.94 ± 3.81	43.76 ± 9.82
# *A. indica* L.	A	FO	H	P	–	–	–	–
Santalaceae								
# *Santalum album* L.	A	FO	T	P	–	–	–	–
Euphorbiaceae								
# *Acalypha ciliata* Forssk.	A	GL	H	A	–	–	–	–
A. fruticosa Forssk.	B	FO	US	A	12.33 ± 4.08	5.37 ± 1.32	13.19 ± 3.48	30.89 ± 9.27
A. indica L.	A	GL	H	A	2.67 ± 1.91	31.85 ± 2.63	6.01 ± 2.04	40.53 ± 4.35
* *A. lanceolata* Willd.	B	FO	H	A	18.37 ± 9.10	14.18 ± 4.21	24.92 ± 3.10	57.47 ± 12.84
Croton bonplandianum Baill.	B	FO	H	A	–	–	–	–
Euphorbia antiquorum L.	A	FO	S	P	45.85 ± 1.74	5.99 ± 0.59	38.18 ± 2.14	90.02 ± 1.85
# *E. cyathophora* Murr.	A	GL	H	A	–	–	–	–
E. geniculata Orteg.	A	GL	H	A	–	–	–	–

Table 2 (Continued)

Plant species	Site[a]	Habitat[b]	Life-form[c]	Life-cycle[d]	AM colonization (%)[e]			
					HC	AC	VC	TC
E. hirta L.	A	FO	H	A	10.00 ± 3.74	27.63 ± 4.92	24.05 ± 2.22	61.68 ± 7.30
* *E. indica* Lam.	A	GL	H	A	20.11 ± 4.83	2.31 ± 1.58	30.86 ± 12.41	53.28 ± 9.15
* *E. thymifolia* L.	A	GL	H	A	1.41 ± 0.85	12.50 ± 2.36	2.78 ± 0.11	16.69 ± 3.12
* *E. tirucalli* L.	A	SC	S	P	12.15 ± 3.17	10.39 ± 2.06	23.11 ± 2.87	45.65 ± 9.01
# *E. tortilis* Rottl. ex Ainslie	A	SC	H	P	–	–	–	–
* *Jatropha glandulifera* Roxb.	A	SC	S	P	35.41 ± 13.85	9.49 ± 4.25	24.24 ± 9.76	69.14 ± 14.01
* *Micrococca mercurialis* (L.) Benth.	B	FO	H	A	21.05 ± 4.31	19.24 ± 6.10	13.41 ± 2.81	53.70 ± 9.86
Phyllanthus amarus Schum. & Thonn.	A	GL	H	A	–	–	–	–
* *P. maderaspatensis* L.	A	GL	H	A	13.59 ± 7.59	30.57 ± 6.17	2.05 ± 0.18	46.21 ± 0.18
* *P. emblica* L.	A	FO	T	P	18.54 ± 7.81	4.32 ± 1.08	28.94 ± 8.61	51.80 ± 14.98
P. reticulatus Poir.	B	FO	S	A	–	–	–	–
# *Sebastiania chamaelea* (L.) Muell-Arg.	B	FO	H	A	–	–	–	–
# *S. leulopyrus* (Willd.) Muell-Arg.	B	FO	S	P	–	–	–	–
Urticaceae								
# *Pilea microphylla* (L.) Liebm.	B	FO	H	A	–	–	–	–
# *Pouzolzia auriculata* Wight	B	FO	H	A	–	–	–	–
# *P. zeylanica* (L.) Benn.	B	FO	H	P	–	–	–	–
Moraceae								
# *Artocarpus heterophyllus* Lam.	B	FO	T	P	–	–	–	–
# *Ficus benghalensis* L.	A	FO	T	P	–	–	–	–
# *F. religiosa* L.	A	SC	T	P	–	–	–	–
Agavaceae								
# *Agave angustifolia* Haw.	A	SC	H	P	–	–	–	–
# *Sansevieria roxburghiana* Schultes & Schultes f.	A	SC	H	P	–	–	–	–
Hypoxidaceae								
Curculigo orchioides Gaertn.	B	FO	H	P	17.24 ± 2.36	18.97 ± 5.62	23.27 ± 9.52	59.48 ± 10.34
Dioscoreaceae								
Dioscorea bulbifera L.	B	FO	CLH	P	29.87 ± 5.21	8.12 ± 1.37	18.39 ± 4.72	56.37 ± 3.12
* *D. pentaphylla* L.	B	FO	CLH	P	18.77 ± 2.73	13.18 ± 3.42	35.17 ± 8.56	67.12 ± 5.32
Liliacea								
Aloe vera (L.) Burm. f.	A	SC	H	P	17.69 ± 8.26	8.12 ± 4.15	19.57 ± 4.18	45.38 ± 12.82
Asparagus racemosus Willd.	A	SC	CLS	P	44.91 ± 2.50	12.36 ± 1.52	23.56 ± 6.86	80.83 ± 15.17
Gloriosa superba L.	A	SC	CLH	P	1.3 ± 1.18	7.12 ± 2.91	23.96 ± 9.12	32.38 ± 9.37
Iphigenia indica (L.)	A							
Gray ex Kunth	B	FO	H	P	2.89 ± 1.38	12.95 ± 8.32	33.28 ± 8.79	49.12 ± 18.54
Scilla hyacinthina (Roth) Macbr.	B	FO	H	P	11.31 ± 5.38	9.36 ± 3.18	28.50 ± 3.19	49.31 ± 12.51
Commelinaceae								
* *Commelina attenuata* Koen. ex. Vahl.	B	FO	H	P	18.36 ± 1.52	3.21 ± 0.58	21.61 ± 5.32	43.18 ± 7.39
# *C. benghalensis* L.	A	GL	H	P	–	–	–	–
* *C. diffusa* Burm. f.	B	GL	H	P	10.26 ± 3.18	4.91 ± 2.52	3.35 ± 1.24	18.52 ± 4.98
# *C. forskalaei* Vahl	B	GL	H	P	–	–	–	–
# *C. hirsuta* (Wight) Clarke	B	FO	H	P	–	–	–	–
# *Cyanotis cristata* (L.) Don	B	FO	H	P	–	–	–	–
# *C. tuberosa* (Roxb.) Schultes & Schultes f.	A	GL	H	P	–	–	–	–
Murdannia semiteres (Dalz.) Sant.	A	GL	H	A	–	–	–	–
Tonningia axillaris (L.) Kuntze	A	GL	H	P	–	–	–	–
Eriocaulaceae								
Eriocaulon cinereum R.Br.	F	GL	H	A	–	–	–	–
E. conicum (Fyson) Fisher	F	GL	H	A	–	–	–	–
E. elenorae Fyson	F	GL	H	A	–	–	–	–
Cyperaceae								
Bulbostylis barbata (Rottb.) Clarke	A	GL	H	A	27.29 ± 12.18	2.12 ± 1.14	18.15 ± 5.71	47.56 ± 9.12
B. barbata (Rottb.) Clarke	B	GL			16.95 ± 8.64	5.08 ± 1.26	11.44 ± 3.41	33.47 ± 12.95
# *B. densa* (Wall.) Hand.-Mazz.	C	GL	H	A	–	–	–	–
# *Carex baccans Nees*	C	GL	H	P	–	–	–	–
C. baccans Nees	D	FO	H	P	22.14 ± 12.05	17.48 ± 5.86	14.08 ± 2.70	53.70 ± 6.43
# *C. lindleyana* Nees	C	GL	H	P	–	–	–	–
C. myosurus Nees	C	GL	H	P	30.98 ± 15.80	7.89 ± 6.44	8.84 ± 3.03	47.71 ± 5.53
# *C. speciosa* Kunth	C	GL	H	P	–	–	–	–

Table 2 (Continued)

Plant species	Site[a]	Habitat[b]	Life-form[c]	Life-cycle[d]	AM colonization (%)[e]			
					HC	AC	VC	TC
# *Cyperus brevifolius* (Rottb.) Haask	B	FO	H	P	–	–	–	–
# *C. clarkei* Cooke	A	GL	H	P	–	–	–	–
C. compressus L.	A	GL	H	A	14.97 ± 9.31	8.06 ± 1.35	1.16 ± 0.91	24.19 ± 5.95
# *C. cyperinus* (Retz.) Valcken.	A	GL			–	–	–	–
C. cyperinus (Retz.) Valcken.	B	GL			16.05 ± 3.87	1.16 ± 1.00	7.25 ± 2.45	24.46 ± 4.22
# *C. cyperinus* (Retz.) Valcken.	D	CL	H	P	–	–	–	–
# *C. distans* L.f.	B	FO	H	P	–	–	–	–
# *C. dubius* Rottb.	B	FO	H	P	–	–	–	–
# *C. iria* L.	A	GL	H	P	–	–	–	–
# *C. iria* L.	B	GL			–	–	–	–
# *C. kyllinga* Endlicher	B	GL	H	P	–	–	–	–
# *C. nutans* Vahl	B	GL	H	P	–	–	–	–
# *C. paniceus* (Rottb.) Boeckeler	B	FO	H	P	–	–	–	–
# *C. rotundus* L.	A	GL	H	P	–	–	–	–
# *C. rotundus* L.	B	GL			–	–	–	–
# *C. rotundus* L.	E	CL			–	–	–	–
# *C. squarrosus* L.	B	GL	H	A	–	–	–	–
C. triceps (Rottb.) Endlicher	B	GL	H	P	13.29 ± 4.15	2.06 ± 1.46	1.03 ± 0.73	16.38 ± 8.10
# *Eleocharis acutangula* (Roxb.) Schultes	B	FO	H	P	–	–	–	–
# *Fimbristylis consanguinea* Kunth	B	FO	H	P	38.88 ± 10.05	5.56 ± 3.25	13.89 ± 6.15	58.33 ± 10.15
# *F. falcata* (Vahl) Kunth	A	GL	H	P	–	–	–	–
F. ovata (Burm.f.) Kern	A	GL	H	P	5.17 ± 1.32	4.74 ± 1.25	15.95 ± 6.15	25.86 ± 10.26
# *Scleria lithosperma* (L.) SW	A	SC	H	P	–	–	–	–
S. lithosperma (L.) SW.	B	FO			41.67 ± 10.48	8.33 ± 3.21	11.67 ± 1.75	61.67 ± 21.15
Poaceae								
# *Alloteropsis cimicina* (L.) Stapf.	A	GL	H	A	–	–	–	–
A. cimicina (L.) Stapf.	B	GL			28.42 ± 3.94	13.10 ± 4.36	27.10 ± 1.82	68.63 ± 3.15
# *Andropogon pumilus* Roxb.	A	GL	H	A	–	–	–	–
# *Aristida adscensionis* L.	A	GL	H	A	–	–	–	–
* *A. setacea* Retz.	A	GL	H	A	10.67 ± 1.79	13.97 ± 1.48	1.91 ± 1.25	26.54 ± 3.59
Bambusa bambos L.	B	PL	H	A	10.38 ± 2.03	15.16 ± 3.15	25.12 ± 4.11	50.66 ± 8.01
# *Bothrichola pertusa* (L.) A. Camus	B	GL	S	P	–	–	–	–
* *Braciaria ramosa* (L.) Stapf	B	FO	H	P	11.36 ± 6.70	2.83 ± 2.00	1.04 ± 0.74	15.24 ± 5.43
# *B. reptans* (L.) Gard. & Hubbard	B	FO	H	A	–	–	–	–
# *Chloris barbata* Sw.	A	CL	H	A	–	–	–	–
# *Chrysopogon aciculatus* (Retz.) Trin.	B	GL	H	P	–	–	–	–
C. fulvus (Spreng.) Chiov.	A	GL	H	P	–	–	–	–
* *C. zeylanicus* (Nees ex. Steud.) Thw. Enum.	E	GL	H	P	15.11 ± 3.86	8.95 ± 2.14	25.68 ± 5.11	49.74 ± 6.78
Cymbopogon caesius (Nees ex Hook. & Arn.) Stapf	A	GL	H	P	6.52 ± 1.32	9.56 ± 3.12	10.32 ± 2.14	26.58 ± 5.62
# *C. flexuosus* (Nees ex Steud.) Wats.	B	GL	H	P	–	–	–	–
Cyanodon arcuatus J.S. Presl	B	GL	H	P	11.50 ± 5.48	8.02 ± 3.44	3.25 ± 2.66	22.77 ± 8.82
C. dactylon (L.) Pers.	A	CL	H	P	–	–	–	–
* *Cyrtococcum patens* (L.) A. Camus	B	GL	H	P	22.83 ± 5.62	8.51 ± 1.03	25.33 ± 6.13	56.67 ± 8.85
# *Dactyloctenium aegypticum* (L.) Willd.	B	GL	H	A	–	–	–	–
# *Dendrocalamus strictus* (Roxb.) Ness.	A	FO	S	P	–	–	–	–
# *Dichanthium caricosum* (L.) A. Camus	A	GL	H	P	–	–	–	–
Digitaria bicornis (Lam.) Roem. & Schultes ex Loud.	B	GL	H	P	21.42 ± 6.17	16.37 ± 4.83	1.08 ± 0.42	38.87 ± 5.48
* *D. ciliaris* (Retz.) Koeler	A	GL	H	A	7.26 ± 1.76	5.83 ± 1.35	2.44 ± 0.42	15.53 ± 2.70
# *D. ciliaris* (Retz.) Koeler	B	GL						
* *Dinebra retroflexa* (Vahl.) Panzer	B	GL	H	A	–	–	–	–
Echinochloa colona (L.) Link	B	GL	H	P	–	–	–	–
Enneapogon schimperanus (Hoechst. ex A. Rich.) Renvoize	A	GL	H	P	–	–	–	–
* *Eragrostiella bifaria* (Vahl.) Bor	A	GL	H	P	29.38 ± 6.82	3.00 ± 4.50	40.52 ± 13.86	73.12 ± 4.50
# *Eragrostis gangetica* (Roxb.) Steud.	A	GL	H	A	–	–	–	–
# *E. pilosa* P. Beauv.	B	GL	H	A	–	–	–	–
# *E. tenella* (L.) P. Beauv. ex Roem & Schultes	A	GL	H	A	–	–	–	–
Eremopogon foveolatus (Del.) Stapf	A	GL	H	A	–	–	–	–
Eriochloa procera (Retz.) Hubbard	B	GL	H	P	–	–	–	–
Hackelochloa granularis (L.) Kuntze	B	GL	H	A	–	–	–	–
Heteropogon contortus (L.) P. Beauv. ex. Roehm. & Schultes	A	GL	H	P	23.99 ± 5.32	12.52 ± 3.61	35.36 ± 5.72	71.87 ± 5.32

Table 2 (Continued)

Plant species	Site[a]	Habitat[b]	Life-form[c]	Life-cycle[d]	AM colonization (%)[e]			
					HC	AC	VC	TC
# *Imperata cylindrica* (L.) Raeusch.	B	GL	H	P	–	–	–	–
* *Isachne globosa* (Thunb.) Kuntze	B	GL	H	P	–	–	–	–
* *Oplismenus compositus* (L.) P. Beauv.	B	GL	H	P	12.08 ± 3.12	15.31 ± 4.86	7.14 ± 2.31	34.53 ± 8.15
* *Panicum psilopodium* Trin.	A	GL	H	A	24.98 ± 2.77	7.94 ± 2.46	27.75 ± 1.59	60.67 ± 2.78
# *P. trypheron* Schultes	B	GL	H	A	–	–	–	–
* *Paspalidium flavidum* (Retz.) A. Camus	B	FO	H	P	8.01 ± 0.16	7.69 ± 5.44	0.00 ± 0.00	15.71 ± 5.22
# *Paspalum distichum* L.	A	FO	H	P	–	–	–	–
* *P. scrobiculatum* L.	B	GL	H	A	25.31 ± 5.10	12.88 ± 3.10	30.81 ± 5.86	69.00 ± 9.15
Pennisetum hohenackeri Hockst. ex Steud.	B	GL	H	P	20.31 ± 4.85	12.19 ± 3.16	23.11 ± 5.38	55.50 ± 6.53
# *Perotis indica* (L.) Kuntze	A	SC	H	A	–	–	–	–
# *Pogonatherum crinitum* (Thunb.) Kunth	B	FO	H	P	–	–	–	–
# *Rottboelia cochinchinensis* (Lour.) Clayton	B	FO	H	P	–	–	–	–
Sacciolepsis interrupta (Willd.) Stapf.	B	FO	H	P	–	–	–	–
Setaria pumila (Poir.) Roem. & Schultes	B	GL	H	A	23.55 ± 4.18	18.36 ± 4.05	15.38 ± 2.16	57.29 ± 7.32
S. verticillata (L.) P. Beauv.	B	GL	H	A	–	–	–	–
Sporobolus indicus (L.) R.Br. var. *diander* (Retz.) Jovet & Guedes	A	GL	H	P	8.69 ± 2.32	5.64 ± 2.58	4.07 ± 1.66	18.40 ± 1.91
S. indicus (L.) R.Br. var. *diander* (Retz.) Jovet & Guedes	B	GL	H	P	6.64 ± 1.64	21.85 ± 3.86	2.42 ± 1.21	30.90 ± 2.74
Themeda cymbaria Hack.	F	GL	H	P	13.28 ± 3.16	15.17 ± 2.83	21.81 ± 4.85	50.26 ± 7.28
Vetiveria zizanoides (L.) Nash	A	GL	H	P	–	–	–	–

[a] For site names, see Table 1
[b] *FO* forest, *SC* scrub, *GL* grassland, *PL* plantation, *CL* cultivated land
[c] *H* herb, *S* shrub, *US* under shrub, *CLH* climbing herb, *CLS* climbing shrub
[d] *A* annual, *A/B* annual or biennial, *P* perennial
[e] *HC* hyphae, *VC* vesicule, *AC* arbuscule, *TC* total root/length colonized

rhizal colonization (Ragupathy et al. 1990; Ragupathy and Mahadevan 1993), even though the presence of arbuscules is an indication of mutualism between plants and AM fungi (Smith and Smith 1989).

The proportion of non-mycorrhizal species in the Western Ghats region is high compared with other vegetation world wide (Brundrett 1991; Koske et al. 1992; Allsopp and Stock 1993). As non-mycorrhizal plants are normally associated with high levels of disturbance, or edaphically and climatically extreme conditions, the high incidence of non-mycotrophy in Western Ghats is atypical and its ecological significance needs further exploration. Most plant species lacking AM colonization in the present study have been reported as such before. These were concentrated in supposedly non-mycorrhizal families like Amaranthaceae, Caryophyllaceae, Cleomaceae, Commelinaceae, Cyperaceae, Euphorbiaceae, Eriocaulaceae, Lentibulariaceae, Molluginaceae and Portulacaceae (Tester et al. 1987; Brundrett 1991). However, other species lacking mycorrhizas belonged to families reported to be mycorrhizal. Plants lacking mycorrhizas in the field cannot be considered as conclusive evidence for a non-mycorrhizal species since the present and some recent studies have indicated the widespread occurrence of mycorrhizas in several species previously considered to be non-mycorrhizal (Neeraj et al. 1991; Meney et al. 1993; Muthukumar et al. 1996). Forty-one percent of the plant species in this study had roots colonized by "*Glomus*-type" vesicles and hyphae, not coupled with arbuscules. Vesicles in AM host roots usually occur after arbuscule development and are present for only a short period of time in actively growing roots. However, many authors (see Giovannetti and Sbrana 1998) have described colonization of non-host roots with intercellular development of hyphae, often with the formation of vesicles but not arbuscules. Thus, different experimental approaches, such as growing plants in pot cultures to ascertain mycorrhizal status would be useful (Tester et al. 1987).

Eight of the 24 sedges examined in the present study were mycorrhizal, which contrasts with the reports of Allsopp and Stock (1993) and Peat and Fitter (1993), in which members of Cyperaceae were found to be non-mycorrhizal. Non-mycotrophy in members of Cyperaceae has been mainly ascribed to anaerobic water-logged habitats (Tester et al. 1987) or to the presence of chemicals in roots that inhibit mycorrhizal formation (Brundrett 1991). In a recent study, Lovera and Cuenca (1996) reported the widespread occurrence of mycorrhizae in sedges and attributed this to low soil nutrient levels. However, this may not be so, since in the present study *Carex baccans, Cyperus cyperinus* and *Scleria lithosperma* were mycorrhizal and non-mycorrhizal at different sites which varied very little in soil nutrient levels. Root characters are known to significantly affect the mycorrhizal status of plant species (Hetrick 1991) and several members of Cyperaceae possess long, dense root hairs (Muthukumar et al. 1996) or form cluster roots (Lamnot 1974), Thus, the mycorrhizal status of members of this family should be investigated with

Table 3 Distribution of AM species between the study sites and vegetation types. For site names, see Table 1. For other abbreviations, see Table 2

AM fungal species	Site					
	A	B	C	D	E	F
Acaulospora						
A. laevis Gerd. & Trappe	–	FO, GL	–	–	PL, CL	–
A. morrowiae Spain & Schenck	GL	FO, GL	–	–	–	–
A. scrobiculata Trappe	FO, SC, GL	–	–	–	PL	–
Gigaspora						
G. decipiens Hall & Abbott	–	–	GL	–	–	–
G. gigantea (Nicol. & Gerd.) Gerd. & Trappe	GL	GL	–	–	–	–
Glomus						
G. aggregatum Schenck & Smith emend. Koske	FO, SC, GL	FO, GL	GL	FO	PL, CL	FO, GL
G albidum Walker & Rhodes		FO, GL				
G. etunicatum Becker & Gerd.	FO, GL	FO, GL	–	FO	–	–
G. fasciculatum (Thatcher) Gerd. & Trappe emend. Walker & Koske	FO, SC, GL	FO	–	–	–	–
G. fecundisporum Schenck & Smith	SC	FO	GL	–	PL, CL	GL
G. formosanum Wu & Chen	FO, SC, GL	–	GL	–	–	–
G. geosporum (Nicol. & Gerd.) Walker	–	FO, GL	GL	FO	–	–
G. intraradices Shenck & Smith	–	FO, GL	–	FO	–	FO
G. macrocarpum Tul. & Tul.	SC	FO	GL	–	PL, CL	FO, GL
G. microaggregatum Koske, Gemma & Olexia	FO, SC, GL	GL	–	FO	–	FO, GL
G. microcarpum Tul. & Tul.	–	FO, GL	–	–	–	–
G. mossea (Nicol. & Gerd.) Gerd. & Trappe	FO, GL	FO, GL	–	FO	PL, CL	FO, SC
G. occultum Walker	–	GL	–	–	–	–
G. palladium Hall	GL	–	–	–	–	–
G. versiforme (Karsten) Berch	FO, SC	–	–	–	–	–
G. viscosum Nicolson	SC, GL	–	–	–	–	–
Glomus No. 1	SC, GL	–	–	–	–	–
Glomus No. 2	SC, GL	–	–	–	–	–
Glomus No. 3	SC, GL	–	–	–	–	–
Glomus No. 4	–	–	–	–	–	–
Glomus No. 5	–	FO, GL	–	–	–	FO
Sclerocystis						
S. clavispora Trappe	–	–	–	–	PL	–
S. rubiformis Gerd. & Trappe	SC	FO	–	–	–	–
S. sinuosa Gerd. & Bakshi	FO, SC, GL	FO	GL	–	PL	–
S. taiwanensis Wu & Chen	GL	–	–	–	–	–
Scutellospora						
S. calospora (Nicol. & Gerd.) Walker & Sanders	FO, SC, GL	FO, GL	–	–	–	–
S. heterogama (Nicol. & Gerd.) Walker & Sanders	GL	–	GL	–	–	–
S. pellucida (Nicol. & Gerd.) Walker & Sanders	–	FO, GL	–	–	–	–
S. persica (Koske & Walker) Walker & Sanders	–	–	GL	–	–	–
S. nigra (Redhead) Walker & Sanders	–	–	GL	–	–	–
Total species	22	20	10	6	8	7

respect to root architecture as well as to habitat conditions.

Mycorrhizal incidence in dicots (57%) was higher than in monocots (39%), which is in accordance with the observation of Newman et al. (1992). The highly efficient root system may render monocots less dependent on mycorrhizas (Hetrick 1991), but members of some monocot families, e.g. Liliaceae, are highly mycorrhizal dependent, as observed in the present study and elsewhere (Daft et al. 1980).

The lower frequency and levels of AM colonization in herbs than in other life-forms is in accord with the statement of Malloch et al. (1980) that “most woody plants need mycorrhizas to survive and most herbaceous plants need them to thrive”. The correlation between high mycorrhizal incidence in annuals and undis-

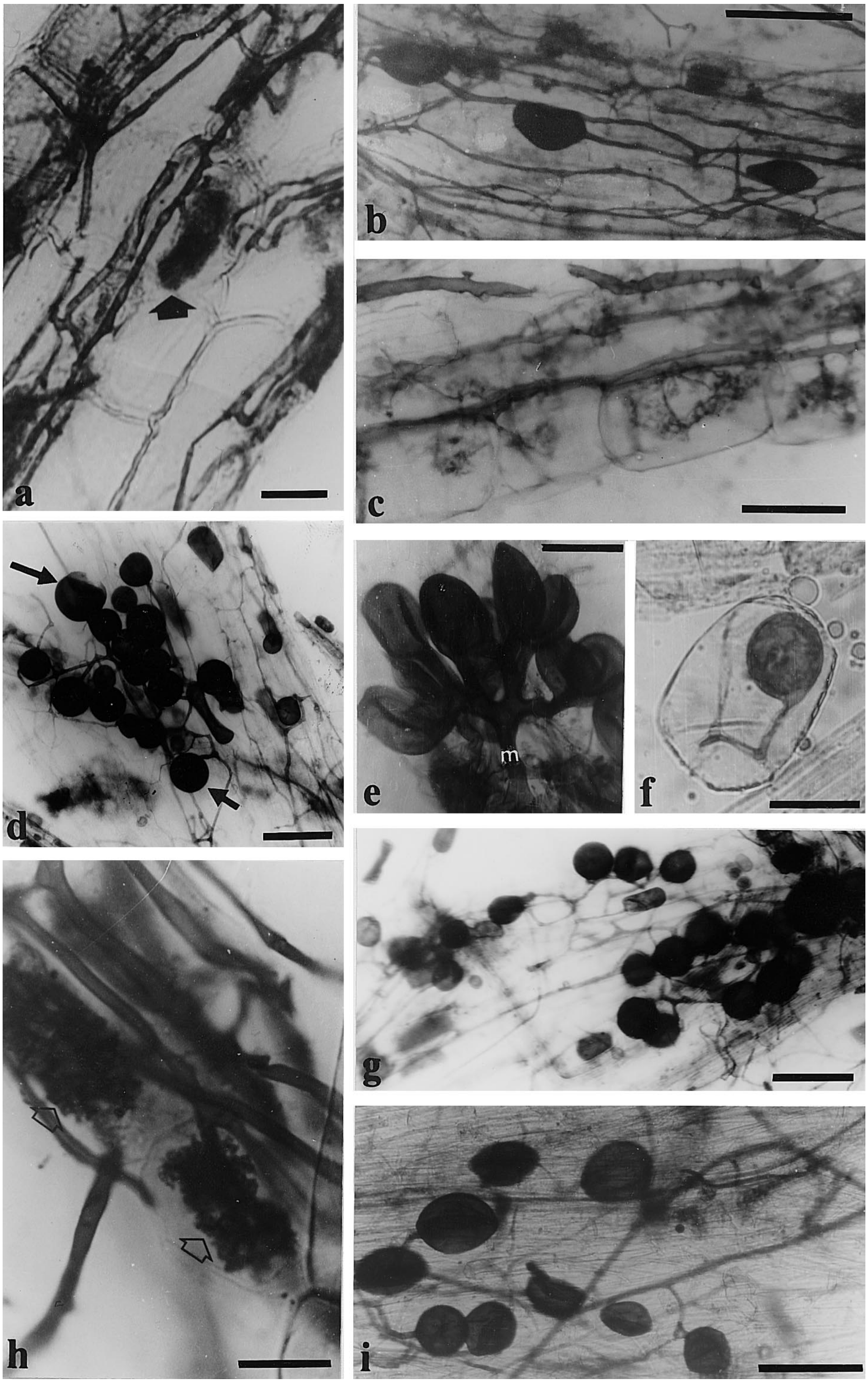


Fig. 2a–i Arbuscular mycorrhiza (AM) in angiosperms of the Western Ghats. **a** Arbuscule (*arrow*) in cortical cell of *Aspargus racemosus*; *bar* 50 µm. **b** Vesicles and hyphae in *Clitoria ternatea*; *bar* 100 µm. **c** Arbuscules in *Commelina attenuata*; *bar* 50 µm. **d** Vesicles, spores (*arrows*) and hyphae in *Bulbostylis barbata*; *bar* 100 µm. **e** A young sporocarp of *Sclerocystis rubiformis* within root of *Pongmia pinnata.* Monohyphal trunk (*m*); bar 50 µm. **f** Vesicle in root cell of *Cyperus compressus*; *bar* 50 µm. **g** *Cymbopogon caesius* root with hyphae and vesicles; *bar* 100 µm. **h** Two cortical cells of *Glossogyne bidens* with arbuscules (*arrows*); *bar* 20 µm. **i** Hyphae and vesicles in *Rauwolfia serpentina*; *bar* 100 µm

turbed ecosystems (Peat and Fitter 1993) is consistent with our results. Seedling establishment and survival in natural ecosystems depend on the quality of the seeds produced and AM association is known to improve both the quality and the quantity of seeds produced (Koide and Lu 1991). Thus mycorrhizal association may be advantageous for annuals, which are dependent on reproduction by seed.

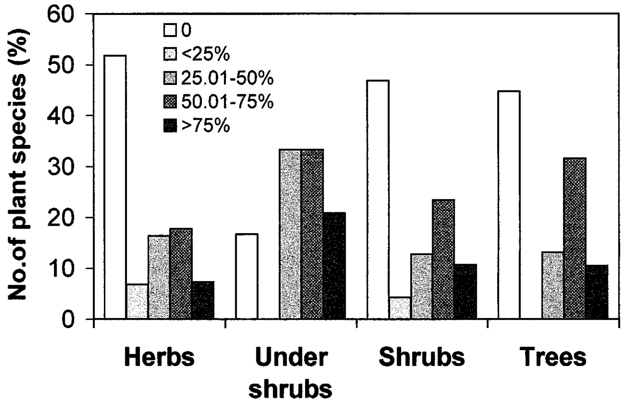


Fig. 3 Percentage plant species of different AM colonization classes in different life-form classes

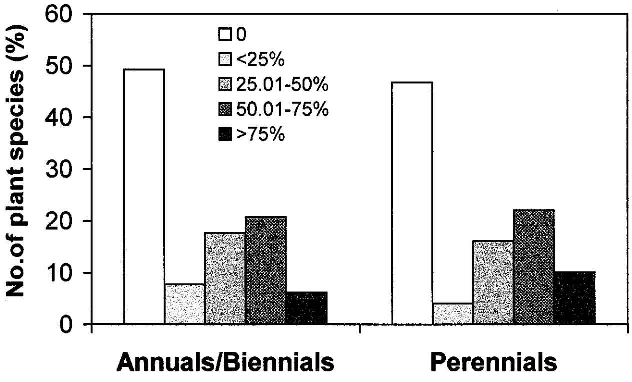


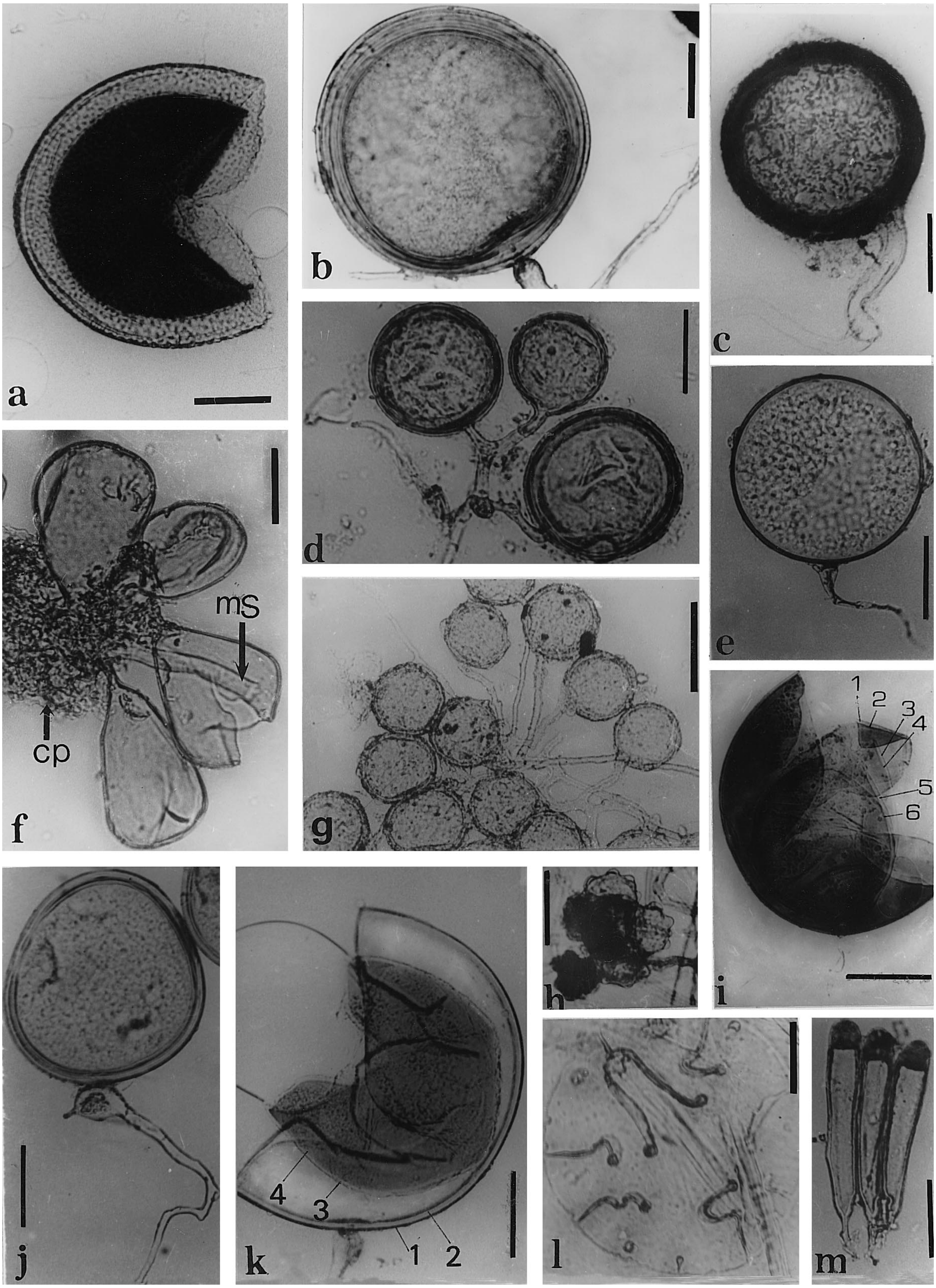
Fig. 4 Percentage plant species of different AM colonization classes in the two life-cycle classes

AM fungi displayed little or no host specificity in the present study, where only 35 AM fungal species were identified from the rhizospheres of about 329 plant species. In the present study, 22 and 20 species were recorded at the sites Coimbatore and Siruvani, respectively, whilst the other sites had in the range of 6 to 10 species. This is in accordance with Johnson et al. (1991), who isolated 12–22 different AM fungal species per site but contrasts with the observation of Allen et al. (1995), who found that none of the 68 sites they surveyed in western United States contained more than a dozen species. Although species like *Glomus aggregatum, G. geosporum, G. macrocarpum* and *G. mosseae* were widely distributed at different sites, some species like *G. viscosum, Sclerocystis taiwanensis, Scutellospora persica* and *S. nigra* were confined to a particular site. In western United States, 16 of the 38 AM fungal species isolated were restricted to a particular site (Allen et al. 1995). Although AM fungi are known to exhibit little or no host specificity, ecological specificity may exist (McGonigle and Fitter 1990).

AM fungal species may prefer certain habitats and earlier studies clearly demonstrated the role of environmental factors and vegetation on AM fungal community composition (Brundrett 1991). In contrast to the assumption that the genera *Acaulospora* and *Scutellospora* are particularly diverse in the tropics (Walker 1992; Allen et al. 1995), the present study indicates a predominance of *Glomus* over other genera. Similar observations have been made in the tropics by Ragupathy and Mahadevan (1993) and Thapar and Khan (1985). Two possible reasons for the predominance of *Glomus* are, firstly, that *Acaulospora* species are often associated with acidic soils (Morton 1986; Abbott and Robson 1991), whereas the soils sampled at the Western Ghats were near neutral to slightly alkaline. Secondly, *Gigaspora* species predominate in soils with a high sand content, especially dunes (Day et al. 1987; Lee and Koske 1994); the genus *Scutellospora* is ancestral to *Gigaspora* (Walker 1992) and probably prefers similar sandy soils. The soil at the present study sites (Muthukumar et al. 1996) was less sandy than those examined by most of the authors cited above.

Four of the six known species of *Sclerocystis* were recorded during this study, suggesting the common and diverse occurrence of this genus in tropical soils. Almeida and Schenck (1990) transferred most of the *Sclerocystis* spp. to *Glomus* but retained *S. coremioides* Berk. & Br. based on four unique characters: a) spore formation individually on an unbranched sporophore, b) arrangement of spores in an hemispherical layer, c) delimitation of spores by a well-defined septum and d) distal or lateral formation of sporocarps from older sporocarps appear fused in a column or branch. They applied Madeline's (1979) mode of sympodial conidial formation to distinguish the spore ontogeny of *Glomus* from *Sclerocystis.* Furthermore, Almeida and Schenck (1990) indicated similarities in spore ontogeny in several *Sclerocystis* and *Glomus* species, e.g. *G. ambisporum* Smith & Schenck, *G. heterosporum* Smith & Schenck and *G. dimorphicum* Boyetchko & Tewari, which generated lateral sporophores in the subtending hyphae near the spore base. However, later studies on spore ontogeny and sporocarp formation in several *Sclerocystis* species by Wu (1993) indicated the affinity of *S. coremeoides* to other *Sclerocystis* species and retained all the transferred species under *Sclerocystis*. Although, *G. ambisporum, G. heterosporum* and *G. dimorphicum* produce sporocarps similar to *S. rubiformis,* the ability to produce dimorphic spores clearly dis-

Fig. 5a–m AM fungal spores. Numbers indicate wall layers. **a** Crushed spore of *Acaulospora scrobiculata* in Melzer's reagent; *bar* 100 μm. **b** Intact spore of *Gigaspora decipens*; *bar* 100 μm. **c** Intact spore of *Glomus geosporum*; *bar* 100 μm. **d** Spores of *G. intraradices*; *bar* 50 μm. **e** Intact spore of *Scutellospora pellucida*; *bar* 40 μm. **f** Spores, monohyphal stalk (*ms*) and central hyphal plexus (*cp*) of *Sclerocystis sinuosa*; *bar* 50 μm. **g** Spores of *G. viscosum*; bar 50 μm. **h** Auxiliary cells (*bar* 20 μm) and **i** crushed spore of *S. pellucida* in Melzer's reagent (*bar* 40 μm). **j** Spore of *Scutellospora calospora* (*bar* 100 μm), **k** crushed in Melzer's reagent. **l** Germination shield of *S. persica*; *bar* 20 μm. **m** Spores of *Sclerocystis clavispora*; *bar* 50 μm


a
b
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tinguishes them from *Sclerocystis* (Wu 1993). In addition, the arrangement of spores in sporocarps in *Glomus* is random compared with the orderly arrangement in *Sclerocystis.* So the dimorphic species of *Glomus* probably represents a transitional taxa linking *Glomus* and *Sclerocystis*.

During the present investigation, sporocarps of *Sclerocystis* spp. were often found in soils under permanent vegetation and were absent in cultivated soils. This is accordance with the observations of Sieverding (1989), who reported the frequent occurrence of *Sclerocystis* spp. under scrub and permanent crops in tropical savannas and their disappearance from limed or fertilized soils. One possible reason for the exclusion of *Sclerocystis* spp. sporocarps from soils under short-duration crops may be the long time taken for sporocarp formation (Almeida and Schenck 1990). Five forms of the 35 AM fungal species isolated in the present study do not fit into known descriptions. Allen et al. (1995) also found that 42% of the 38 AM fungal species they isolated in western United States were undescribed.

As Hendrix (1993) pointed out, failing to maintain plant and, in turn, AM fungal diversity could change the nature of phyto- and myco-biont association such that pathogenicity will replace mutualism. The present recording of putatively undescribed taxa clearly indicates how little the AM fungal flora in the Western Ghats have been explored. Studies on the distribution and mycorrhizal status of plants should enable us to understand the influence of these mycobionts on plant species diversity and distribution.

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