

## The state of arbuscular mycorrhizal fungal diversity in India: an analysis

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During the last few years there have been revolutionary changes in understanding of arbuscular mycorrhizal (AM) fungi distribution, conservation and prospecting using computational databases and platforms. In the present study a searchable biodiversity database available at <http://amfungi.aurobindo.du.ac.in> and [www.amfungi.in](http://www.amfungi.in) is presented using MS access and visual basic applications (VBA). A consolidated region-wise distribution checklist of 148 species of AM fungi belonging to 21 genera of the phylum Glomeromycota is developed, which can be searched either species-wise or state-wise to retrieve information about latest consensus classification, type specimen description, apart from occurrence and abundance. We report *Funnelformis mosseae* to be the most widely distributed species of Glomeromycota in India, present in the largest number of states which is in dissent with earlier reports of *Glomus fasciculatum* and *Glomus macrocarpum* as the most widely distributed species. The genus *Glomus* is represented by the highest number of species followed by *Acaulospora* and *Scutellospora*. The states falling in the Western Ghats region, i.e. Karnataka, Goa and Maharashtra, contain more than 68.9 % of total AM fungal species reported from India. Many important states of India especially Himachal Pradesh, North Eastern India which covers the region of Himalayas and Aravallis remain less represented. We hope that the checklist serves as a quick reference for knowing which Glomeromycota are expected at any Indian location and can be further used to fill gaps in world distribution maps of AMF apart from providing latest classification and quick links to the availability of monospore cultures and original species description.

Keywords: AM fungi, Glomeromycota, distribution, MS access, VBA programming, checklist, database.

The phylum Glomeromycota (Schüßler *et al.* 2001) includes arbuscular mycorrhizal fungi (AMF), which symbiotically form associations with plant roots and benefit plant nutrition, growth and survival, due to their greater exploitation of soil nutrients (Brundrett *et al.* 1996, Smith & Read 2008). These associations represent a key factor in the below ground dynamics which influence diversity and plant community structure (Chaudhary *et al.* 2008, Turrini & Giovannetti 2012). Understanding distribution and occur-

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rence of AM fungi in forest ecosystems is hampered due to their microscopic nature, hidden habitat in soil, tedious lengthy procedures for pot culturing and accurate/correct identification. A checklist on their taxonomic status, geographical distribution, occurrence and abundance is of prime importance in understanding ecosystems functioning (Fitter 2005, Turrini & Giovannetti 2012) and forms the basis in many conservation priority approaches, e.g. in reserve selection procedures (Goswami *et al.* 2012, Halme *et al.* 2012) and IUCBN red listing (Dahlberg & Mueller 2011). Several checklists such as catalogue of life (Roskov *et al.* 2013), INVAM (<http://invam.wvu.edu/>) and species lists (Schüßler & Walker 2010, <http://schuessler.userweb.mwn.de/amphylo/>) or identification manuals (Schenck & Pérez 1990; Oehl *et al.* 2011 a, b; Błaszczowski 2012) have proven as effective tools for mycorrhizal research and application. Indian Glomeromycota are poorly represented in all these databases of AMF such as GBIF (Turrini & Giovannetti 2012) and MAARJAM, the mycorrhizal distribution database (Yang *et al.* 2012; Schüßler 2013; Öpik *et al.* 2010, 2013).

AMF species diversity in India is poorly known despite the fact that India is one of the major centres for culture collection and production of large quantity of AMF inocula as biofertilisers and synthetic seeds (Puri & Adholeya 2013, Adholeya *et al.* 2013). Earlier studies indicate the uneven distribution of Glomeromycota among states, climatic zones and ecosystems, and the tendency of fungi with a wide geographical distribution to have a broad host range (Bansal *et al.* 2012, Lakshmipathi *et al.* 2012, Sharma & Yadav 2013, Bhattacharya *et al.* 2013). Presence of AMF has been recorded from 88 % of the sites examined in India with *Glomus fasciculatum* (currently named as *Rhizophagus fasciculatus*) and *Glomus macrocarpum* being the most commonly recorded species (Rani & Mukerji 1990). More than 105 Glomeromycota species were known to exist up to 2005 but a systematic record of occurrence and diversity of AMF in India was not available. The names have been updated based on the availability of type specimens and molecular sequence data (Manoharachary *et al.* 2005; Oehl *et al.* 2008, 2011 a, b; Schüßler & Walker 2010; Goto *et al.* 2012; Redecker *et al.* 2013).

The present study is aimed at monitoring arbuscular mycorrhizal fungi distribution patterns and building a checklist on their taxonomic and biodiversity status across 18 states of India namely: Andhra Pradesh (AP), Assam, Bihar, Goa, Haryana (HAR), Jammu and Kashmir (JK), Karnataka (KN), Kerala, Madhya Pradesh (MP), Maharashtra (MAH), Meghalaya (MEGH), Orissa, Punjab, Rajasthan (RAJ), Tamil Nadu (TN), Uttarkhand (UK), Uttar Pradesh (UP) and West Bengal (WB).

### Materials and methods

The available literature consisting of a collection of 64 citations since Manoharachary *et al.* (2005) onwards was studied. Several records, referring to new species descriptions from different regions in India, prior to 2005, e.g.

*Glomus delhiense*, *G. hyderabadensis*, and *G. goaensis* were also included. A searchable database with information about the biodiversity status of AMF species in different states of India was built using MS access and Visual Basic Applications (VBA). The checklist hence developed is available at <http://amfungi.aurobindo.du.ac.in> and [www.amfungi.in](http://www.amfungi.in) (Fig. 1) and can be searched in two ways: (1) species name, whether the given species is recorded from

The screenshot shows the website's interface. At the top, there is a blue banner with the text 'Innovative Project 2013-2014 The AMF Distribution in India - A Checklist' and logos for the project and the host institution. A search bar is located on the right side of the banner. Below the banner is a navigation menu with links: Home, Vision, Project, Checklist, FutureProspects, About, and Contact Us. The main content area features a large photograph of a man in a suit presenting to a group of people seated in a room. Below this is a 'Welcome to' section with a blue underline. The text in this section describes the focus of the website on Glomeromycota and arbuscular mycorrhizal fungi (AMF), their symbiotic relationship with plants, and their importance in biodiversity. To the right of the text is a map of India titled 'AMF Distribution Map'. At the bottom of the page, there are two smaller photographs: one showing a person working in a laboratory and another showing a person in a field.

**Fig. 1.** Present web view of the checklist available at <http://amfungi.aurobindo.du.ac.in> and [www.amfungi.in](http://www.amfungi.in)

India or not and if available at which locations, (2) geographical location / states of India which are included in the present study. The checklist can be used to retrieve information about occurrence and abundance of 148 species of AMF in India. It also provides latest consensus classifications of these species (Redecker *et al.* 2013, <http://schuessler.userweb.mwn.de/amphylo>), the study methodology like culture based / field studies for spore isolation or morphological or molecular methods used for AMF taxonomy and a link to the original description of the species. It can also be used to retrieve information about the availability of the species as monoculture at CMCC (Centre for Mycorrhizal Culture Collection), TERI, India, which has been designated as the mycorrhizal germplasm culture collection by the Department of Biotechnology, Government of India.

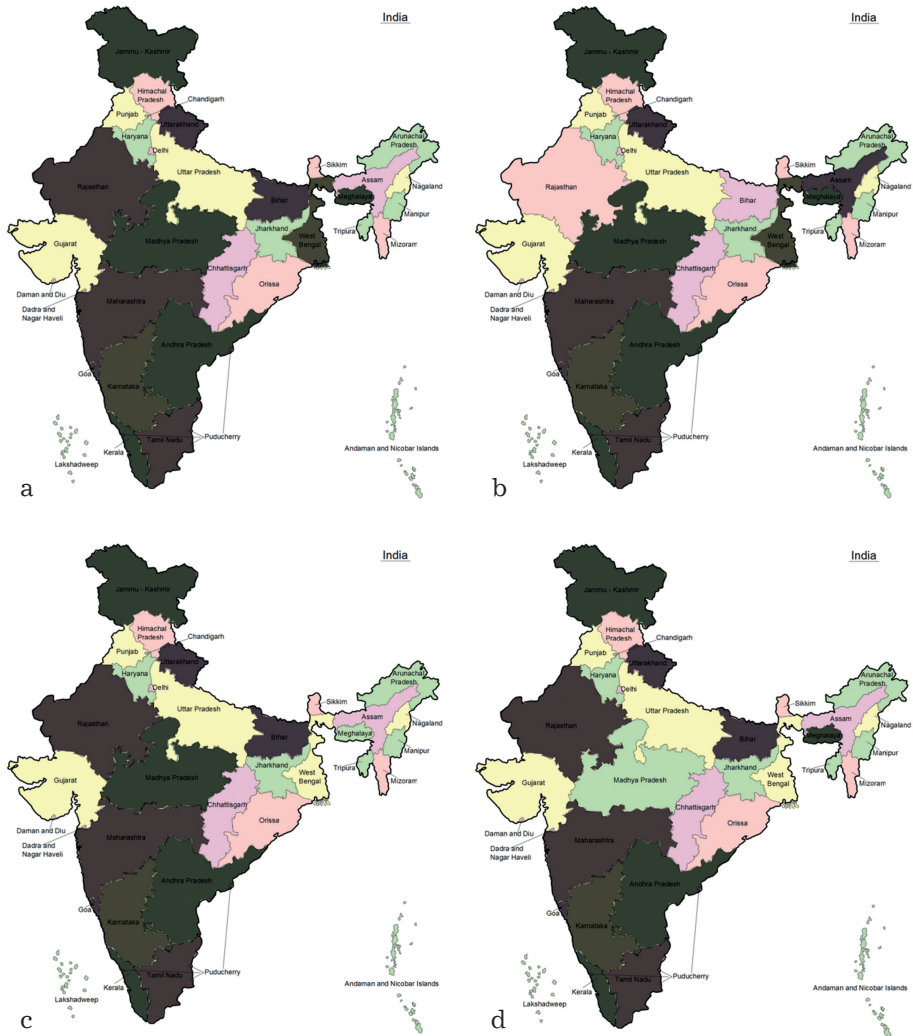
The primary structure of the database consists of 21 tables namely:

- (i) Table (i) named 'literature' with detailed reference along with complete list of species and region of study.
- (ii) Table (ii) named 'species\_list' a list of all species present, extracted from table 'literature'.
- (iii) Table (iii) named 'standard\_species' table with all the new names as given by species list (Schüßler & Walker 2010; <http://schuessler.userweb.mwn.de/amphylo>), Oehl *et al.* (2011 a, b, 2014; <http://www.agroscope.admin.ch/grandes-cultures-systemes-pastoraux/05911/07581/index.html?lang=en>) and Goto *et al.* (2012) along with all synonyms.
- (iv) Tables (iv) to (xxi) are tables for the individual 18 states of India.

A complete checklist of species occurring in India was developed using the data from the table species\_list. Final numbers were obtained by removing duplicate entries and comparing these names given in table 'standard\_species'. All older names were replaced with new names and all synonyms were merged to one present accepted name according to consensus classification (Redecker *et al.* 2013). With the help of SQL queries, separate tables were created for each state and per cent occurrence of species across a state was calculated on the basis of number of studies in which it occurred divided by total number of studies. Species present in more than 50 % of the studies were recorded as common species of that region. The wider distribution of a species is judged on the basis of number of states where it is present.

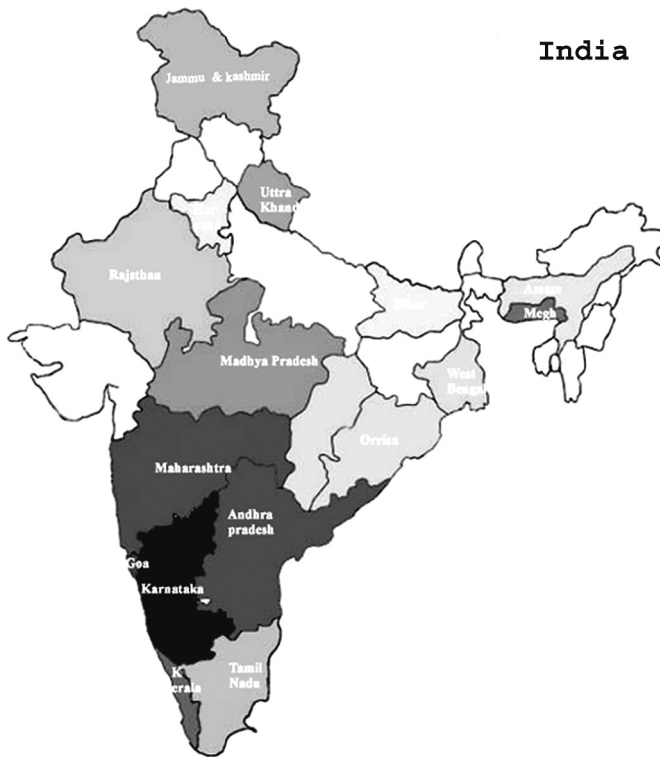
## Results

In the checklist (Tab. 1) 148 species of Glomeromycota are reported for India. This number of species is much higher than that of 105 as reported by Manoharachary *et al.* (2005) and much lower than the estimated number of species known to exist in the global flora (~270) developed on the basis of DNA sequence data from the epitypes (Schüßler & Walker 2010, <http://schuessler.userweb.mwn.de/amphylo/>, Öpik *et al.* 2013, Oehl *et al.* 2014, <http://www.agroscope.admin.ch/grandes-cultures-systemes-pastoraux/05911/07581/index.html?lang=en>). The present checklist (Table 1) includes several species, which have been reported from India for the first time, e.g. *Glomus delhiense* and *G. multisustenum* from soils of Delhi (Mukerji *et al.* 1983), *G. goaensis*, from Goa (Khade 2009) and *G. hyderabadensis* from Hyderabad (Swarupa Rani *et al.* 2004). Likewise there are many species in the Indian Glomeromycota, such as *Glomus pachycaulis*, which is reported from five states in several studies and yet is not included in the phylogenetic list of AMF (<http://schuessler.userweb.mwn.de/amphylo/>). This emphasizes the need of more DNA sequence data from type material established on the basis of living spores and fungal cultures before the new classification can universally be accepted and applied in drawing general conclusions.



**Fig. 2.** Distribution map of 4 most common AM Fungi across different states in India (a to d) **a.** *Funneliformis mosseae*, **b.** *Acaulospora spinosa*, **c.** *Rhizophagus fasciculatus*, **d.** *Acaulospora laevis*. (Dark colour indicates presence)

The AMF species reported from India belong to 21 genera with *Glomus* being represented by the highest number of species (Table 1). The list of genera arranged in decreasing order according to the number of representative species is : *Glomus*, *Acaulospora*, *Scutellospora*, *Gigaspora*, *Sclerocystis*, *Funneliformis*, *Rhizophagus*, *Racocetra*, *Ambispora*, *Claroideoglomus*, *Entrophospora*, *Pacispora*, *Paraglomus*, *Archaeospora*, *Redeckera*, *Diversispora*, *Dentiscutata*, *Septoglomus*, *Cetraspora*, *Corymbioglomus* and *Geosiphon*. Of



**Fig. 3.** Comparative species richness of Glomeromycota across several states of India presented in terms of darkness of black colour.

these *Dentiscutata*, *Cetraspora*, *Corymbioglomus* and *Septoglomus* have recently been included in the list of consensus genera (Redecker *et al.* 2013). We should expect a much richer species diversity of AMF in soils of India because many species may have been ignored in the present checklist in absence of data about the site of their collection. Also the identification of AMF mainly depends on the ability of extracting spores and raising monosporal cultures (Bhattacharya *et al.* 2013) apart from other constraints.

The nine most widely distributed species arranged based on their representation in more number of states in India are: *Funneliformis mosseae*, *Acaulospora spinosa*, *Rhizophagus fasciculatus*, *Acaulospora laevis*, *Acaulospora scrobiculata*, *Glomus aggregatum*, *Rhizophagus intaradices*, *Claroideoglomus claroideum* and *Claroideoglomus etunicatum*. These reports contradict the earlier reports of *Glomus fasciculatum* (currently known as *Rhizophagus fasciculatus*) and *Glomus macrocarpum* being the most common species in India (Rani & Mukerji 1990). However, the empty areas in the distribution maps of these fungi indicate that there is a need for more studies in the regions of North Eastern India and Northern India before a substan-

Tab. 1. Alphabetical list of Glomeromycota reported from different states of India on the basis of morphological (Mor) or molecular (Mol) or culture (C) based field (F) studies. Abbreviations for state name are explained in the text

ID	Species name	Family	Study type	State	Reference
1.	<i>Acaulospora alpina</i>	Acaulosporaceae	MorF	KN	Rajkumar <i>et al.</i> (2012)
2.	<i>Acaulospora bireticulata</i>	Acaulosporaceae	MorCF	KN, TN, KER, GOA, AP, MAH	Baiju <i>et al.</i> (2012), D'Souza & Rodrigues (2013), Deotare & Wankhede (2010), Khamat Jahan <i>et al.</i> (2012), Rajkumar <i>et al.</i> (2012)
3.	<i>Acaulospora capsicula</i>	Acaulosporaceae	MorCF	MEGH, UK	Chaturvedi <i>et al.</i> (2012), Songachan & Kayang (2011 a)
4.	<i>Acaulospora delicata</i>	Acaulosporaceae	MolCF	MEGH, ORISSA, GOA, KN	Khade (2011), Lakshmiopathy <i>et al.</i> (2012), Singh & Jamaluddin (2011), Songachan & Kayang (2011 a)
5.	<i>Acaulospora denticulata</i>	Acaulosporaceae	MorF	ORISSA, GOA, MEGH, AP, KER, KN, MAH	Baiju <i>et al.</i> (2012), Deotare & Wankhede (2010), Dessai & Rodrigues (2012), Hindumathi & Reddy (2011), Rajkumar <i>et al.</i> (2012), Singh & Jamaluddin (2011), Songachan & Kayang (2011 a)
6.	<i>Acaulospora dilatata</i>	Acaulosporaceae	MolCF	MEGH, KER, GOA, KN	Baiju <i>et al.</i> (2012), Dessai & Rodrigues (2012), Lakshmiopathy <i>et al.</i> (2012), Songachan & Kayang (2011 a)
7.	<i>Acaulospora elegans</i>	Acaulosporaceae	MorF	GOA, KER, TN	Baiju <i>et al.</i> (2012), Dessai & Rodrigues (2012), Nisha <i>et al.</i> (2010), Hindumathi & Reddy (2011)
8.	<i>Acaulospora forenta</i>	Acaulosporaceae	MolCF	UK, KN, JK, AP, GOA	Chaurasia <i>et al.</i> (2005), Dessai & Rodrigues (2012), Renuka <i>et al.</i> (2012), Shah <i>et al.</i> (2010), Nirmalnath (2010)
9.	<i>Acaulospora koskei</i>	Acaulosporaceae	MorF	MEGH	Songachan & Kayang (2011 a)
10.	<i>Acaulospora lacunosa</i>	Acaulosporaceae	MolCF	AP, MEGH, KN, KER	Baiju <i>et al.</i> (2012), Hindumathi & Reddy (2011), Lakshmiopathy <i>et al.</i> (2012), Songachan & Kayang (2011 a)
11.	<i>Acaulospora laevis</i>	Acaulosporaceae	MorCF	KN, TN, GOA, JK, MEGH, KER, AP, UK, BIHAR, RAJ, MAH	Charles <i>et al.</i> (2008), Chaturvedi <i>et al.</i> (2012), D'Souza & Rodrigues (2013), Deotare & Wankhede (2010), Khamar Jahan <i>et al.</i> (2012), Lakshmiopathy <i>et al.</i> (2012), Prasad <i>et al.</i> (2011), Selwin <i>et al.</i> (2009), Shah <i>et al.</i> (2010), Songachan & Kayang (2011 a)
12.	<i>Acaulospora longula</i>	Acaulosporaceae	MolCF	KN, KER, UK	Baiju <i>et al.</i> (2012), Chaturvedi <i>et al.</i> (2012), Nirmalnath (2010)
13.	<i>Acaulospora mellea</i>	Acaulosporaceae	MolCF	AP, GOA, KN, MEGH, MP, ASSAM, KER, UK	Baiju <i>et al.</i> (2012), Chaturvedi <i>et al.</i> (2012), Dessai & Rodrigues (2012), Hindumathi & Reddy (2011), Jha <i>et al.</i> (2011), Rajkumar <i>et al.</i> (2012), Sharmah & Jha (2011), Songachan & Kayang (2011 a)

ID	Species name	Family	Study type	State	Reference
14.	<i>Acaulospora morrowiae</i>	Acaulosporaceae	MolCF	GOA,KER,MEGH,KN,AP,RAJ	Baiju <i>et al.</i> (2012), Dessai & Rodrigues (2012), Hindumathi & Reddy (2011), Lakshminipathy <i>et al.</i> (2012), Songachan & Kayang (2011 a), Vyas & Vyas (2012)
15.	<i>Acaulospora myriocarpa</i> (= <i>Archaeospora myriocarpa</i> )	Acaulosporaceae (Archaeosporaceae)	MolCF	KER,KN,GOA	Baiju <i>et al.</i> (2012), Dessai & Rodrigues (2012), Rajkumar <i>et al.</i> (2012)
16.	<i>Acaulospora nicosoni</i> (= <i>Ambispora nicosoni</i> )	Acaulosporaceae (Ambisporaceae)	MorF	KN,WB,AP,MP,GOA	Dessai & Rodrigues (2012), Khamar Jahan <i>et al.</i> (2012), Nirmalath (2010), Vyas <i>et al.</i> (2007)
17.	<i>Acaulospora paulineae</i>	Acaulosporaceae	MorCF	JK,UK	Chaturvedi <i>et al.</i> (2012), Shah <i>et al.</i> (2010)
18.	<i>Acaulospora rehmtii</i>	Acaulosporaceae	MorF	GOA, KER,MAH,KN	Baiju <i>et al.</i> (2012), Deotare & Wankhede (2010), Dessai & Rodrigues (2012), Rajkumar <i>et al.</i> (2012)
19.	<i>Acaulospora rugosa</i>	Acaulosporaceae	MorF	GOA	Dessai & Rodrigues (2012)
20.	<i>Acaulospora scrobiculata</i>	Acaulosporaceae	MolCF	WB,MAH,MEGH,KER,ORISSA,AP,MP,TN,UK,GOA,KN	Baiju <i>et al.</i> (2012), Deotare & Wankhede (2010), Dessai & Rodrigues (2012), Gupta <i>et al.</i> (2009), Hindumathi & Reddy (2011), Lakshminipathy <i>et al.</i> (2012), Nisha <i>et al.</i> (2010), Singh & Jamaluddin (2011), Songachan & Kayang (2011 a), Vyas <i>et al.</i> (2007)
21.	<i>Acaulospora soloidea</i>	Acaulosporaceae	MorF	KN	Rajkumar <i>et al.</i> (2012)
22.	<i>Acaulospora spinosa</i>	Acaulosporaceae	MorCF	WB,AP,MEGH,JK,ASSAM, KER,TN,MP,KN,GOA,MAH,UK	Baiju <i>et al.</i> (2012), Dessai & Rodrigues (2012), Gupta <i>et al.</i> (2009), Lakshminipathy <i>et al.</i> (2012), Renuka <i>et al.</i> (2012), Sarwade <i>et al.</i> (2012), Selwin <i>et al.</i> (2009), Shah <i>et al.</i> (2010), Sharmah & Jha (2011), Songachan & Kayang (2011 a), Vyas <i>et al.</i> (2007)
23.	<i>Acaulospora splendida</i>	Acaulosporaceae	MorF	GOA	Khade (2011)
24.	<i>Acaulospora sporocarpia</i>	Acaulosporaceae	MorCF	RAJ	Vyas & Vyas (2012)
25.	<i>Acaulospora thomii</i>	Acaulosporaceae	MorF	KER,MAH	Bindu & Harikumar (2008), Sarwade <i>et al.</i> (2012)
26.	<i>Acaulospora tuberculata</i>	Acaulosporaceae	MorF	KER,MEGH,RAJ,KN,GOA,BIHAR	Baiju <i>et al.</i> (2012), Dessai & Rodrigues (2012), Prasad <i>et al.</i> (2011), Rajkumar <i>et al.</i> (2012), Songachan & Kayang (2011 a)
27.	<i>Acaulospora undulata</i>	Acaulosporaceae	MorF	GOA,KN	Dessai & Rodrigues (2012), Rajkumar <i>et al.</i> (2012)
28.	<i>Ambispora appendiculata</i>	Ambisporaceae	MorF	KER,KN,GOA,MAH,AP	Baiju <i>et al.</i> (2012), Dessai & Rodrigues (2012), Pawaar & Kakde (2012), Lakshminipathy <i>et al.</i> (2012), Renuka <i>et al.</i> (2012)

ID	Species name	Family	Study type	State	Reference
29.	<i>Ambispora callosa</i>	Ambisporaceae	MorF	MAH	Deotare & Wankhede (2010)
30.	<i>Ambispora fecundispora</i>	Ambisporaceae	MorF	MAH	Deotare & Wankhede (2010)
31.	<i>Ambispora gerdemannii</i>	Ambisporaceae	MorCF	KN,UK	Chaturvedi <i>et al.</i> (2012), Lakshminipathy <i>et al.</i> (2012)
32.	<i>Ambispora leptoticha</i>	Ambisporaceae	MolCF	KN, MAH	Deotare & Wankhede (2010) Lakshminipathy <i>et al.</i> (2012)
33.	<i>Archaeospora schenckii</i>	Archaeosporaceae	MorF	KN	Lakshminipathy <i>et al.</i> (2012)
34.	<i>Archaeospora trappei</i>	Archaeosporaceae	(MorF)	TN,JK,KN	Lakshminipathy <i>et al.</i> (2012), Selwin <i>et al.</i> (2009), Shah <i>et al.</i> (2010)
35.	<i>Cetranspora pellucida</i>	Gigasporaceae	MorCF	MAH,JK,UK,MEGH	Chaturvedi <i>et al.</i> (2012), Pawar & Kakde (2012), Shah <i>et al.</i> (2010), Songachan & Kayang (2011b)
36.	<i>Clarioideoglomus claroidium</i>	Clarioideo-glomeraceae	MorCF	KER,MEGH,UK,MAH,MP,ASSAM,GOA,JK,UP	Baiju <i>et al.</i> (2012), Chaturvedi <i>et al.</i> (2012), Deotare & Wankhede (2010), Dessai & Rodrigues (2012), Khade & Adholeya 2008, Shah <i>et al.</i> (2010), Sharmah & Jha (2011), Songachan & Kayang (2011a), Vyas <i>et al.</i> (2007)
37.	<i>Clarioideoglomus etunicatum</i>	Clarioideo-glomeraceae	MorCF	AP,UK,TN,JK,KN,MEGH,MAH,GOA,MP	Chaturvedi <i>et al.</i> (2012), Deotare & Wankhede (2010), Dessai & Rodrigues (2012), Hindumathi & Reddy (2011), Jha <i>et al.</i> (2011), Lakshminipathy <i>et al.</i> (2012), Priyadharsini <i>et al.</i> (2012), Shah <i>et al.</i> (2010), Songachan & Kayang (2011 a)
38.	<i>Clarioideoglomus lamellosum</i>	Clarioideo-glomeraceae	MorF	JK	Shah <i>et al.</i> (2010)
39.	<i>Clarioideoglomus luteum</i>	Clarioideoglomeraceae	MorF	KN,MEGH,JK	Rajkumar <i>et al.</i> (2012), Shah <i>et al.</i> (2010), Songachan & Kayang (2011 a)
40.	<i>Corymbiglomus tortuosum</i>	Diversisporaceae	MorF	MEGH,MAH,KN	Pawar & Kakde (2012), Lakshminipathy <i>et al.</i> (2012), Songachan & Kayang (2011 b)
41.	<i>Denticutata heterogama*</i>	Gigasporaceae	MorF	MAH,MEGH,KN,JK	Deotare & Wankhede (2010), Lakshminipathy <i>et al.</i> (2012), Shah <i>et al.</i> (2010), Songachan & Kayang (2011 b)
42.	<i>Denticutata nigrita</i>	Gigasporaceae	MorF	KN,GOA	Khade (2010), Rajkumar <i>et al.</i> (2012)
43.	<i>Denticutata reticulata</i>	Gigasporaceae	MorF	AP, GOA	Renuka <i>et al.</i> (2012), Khade (2011)
44.	<i>Diversispora epigaea</i>	Diversisporaceae	MorF	AP	Hindumathi & Reddy (2011)
45.	<i>Diversispora pustulata</i>	Diversisporaceae	MolCF	UK, WB,KN,MAH,AP,MPKER	Baiju <i>et al.</i> (2012), Chaurasia <i>et al.</i> (2005), Deotare & Wankhede (2010), Lakshminipathy <i>et al.</i> (2012), Swarupa Rani <i>et al.</i> (2004), Vyas <i>et al.</i> (2007)

ID	Species name	Family	Study type	State	Reference
46.	<i>Diversispora versiforme</i>	Diversisporaceae	MorCF	MEGH,KN	Lakshmiopathy <i>et al.</i> (2012), Songachan & Kayang (2011b)
47.	<i>Entrophospora hexagoni</i>	Entrophosporaceae	MorF	MAH	Sarwade <i>et al.</i> (2012)
48.	<i>Entrophospora infrequens</i>	Entrophosporaceae	MorCF	JK,UK	Gupta <i>et al.</i> (2009), Renuka <i>et al.</i> (2012), Shah <i>et al.</i> (2010)
49.	<i>Funneliformis caledonius</i>	Glomeraceae	MorF	AP,GOA,KN,MEGH,JK	Dessai & Rodrigues (2012), Lakshmiopathy <i>et al.</i> (2012), Renuka <i>et al.</i> (2012), Shah <i>et al.</i> (2010), Songachan & Kayang (2011 a)
50.	<i>Funneliformis coronatus</i>	Glomeraceae	MorF	KN	Rajkumar <i>et al.</i> (2012)
51.	<i>Funneliformis fragilistratus</i>	Glomeraceae	MorF	KER, MAH	Bindu & Harikumar (2008), Deotare & Wankhede (2010)
52.	<i>Funneliformis geosporus</i>	Glomeraceae	MolCF	AP,KER,MEGH,TN,MAH,KN,GOA	Charles <i>et al.</i> (2008), Dessai & Rodrigues (2012), Lakshmiopathy <i>et al.</i> (2012), Nisha <i>et al.</i> (2010), Sarwade <i>et al.</i> (2012), Songachan & Kayang (2011 a), Swarupa Rani <i>et al.</i> (2004)
53.	<i>Funneliformis monosporus</i>	Glomeraceae	MolCF	GOA,KN	Dessai & Rodrigues (2012), Lakshmiopathy <i>et al.</i> (2012)
54.	<i>Funneliformis mosseae</i> *	Glomeraceae	MolCF	KN,RAJ,APT,N,UK,BIHAR,JK,WB,GOA,KER,ORISSA,MAH,MP,MEGH	Chaturvedi <i>et al.</i> (2012), Deotare & Wankhede (2010), Dessai & Rodrigues (2012), Hindumathi & Reddy (2011), Lakshmiopathy <i>et al.</i> (2012), Nisha <i>et al.</i> (2010), Prasad (2005), Shah <i>et al.</i> (2010), Singh & Jamaluddin (2011), Songachan & Kayang (2011 a, b), Sudha & Ammani (2010), Vyas & Vyas (2012), Vyas <i>et al.</i> (2007)
55.	<i>Funneliformis verruculosus</i>	Glomeraceae	MorF	KN,MEGH	Rajkumar <i>et al.</i> (2012), Songachan & Kayang (2011 a)
56.	<i>Geosiphon pyriforme</i>	Geosiphonaceae	MorF	MAH	Deotare & Wankhede (2010)
57.	<i>Gigaspora albidia</i> *	Gigasporaceae	MorF	WB,GOA,AP,MAH,KER,KN	Baiju <i>et al.</i> (2012), Deotare & Wankhede (2010), Dessai & Rodrigues (2012), Lakshmiopathy <i>et al.</i> (2012), Renuka <i>et al.</i> (2012), Vyas <i>et al.</i> (2007)
58.	<i>Gigaspora candida</i>	Gigasporaceae	MolCF	AP	Renuka <i>et al.</i> (2012)
59.	<i>Gigaspora decipiens</i> *	Gigasporaceae	MorF	JK,KER,AP,GOA,RAJ	Baiju <i>et al.</i> (2012), Dessai & Rodrigues (2012), Renuka <i>et al.</i> (2012), Shah <i>et al.</i> (2010), Sharma & Yadav (2013),
60.	<i>Gigaspora gigantean</i>	Gigasporaceae	MorCF	KER,UK,GOA,ORISSA,MAH,AP,RAJ	Baiju <i>et al.</i> (2012), Chaturvedi <i>et al.</i> (2012), Dessai & Rodrigues (2012), Hindumathi & Reddy (2011), Kamble <i>et al.</i> (2012 b), Singh & Jamaluddin (2011), Tamboli & Vyas (2012)
61.	<i>Gigaspora margarita</i> *	Gigasporaceae	MorCF	AP,ORISSA,JK,WB,UK,KN,RAJ	Ghosh & Verma (2011), Gupta <i>et al.</i> (2009), Lakshmiopathy <i>et al.</i> (2012), Renuka <i>et al.</i> (2012), Shah <i>et al.</i> (2010), Singh & Jamaluddin (2011), Tamboli & Vyas (2012)

ID	Species name	Family	Study type	State	Reference
62.	<i>Gigaspora ramisporophora</i>	Gigasporaceae		GOA	Dessai & Rodrigues (2012)
63.	<i>Gigaspora rosea</i> *	Gigasporaceae	MolCF	MAH,KER,ORISSA, AP,RAJ,KN	Charles <i>et al.</i> (2008), Kamble <i>et al.</i> (2012b), Lakshminpathy <i>et al.</i> (2012), Singh & Jamaluddin (2011), Swarupa Rani <i>et al.</i> (2004), Vyas & Vyas (2012), Renuka <i>et al.</i> (2012)
64.	<i>Gigaspora verrucosa</i>	Gigasporaceae	MorF	AP	Renuka <i>et al.</i> (2012)
65.	<i>Glomus aggregatum</i>	Glomeraceae	MolCF	AP,BIHAR,GOA,KER, WB,MPRAJ,MAH,TN,KN,UK	Baiju <i>et al.</i> (2012), Chaurasia <i>et al.</i> (2005), D Souza & Rodrigues (2013), Deotare & Wankhede (2010), Ghosh & Verma (2011), Jha <i>et al.</i> (2011), Lakshminpathy <i>et al.</i> (2012), Nisha <i>et al.</i> (2010), Prasad (2005), Prasad <i>et al.</i> (2011), Renuka <i>et al.</i> (2012)
66.	<i>Glomus ambisporum</i>	Glomeraceae	MorCF	KER,TN,AP,GOA,UK, WB,KN,MAH	Baiju <i>et al.</i> (2012), Chaurasia <i>et al.</i> (2005), Dessai & Rodrigues (2012), Rajkumar <i>et al.</i> (2012), Renuka <i>et al.</i> (2012), Sarwade <i>et al.</i> (2012), Selwin <i>et al.</i> (2009), Vyas <i>et al.</i> (2007)
67.	<i>Glomus arborensis</i>	Glomeraceae	MorF	ORISSA,MP	Singh & Jamaluddin (2011), Jha <i>et al.</i> (2011)
68.	<i>Glomus australe</i>	Glomeraceae	MorF	KN,KER,MAH	Bindu & Harikumar (2008), Lakshminpathy <i>et al.</i> (2012), Sarwade <i>et al.</i> (2012)
69.	<i>Glomus boreale</i>	Glomeraceae	MorF	KN,GOA,MAH	Pawaar & Kakde (2012), Khade (2011), Lakshminpathy <i>et al.</i> (2012)
70.	<i>Glomus botryoides</i>	Glomeraceae	MorF	MAH,KER	Baiju <i>et al.</i> (2012), Deotare & Wankhede (2010)
71.	<i>Glomus canadense</i>	Glomeraceae	MolCF	KER,KN	Baiju <i>et al.</i> (2012), Lakshminpathy <i>et al.</i> (2012)
72.	<i>Glomus cerebriforme</i>	Glomeraceae	MorF	MP	Jha <i>et al.</i> (2011)
73.	<i>Glomus citricola</i>	Glomeraceae	MorF	MP,KN	Baiju <i>et al.</i> (2012), Lakshminpathy <i>et al.</i> (2012)
74.	<i>Glomus clarum</i>	Glomeraceae	MorF	MAH,GOA	Dessai & Rodrigues (2012), Sarwade <i>et al.</i> (2012), Baiju <i>et al.</i> (2012), Hindumathi & Reddy (2011), Lakshminpathy <i>et al.</i> (2012)
75.	<i>Glomus clarispora</i>	Glomeraceae	MorF	KN,GOA,MEGH,KN	Khade (2011), Lakshminpathy <i>et al.</i> (2012), Rajkumar <i>et al.</i> (2012), Renuka <i>et al.</i> (2012), Songachan & Kayang (2011 a)
76.	<i>Glomus convolutum</i>	Glomeraceae	MorF	AP	Renuka <i>et al.</i> (2012)
77.	<i>Glomus delhiense</i>	Glomeraceae	MorF	KN	Lakshminpathy <i>et al.</i> (2012)
78.	<i>Glomus deserticola</i>	Glomeraceae	MolCF	ORISSA,AP,KER,KN,RAJ	Bindu & Harikumar (2008), Lakshminpathy <i>et al.</i> (2012), Renuka <i>et al.</i> (2012), Singh & Jamaluddin (2011), Tamboli & Vyas (2012),

ID	Species name	Family	Study type	State	Reference
79.	<i>Glomus diaphanum</i>	Glomeraceae	MolCF	JK	Shah <i>et al.</i> (2010), Jha <i>et al.</i> (2011), Lakshmiopathy <i>et al.</i> (2012)
80.	<i>Glomus dimorphicum</i>	Glomeraceae	MolCF	MAH,WB,JK,KN	Deotare & Wankhede (2010), Nirmanath (2010), Vyas <i>et al.</i> (2007)
81.	<i>Glomus fistulosum</i>	Glomeraceae	MorF	AP	Khamar Jahan <i>et al.</i> (2012)
82.	<i>Glomus flavisporum</i>	Glomeraceae	MorF	KN,GOA	Dessai & Rodrigues (2012), Kamble <i>et al.</i> (2012 a, b)
83.	<i>Glomus formosum</i>	Glomeraceae	MorF	GOA,MAH	Deotare & Wankhede (2010), Dessai & Rodrigues (2012)
84.	<i>Glomus globiferum</i>	Glomeraceae	MolCF	GOA,KN,AP	Khade & Rodrigues (2008), Lakshmiopathy <i>et al.</i> (2012), Swarupa Rani <i>et al.</i> (2004)
85.	<i>Glomus glomerulatum</i>	Glomeraceae	MorF	GOA	Dessai & Rodrigues (2012)
86.	<i>Glomus goensis</i>	Glomeraceae	MorF	MAH,GOA	Kamble <i>et al.</i> (2012b)
87.	<i>Glomus halan</i>	Glomeraceae	MorF	MAH	Sarwade <i>et al.</i> (2012)
88.	<i>Glomus halonatum</i>	Glomeraceae	MorF	KN	Lakshmiopathy <i>et al.</i> (2012)
89.	<i>Glomus heterosporum</i>	Glomeraceae	MolCF	GOA,MAH,KN	Deotare & Wankhede (2010), Khade & Rodrigues 2008, Lakshmiopathy <i>et al.</i> (2012)
90.	<i>Glomus hoi</i>	Glomeraceae	MorF	GOA,KN,MP	Dessai & Rodrigues (2012), Lakshmiopathy <i>et al.</i> (2012) Vyas <i>et al.</i> (2007)
91.	<i>Glomus hyderabadensis</i>	Glomeraceae	MolCF	AP	Swarupa Rani <i>et al.</i> (2004)
92.	<i>Glomus invernatum</i>	Glomeraceae	MorF	KN,AP,MP	Jha <i>et al.</i> (2011), Lakshmiopathy <i>et al.</i> (2012), Renuka <i>et al.</i> (2012)
93.	<i>Glomus lacteum</i>	Glomeraceae	MolCF	MAH,KN	Deotare & Wankhede (2010), Lakshmiopathy <i>et al.</i> (2012)
94.	<i>Glomus macrocarpum</i>	Glomeraceae	MolCF	AP,UK,KN,MAH,GOA,MEGH,TN	Chaturvedi <i>et al.</i> (2012), Das & Kayang (2010), Dessai & Rodrigues (2012), Lakshmiopathy <i>et al.</i> (2012), Nisha <i>et al.</i> (2010), Renuka <i>et al.</i> (2012), Sarwade <i>et al.</i> (2012)
95.	<i>Glomus magnicaule</i>	Glomeraceae	MorF	KN,WB,MP	Lakshmiopathy <i>et al.</i> (2012), Vyas <i>et al.</i> (2007)
96.	<i>Glomus melanosprum</i>	Glomeraceae	MorF	MAH	Deotare & Wankhede (2010)
97.	<i>Glomus microaggregatum</i>	Glomeraceae	MorF	KER,MEGH	Bindu & Harikumar (2008), Songachan & Kayang (2011b)
98.	<i>Glomus microcarpum</i>	Glomeraceae	MorF	KN,KER,MEGH,RAJ,AP, TN,GOA	Charles <i>et al.</i> (2008), Dessai & Rodrigues (2012), Hindumathi & Reddy (2011), Kamble <i>et al.</i> (2012 a, b), Nisha <i>et al.</i> (2010), Prasad <i>et al.</i> (2011), Songachan & Kayang (2011 b)

ID	Species name	Family	Study type	State	Reference
99.	<i>Glomus minutum</i>	Glomeraceae	MorF	MEGH	Songachan & Kayang (2011 b)
100.	<i>Glomus multicaule</i>	Glomeraceae	MolCF	MAH,MEGH,GOA,KN	Das & Kayang (2010), Dessai & Rodrigues (2012), Lakshminipathy <i>et al.</i> (2012), Sarwade <i>et al.</i> (2012)
101.	<i>Glomus multisubstansum</i>	Glomeraceae	MolCF	KN,AP,MAH	Deotare & Wankhede (2010), Lakshminipathy <i>et al.</i> (2012), Renuka <i>et al.</i> (2012)
102.	<i>Glomus nanolumen</i>	Glomeraceae	MorCF	GOA	D'Souza & Rodrigues (2013),
103.	<i>Glomus pachycaulis</i>	Glomeraceae	MorCF	GOA,UK,KN,MAH	Chaturvedi <i>et al.</i> (2012), Kamble <i>et al.</i> (2012 b), Khade (2008), Lakshminipathy <i>et al.</i> (2012)
104.	<i>Glomus pansihalos</i>	Glomeraceae	MorF	MAH,KER,KN	Deotare & Wankhede (2010), Baiju <i>et al.</i> (2012), Lakshminipathy <i>et al.</i> (2012)
105.	<i>Glomus perpusillum</i>	Glomeraceae	MorF	KN	Rajkumar <i>et al.</i> (2012)
106.	<i>Glomus radiatum</i>	Glomeraceae	MorF	KER,MAH,KN	Baiju <i>et al.</i> (2012), Lakshminipathy <i>et al.</i> (2012), Pawar & Kakde (2012)
107.	<i>Glomus reticulatum</i>	Glomeraceae	MorF	KN,KER,TN,MAH,AP	Charles <i>et al.</i> (2008), Deotare & Wankhede (2010), Hindumathi & Reddy (2011), Lakshminipathy <i>et al.</i> (2012), Nisha <i>et al.</i> (2010)
108.	<i>Glomus segmentatum</i>	Glomeraceae	MorF	MAH,KER,KN	Baiju <i>et al.</i> (2012), Pawar & Kakde (2012), Lakshminipathy <i>et al.</i> (2012)
109.	<i>Glomus sinuosum</i>	Glomeraceae	MorF	TN	Priyadharsini <i>et al.</i> (2012)
110.	<i>Glomus spinosum</i>	Glomeraceae	MorF	MEGH	Songachan & Kayang (2011 b)
111.	<i>Glomus tenebrosum</i>	Glomeraceae	MolCF	MEGH	Songachan & Kayang (2011 b)
112.	<i>Glomus viscosum</i>	Glomeraceae	MorF	MEGH,TN	Songachan & Kayang (2011 b)
113.	<i>Pacispora chimonobambusae</i>	Pacisporaceae	MorF	KN	Rajkumar <i>et al.</i> (2012)
114.	<i>Pacispora robigna</i>	Pacisporaceae	MorF	MEGH	Songachan & Kayang (2011 b)
115.	<i>Pacispora scintillans</i>	Pacisporaceae	MorCF	KN,KER	Lakshminipathy <i>et al.</i> (2012)
116.	<i>Paraglomus albidum</i>	Paraglomeraceae	MorF	MAH,KER,GOA,KN	Baiju <i>et al.</i> (2012), Deotare & Wankhede (2010), Dessai & Rodrigues (2012), Lakshminipathy <i>et al.</i> (2012)
117.	<i>Paraglomus laccatum</i>	Paraglomeraceae	MorF	UK	Chaturvedi <i>et al.</i> (2012)
118.	<i>Paraglomus occultum</i>	Paraglomeraceae	MorCF	TN,WB,KN,MP	Rajkumar <i>et al.</i> (2012), Selwin <i>et al.</i> (2009), Vyas <i>et al.</i> (2007)
119.	<i>Racocetra coralloidea</i>	Gigasporaceae	MorF	MEGH	Songachan & Kayang (2011 b)

ID	Species name	Family	Study type	State	Reference
120.	<i>Racocetra fulgida</i>	Gigasporaceae	MorF	MEGH	Songachan & Kayang (2011 b),
121.	<i>Racocetra gregaria</i>	Gigasporaceae	MorCF	TN,RAJ	Nisha <i>et al.</i> (2010), Sharma & Yadav (2013)
122.	<i>Racocetra gregaria</i>	Gigasporaceae	MorF	AP,GOA	Dessai & Rodrigues (2012), Renuka <i>et al.</i> (2012)
123.	<i>Racocetra minuta</i>	Gigasporaceae	MorF	MAH	Deotare & Wankhede (2010)
124.	<i>Racocetra persica</i>	Gigasporaceae	MorCF	ORISSA,UK,KER	Bindu & Harikumar (2008), Chaturvedi <i>et al.</i> (2012), Singh & Jamaluddin (2011)
125.	<i>Racocetra verrucosa</i>	Gigasporaceae	MorF	KN,JK	Lakshminipathy <i>et al.</i> (2012), Shah <i>et al.</i> (2010),
126.	<i>Racocetra weresubiae</i>	Gigasporaceae	MorF	AP	Renuka <i>et al.</i> (2012)
127.	<i>Redeokera fulva</i>	Diversisporaceae	MorF	KN	Lakshminipathy <i>et al.</i> (2012)
128.	<i>Redeokera pulvinata</i>	Glomeraceae	MorF	KER,	Baiju <i>et al.</i> (2012)
129.	<i>Rhizophagus fasciculatus</i>	Glomeraceae	MolCF	JK,BIHAR,UK,TN,KER, ORISSA,GOA,MP,RAJ, KN,MAH,AP	Bindu & Harikumar (2008), Chaurasia <i>et al.</i> (2005), D'Souza & Rodrigues (2013), Jha <i>et al.</i> (2011), Nirmalath (2010), Nisha <i>et al.</i> (2010), Prasad (2005), Renuka <i>et al.</i> (2012), Sarwade <i>et al.</i> (2012), Shah <i>et al.</i> (2010), Sharma & Yadav (2013), Singh & Jamaluddin (2011)
130.	<i>Rhizophagus intraradices</i> * (= <i>Rhizophagus irregularis</i> )	Glomeraceae	MorCF	MAH,BIHAR,MP,MEGH, GOA,JK,RAJ,ORISSA, UK,KN,AP	Chaturvedi <i>et al.</i> (2012), D'Souza & Rodrigues (2013), Jha <i>et al.</i> (2011), Prasad (2005), Prasad <i>et al.</i> (2011), Rajkumar <i>et al.</i> (2012), Renuka <i>et al.</i> (2012), Sarwade <i>et al.</i> (2012), Shah <i>et al.</i> (2010), Singh & Jamaluddin (2011), Songachan & Kayang (2011 a)
131.	<i>Rhizophagus manihotis</i>	Glomeraceae	MorF	MAH,GOA,KN,ASSAM	Deotare & Wankhede (2010), Dessai & Rodrigues (2012), Rajkumar <i>et al.</i> (2012), Shaarmah & Jha (2011)
132.	<i>Sclerocystis coremioides</i>	Glomeraceae	MorF	GOA,AP	Dessai & Rodrigues (2012), Renuka <i>et al.</i> (2012)
133.	<i>Sclerocystis dussii</i>	Glomeraceae	MorF	TN	Selwin <i>et al.</i> (2009)
134.	<i>Sclerocystis microcarpus</i>	Glomeraceae	MorF	MAH,AP	Deotare & Wankhede (2010), Renuka <i>et al.</i> (2012)
135.	<i>Sclerocystis rubiformis</i>	Glomeraceae	MorCF	UK,KER,MEGH,KN, AP,GOA	Charles <i>et al.</i> (2008), Chaurasia <i>et al.</i> (2005), Dessai & Rodrigues (2012), Hindumathi & Reddy (2011), Khamar Jahan <i>et al.</i> (2012), Rajkumar <i>et al.</i> (2012), Renuka <i>et al.</i> (2012), Songachan & Kayang (2011b)
136.	<i>Sclerocystis sinuosa</i>	Glomeraceae	MorCF	UK,MEGH,KN,MAH, GOA,AP	Chaurasia <i>et al.</i> (2005), Khade (2011), Khamar Jahan <i>et al.</i> (2012), Rajkumar <i>et al.</i> (2012), Renuka <i>et al.</i> (2012), Sarwade <i>et al.</i> (2012), Songachan & Kayang (2011 b)

ID	Species name	Family	Study type	State	Reference
137.	<i>Sclerocystis taiwanensis</i>	Glomeraceae	MorCF	KN,UK,GOA	Chaturvedi <i>et al.</i> (2012), Dessai & Rodrigues (2012), Rajkumar <i>et al.</i> (2012)
138.	<i>Scutellospora arenicola</i>	Gigasporaceae	MorF	MAH	Pawaar & Kakde (2012)
139.	<i>Scutellospora aurigloba</i>	Gigasporaceae	MorF	MAH,KER	Pawaar & Kakde (2012), Charles <i>et al.</i> (2008)
140.	<i>Scutellospora biornata</i>	Gigasporaceae	MorF	GOA	Dessai & Rodrigues (2012)
141.	<i>Scutellospora calospora</i>	Gigasporaceae	MorCF	KN,MEGH,AP,GOA, UK,JK,KER,RAJ	Charles <i>et al.</i> (2008), Chaturvedi <i>et al.</i> (2012), Dessai & Rodrigues (2012), Lakshminpathy <i>et al.</i> (2012), Renuka <i>et al.</i> (2012), Shah <i>et al.</i> (2010), Songachan & Kayang (2011b), Tamboli & Vyas (2012)
142.	<i>Scutellospora cerradensis</i>	Gigasporaceae	MorF	MEGH,KN	Rajkumar <i>et al.</i> (2012), Songachan & Kayang (2011 b)
143.	<i>Scutellospora dipurpurascens</i>	Gigasporaceae	MorF	JK	Shah <i>et al.</i> (2010)
144.	<i>Scutellospora erythropus</i>	Gigasporaceae	MorF	MEGH,AP,JK	Renuka <i>et al.</i> (2012), Shah <i>et al.</i> (2010), Songachan & Kayang (2011b)
145.	<i>Scutellospora nigra</i>	Gigasporaceae	MolCF	AP,GOA,KN,RAJ	Hindumathi & Reddy (2011), Dessai & Rodrigues (2012), Prasad <i>et al.</i> (2011), Renuka <i>et al.</i> (2012), Shobha & Chandrashekar (2007)
146.	<i>Scutellospora pernambucana</i>	Gigasporaceae	MorF	MEGH	Songachan & Kayang (2011 b)
147.	<i>Scutellospora rubra</i>	Gigasporaceae	MorF	MEGH	Songachan & Kayang (2011 b)
148.	<i>Septoglonus constrictum</i>	Glomeraceae	MolCF	BIHAR,GOA,KER,MEGH, KN,RAJ,AP,UK	Baiju <i>et al.</i> (2012), Chaturvedi <i>et al.</i> (2012), Das & Kayang (2010), Dessai & Rodrigues (2012), Lakshminpathy <i>et al.</i> (2012), Prasad (2005), Renuka <i>et al.</i> (2012), Vyas & Vyas (2012)

\* cultures available at CMCC, TERI

tive conclusion could be drawn at all India level (Figs. 2–3). On the other hand many AMF species (about 60) are more localized in their distribution and are hitherto known only in one state and were reported only in one study (Table 1).

The 18 different states of India studied here include the regions Old Delhi Ridge (Mukerji *et al.* 1983), Godavari Belt Forests, Andhra Pradesh (Renuka *et al.* 2012), disturbed and undisturbed forests of Karbi Anglong Hill, Assam (Sharmah & Jha 2011), Western Ghats of Goa (Khade 2009), Eastern Himalayas in West Bengal (Vyas *et al.* 2008), Konkan sand dunes of Maharashtra (Kamble *et al.* 2012a,b), deserts, arid zones of Rajasthan (Vyas & Vyas 2012), agricultural fields of garlic plantation at Nilgiris, Tamil Nadu (Rajeshkumar & Nisha 2012), University farms of Haryana (Bansal *et al.* 2012), pearl millet, maize, wheat, pigeonpea and chick pea fields in Gwalior, Madhya Pradesh (Koul *et al.* 2012) and polluted sites in UP (Khade & Adholeya 2008). Karnataka tops the biodiversity list with 89 species followed by Goa (69), Maharashtra and Andhra Pradesh (Tab. 2). Very few species are reported from states like HP, Delhi, Punjab, UP, Haryana and JK but this does not in any way imply poor species diversity. It rather suggests that a lesser number of reports are available from these areas and the checklist can be consolidated by conducting more studies in these areas and also motivating scientists from these areas to make their studies public.

## Discussion

Undoubtedly, India is vastly rich in biodiversity, being one of the top ten plant species-rich nations in the world and the fourth in Asia, not only in terms of flowering plants or algae, lichens and bryophytes, etc. but also in diversity of fungi belonging to phylum Glomeromycota which includes 148 of the total 14500 fungal species known to occur in India (source: India's Fourth National Report to the Convention on Biological Diversity) which is roughly 56 % global AMF flora (Öpik *et al.* 2013). While these figures show the significance of Indian biodiversity on the national and global level, there are certain gap areas that need to be addressed in right earnest especially in context of AMF taxonomy and identification. First, there is the need to carry out exhaustive all India-based surveys in order to have a better picture of AMF biodiversity in India. Molecular methods must be applied for species identification in addition to morphological characters. Several authors have already pointed out a general lack of such studies from regions other than Europe and North America and more investigations are suggested to be carried out from regions like Africa and Asia (Kivlin *et al.* 2011, Young 2012, Turrini & Giovannetti 2012, Öpik *et al.* 2013). In absence of molecular data however biodiversity information obtained by traditional morphological identification of spores is also important and can be used to provide meta-data to substantiate the molecular data and generalise the distribution pat-

**Tab. 2.** Common species of different states in India, decided on the basis of per cent occurrence ('-' indicates that no species could be named as common species for that region)

State	Species reported	Genera reported	Common species	Reference
Andhra Pradesh	57	11	<i>Acaulospora bireticulata</i> , <i>Acaulospora foveolata</i> , <i>Acaulospora mellea</i> , <i>Acaulospora morrowiae</i> , <i>Acaulospora scrobiculata</i> , <i>Claroideoglomus etunicatum</i> , <i>Septoglomus constrictum</i> , <i>Funneliformis mosseae</i> , <i>Glomus aggregatum</i> , <i>Glomus multisubstentum</i> , <i>Rhizophagus fasciculatus</i> , <i>Rhizophagus intraradices</i> , <i>Sclerocystis pakistanaica</i> , <i>Sclerocystis sinuosa</i>	Hindumathi & Reddy (2011), Khamar Jahan <i>et al.</i> (2012), Renuka <i>et al.</i> (2012), Swarupa Rani <i>et al.</i> (2004)
Assam	11	9	<i>Glomus</i> sp., <i>Acaulospora</i> sp., <i>Gigaspora</i> sp. & <i>Scutellospora</i> sp.	Borah & Neog (2005), Hazarika <i>et al.</i> (2010), Sharmah & Jha (2011), Toman & Jha (2011)
Bihar	8	6	-	Prasad 2005
Goa	61	9	<i>Sclerocystis rubiformis</i> , <i>Glomus multicaule</i> , <i>Glomus clavispurum</i> , <i>Funneliformis geosporum</i> , <i>Claroideoglomus claroideum</i> , <i>Acaulospora nicolsonii</i> , <i>Acaulospora scrobiculata</i>	D'Souza & Rodrigues (2013), Dessai & Rodrigues (2012), Khade (2008), Khade (2011), Khade & Rodrigues (2008)
Haryana	8	5	-	Bansal <i>et al.</i> (2012), Sharma <i>et al.</i> (2008)
Karnataka	89	15	<i>Rhizophagus manihotis</i> , <i>Rhizophagus fasciculatus</i> , <i>Acaulospora scrobiculata</i> , <i>Glomus multicaule</i> , <i>Glomus monosporum</i> , <i>Glomus macrocarpum</i> , <i>Glomus aggregatum</i> , <i>Funneliformis mosseae</i> , <i>Funneliformis geosporum</i> , <i>Septoglomus constrictum</i> , <i>Acaulospora scrobiculata</i> , <i>Acaulospora mellea</i>	Kamble <i>et al.</i> (2012 a, b), Lakshminipathy <i>et al.</i> (2012), Nirmalnath (2010), Rajkumar <i>et al.</i> (2012), Shobha & Chandrashekar (2007)
Jammu and Kashmir	24	9	-	Shah <i>et al.</i> (2010)
Kerala	49	11	-	Baiju <i>et al.</i> (2012), Bindu & Harikumar (2008), Charles <i>et al.</i> (2008), Sudha & Ammani (2010)
Madhya Pradesh	19	7	<i>Acaulospora scrobiculata</i> , <i>Glomus hoi</i> , <i>Rhizophagus fasciculatus</i>	Jha <i>et al.</i> (2011), Salunkhe & Shukla (2013), Shukla <i>et al.</i> (2013), Vyas <i>et al.</i> (2007)
Maharashtra	57	9	<i>Acaulospora scrobiculata</i> , <i>Rhizophagus fasciculatus</i> , <i>Funneliformis geosporum</i> , <i>Glomus aggregatum</i> , <i>Glomus heterosporum</i> , <i>Glomus formosanum</i> , <i>Gigaspora gigantea</i> , <i>Acaulospora denticulata</i> , <i>Acaulospora spinosa</i> , <i>Glomus australe</i> , <i>Glomus boreale</i>	Deotare & Wankhede (2010), Pawar & Kakde (2012), Kamble <i>et al.</i> (2012 b), Sarwade <i>et al.</i> (2012)

State	Species reported	Genera reported	Common species	Reference
Meghalaya	46	9	<i>Funneliformis verruculosum</i>	Das & Kayang (2010), Songachan & Kayang (2011 a), Singh & Jamaluddin (2011),
Orissa	12	6	-	Giridhar Babu & Sudhakara Reddy (2011)
Punjab	1	1	-	Prasad <i>et al.</i> (2011), Sharma & Yadav (2013), Tamboli & Vyas (2012), Vyas & Vyas (2012)
Rajasthan	19	9	<i>Acaulospora laevis</i> , <i>Funneliformis mosseae</i> , <i>Gigaspora gigantea</i> , <i>Glomus aggregatum</i> , <i>Scutellospora calospora</i>	Nisha <i>et al.</i> (2010), Priyadharsini <i>et al.</i> (2012), Selwin <i>et al.</i> (2009)
Tamil Nadu	22	10	<i>Glomus microcarpum</i> , <i>Glomus aggregatum</i> , <i>Acaulospora elegans</i> , <i>Acaulospora scrobiculata</i> , <i>Claroideoglomus etunicatum</i> , <i>Funneliformis geosporum</i> , <i>Funneliformis mosseae</i>	Chaturvedi <i>et al.</i> (2012), Chaurasia <i>et al.</i> (2005), Gupta & Sharma (2010), Gupta <i>et al.</i> (2009)
Uttarakh&	30	12	-	Khade & Adholeya (2008)
Uttar Pradesh	1	1	-	Rajkumar <i>et al.</i> (2012), Vyas <i>et al.</i> (2007)
West Bengal	13	6	-	

tern of AMF, for instance, recent studies of Mello *et al.* (2013) on distribution of *Paraglomus* in Brazil.

The development of such check lists and distribution maps is expected to greatly boost the understanding of world wide AMF biodiversity, that of India in particular. Earlier biodiversity studies aimed to facilitate the description of distribution and richness patterns of AM fungi in different habitats and climatic regions of world, and host plant association using Glomeromycota DNA sequence and metadata were limited in adding to our understanding of biodiversity of AMF because there exists a wide gap between DNA sequence-based and traditional morphotaxonomy of Glomeromycota (Öpik *et al.* 2013). The main advantage in the present day research is the combination of morphology and molecular phylogeny, which is leading to a gradual development of stable, natural classification of AM fungi. In the past three years, two distinct classifications of Glomeromycota have been proposed both of which are characterised by rearrangement of genera on the basis of rDNA sequence analysis being used for species description (Schüßler & Walker 2010; Oehl *et al.* 2011 a, b, 2014; Stürmer 2012; Goto *et al.* 2012; Silva *et al.* 2012; Redecker *et al.* 2013). World wide meetings and discussions among scientists, like during the INVAM meeting in France (Redecker *et al.* 2013), a progress towards a consensus and robust systematics of Glomeromycota is being made. Further support is coming from recent standardization of easy and convenient methods for culture and maintenance of AMfungi (Błaszczowski 2012, INVAM: <http://invam.wvu.edu/methods>). Future progresses will certainly fill current gaps emerging through unidentified ecological sequences and unidentified phylogenetic clades (Öpik *et al.* 2013).

Main highlight of the present survey and checklist developed is that it is first of its kind which has enlisted the major Glomeromycota of Indian sub-continent with their distribution maps across different states. Since the data included was mainly from last 5 years studies, this can be treated as latest updated list of AMF and can be used for several purposes including filling of gaps representing Indian region in the distribution maps of AMF in several world biodiversity databases. Emerging patterns, including the uneven distribution of Glomeromycota among different states and climatic zones in India, or the tendency of certain AM fungal species to associate with a wide taxonomic range of host plants in many states or just limit itself to one region, can serve as a basis to generate testable hypotheses for future study. This information about region-specific diversity of AMF has important implications for use of non-indigenous AMF inoculation for commercial purposes in horticultural and land reclamation studies (Mummey *et al.* 2009). In addition to providing information to scientists and researchers in the field of mycorrhizal fungi, the list will be used by officials in central and state government, besides Botanical survey of India, to develop a list of AM fungi that are common in each state to help expedite the process for obtaining the research isolates and cultures.

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