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Species diversity of vesicular-arbuscular mycorrhizal (VAM) fungi in jhum fallow and natural forest soils of Arunachal Pradesh, north eastern India

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Abstract: A study was conducted to assess the regeneration pattern and species diversity of vesicular-arbuscular mycorrhizal (VAM) fungi in shifting cultivated abandoned land (jhum fallow) and natural forest soils of Arunachal Pradesh, North-Eastern India. The jhum fallow contained lower VAM fungal population and number of species than the natural forest. A total of 44 VAM species belonging to six genera namely *Acaulospora, Enterophospora, Gigaspora, Glomus, Sclerocystis* and *Scutellospora* were recorded from soils of jhum fallow and natural forest sites. Ten species of VAM fungi were found eliminated from the jhum fallow revealing that the shifting cultivation in the humid tropical soils causes reduction of VAM fungal species. The indices of dominance and general diversity of VAM fungi in the jhum fallow (0.16 and 0.85) and the natural forest (0.13 and 0.99) revealed lower species diversity and dominance of by few VAM fungi species in the jhum fallow whereas species diversity was higher and species dominance was shared by more VAM fungi in the natural forest site. The decreased diversity of VAM fungi species in jhum fallow might be due to (i) repeated slash-and-burn agriculture in the past destroying the VAM fungi propagules, (ii) loss of host plants and (iii) unfavourable edaphic conditions for regeneration of VAM fungi in the jhum fallow land.

Resumen: Se realizó un estudio para evaluar los patrones de regeneración y la diversidad de especies de hongos vesículo-arbusculares (VAM) micorrícicos en tierras abandonadas usadas previamente para la agricultura transhumante (barbecho jhum) y en suelos de bosque natural de Arunachal Pradesh, nordeste de la India. El barbecho jhum contuvo una menor población de hongos VAM y un menor número de especies que el bosque natural. En total se registraron 44 especies VAM pertenecientes a seis géneros, *Acaulospora*, *Enterophospora*, *Gigaspora*, *Glomus*, *Sclerocystis* y *Scutellospora*, en suelos de sitios de barbecho jhum y de bosque natural. Se encontró que diez especies de hongos VAM fueron eliminadas del barbecho jhum, lo que muestra que la agricultura transhumante en suelos del trópico húmedo causa una reducción en las especies de hongos VAM. Los índices de dominancia y diversidad general para los hongos VAM en el barbecho jhum (0.16 y 0.85) y el bosque natural (0.13 y 0.99) revelaron una menor diversidad de especies y una dominancia por parte de unas pocas especies de hongos VAM en el barbecho jhum, mientras que en el sitio de bosque natural la diversidad de especies fue mayor y la dominancia estuvo compartida por más especies de hongos VAM. El decremento de la diversidad de especies de hongos VAM en el barbecho jhum puede deberse a: (i) la agricultura de roza, tumba y quema, usada repetidamente en el pasado hasta destruir los propágulos de hongos VAM, (ii) pérdida de plantas hospederas, y (iii) condiciones edáficas desfavorables para la regeneración de hongos VAM en los terrenos del barbecho jhum.

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Resumo: Em Arunachal Pradesh, nordeste da Índia, foi efectuado um estudo para avaliar o padrão de regeneração e de diversidade das micorrizas vesiculares-arbusculares (VAM) em campos abandonados de agricultura itinerante (pousio "jhum") e em solos de floresta natural. O pousio "jhum" continha menos população micorrízica VAM e menor número de espécies do que na floresta natural. Registou-se um total de 44 espécies VAM pertencente a seis géneros, nomeadamente, *Acaulospora, Enterophospora, Gigaspora, Glomus, Sclerocystis* e *Scutellospora* nos solos de pousio "jhum" e em estações da floresta natural. Dez espécies de micorrizas VAM foram eliminadas nos solos de pousio revelando que a cultura itinerante nos solos tropicais húmidos causam uma redução das espécies micorrízicas VAM. Os índices de dominância e de diversidade geral das micorrizas VAM no pousio (0.16 e 0.85) e na floresta natural (0.13 e 0.99) revelaram menos diversidade específica e dominância por poucas espécies micorrízicas no pousio ao invés do que sucede na floresta natural onde a diversidade específica e a dominância era partilhada por um maior número de micorrizas VAM. O decréscimo da diversidade de micorrizas VAM no pousio pode ser devido a: i) repetida ocorrência de abate e queimada da agricultura itinerante no passado que destruiu os propágulos das micorrizas; ii) perda de plantas-hospedeiras e iii) condições edáficas desfavoráveis para a regeneração das micorrizas VAM nos campos de pousio.

Key words: Jhum fallow, forest soil, shifting cultivation, VAM fungi diversity.

Introduction

Most species of plants are capable of associating with fungi of a single family, *Endogonaceae*, to form V-A mycorrhizae (Gerdemann 1968). This symbiotic association of the endomycorrhizal fungi and roots of plants are beneficial with the exchange of nutrients between the symbionts. Mycorrhizal fungi are benefited with carbon substrates from plants and in turn the plants are provided with nutrients especially phosphorous compounds from soil solution through the hyphal network of the fungi apart from increased absorptive surface area of the roots (Janos 1980; Loyanachan 2000; Ravarkar *et al.* 2000). Any disturbance on this relationship may cause changes in terms of decreased population status and diversity of these mycorrhizal fungi. When a soil is put to agricultural use it undergoes a series of physical, chemical and microbiological changes. One of the most important of which is the changes that affect the root-inhabiting microorganisms and poor plant growth (Bellgard 1994; Roldan *et al.* 1997). Miller (1979) also reported that when soil is disturbed or is partially removed, a decrease in the number of mycorrhizal propagules occurs. It was shown that current forest logging practice influenced significant changes in vesicular-arbuscular mycorrhizae propagules (Ahmad 1996).

In tropical countries after many years of cropping, yields become very low due to loss of soil fertility and it is common to abandon fields as fallow land and this appears to be most rational method to regenerate soil fertility (Duponnois *et al.* 2001; Greenland & Nye 1959). Slash-and-burn agriculture commonly known as shifting cultivation or "jhum fallow" is the most dominant type of agriculture practice in the north-eastern hilly regions of India particularly in the state of Arunachal Pradesh. This is the root cause of decline in soil fertility and loss of top soil leading to soil degradation in the region. The restoration of the degraded soil systems in the region are not successful due to the lack of knowledge of important processes taking place inside the soil environment. The mycorrhizal fungi as one of the important biological component of soil have been reported to play important role in the regeneration of the abandoned forests because of their symbiotic association with the plant roots. There have been large reports on the nature of redistribution and diversity of mycorrhizal fungi in the disturbed soil environments. However, no such reports are available from this humid tropical region where shifting cultivation is widely practiced as a dominant agricultural system despite its recognition as one of the important hotspots of biological diversity reserve in the eastern himalayan region. Therefore, present study aims to investigate the impact of soil disturbance due to slash-and burn agriculture practice on abundance, diversity and re-distribution pattern of vesicular-arbuscular mycorrhizal (VAM) fungi in comparison to natural forest site in humid tropics of Arunachal Pradesh, North-Eastern India.

Materials and methods

Study site and soil characteristics

The Banderdewa forest range in Papumpare district of Arunachal Pradesh, north-eastern India was selected as an experimental site for the present study. The study site is located between 27°6′ N latitude and 93°49′ E longitude at an elevation of 350 m amsl. The soil in the study site falls under Karsingsa series, which is a member of mixed loamy sand of hyperthermic family, typic Haplustalfs i.e. class of Alfisol (Surendra 1999). The geology of the soil consists of sedimentary (sandstone) parent rock, which is drained by small tributaries of Dikrong river towards Brahmaputra river in Assam.

The climate of the study site is humid tropical characterized by high rainfall and high humidity (80%). The annual mean precipitation in the last three years ranged from 3400 to 5700 mm of which 80 per cent is received during monsoon season from May to August and 20 per cent during dry periods from September to March. The mean ambient temperature is 26°C.

Vegetation types

The natural vegetation consists of evergreen mixed forests with varying tree species ranging from primitive *Magnolia* to newly introduced Teak (Table 2). The presence of a protected forest area in the range allowed us to select natural forest (NF) as control site and a regenerating jhum fallow (JF) for the present study. The selection of study sites was based on living tree stump density, soil profile thickness, dominant tree species composition and land use history and other geographical characteristics (Tables 1 & 2).

The jhum fallow was a 5 years old regenerating jhum fallow land when the research was conducted in October 1998. This site had been used for cultivation of rice, maize, finger millet, ginger, cabbage and tuber crops etc., from 1980 to 1993 without proper input of nutrients based on organic and inorganic fertilizers. Thus the available nutrients were only from the debris of plant parts and ashes after burning of dried slash prior to cropping in each jhum fallow cycle. This site has not been

Table 1. Particle size distribution, textural class and degree of soil disturbance, profile thickness, slope and aspect of jhum fallow and natural forest sites.

Parameters	Jhum fallow site	Natural forest site
Sand (%)	72.8	74.9
Silt (%)	20.1	18.1
Clay (%)	7.1	7.0
Textural class	Loamy sand	Loamy sand
Profile (Ah) thickness (cm)	0 – 5	0 – 16
*Degree of soil degradation (%)	85	0.0
Slope (%)	4 – 8	4 – 8
Aspect	NE	NE

*Percentage degree of soil disturbance was calculated based on number of living tree stumps.

Table 2. Distribution of dominant tree species in jhum fallow and natural forest sites.

Tree species	Jhum fallow site	Natural forest site
Ailanthus grandis Prain.	–	+
Altinga excelsa Noron.	–	+
Arthocarpus chaplasha Roxb.	–	+
Bombax ceiba Linn	–	+
Canarium strictum Roxb	–	+
Chukrasia tabularis Andr. Juss.	–	+
Dillenia indica Linn	+	+
Duabanga grandiflora (Roxb. ex. D.C.) Walp	+	+
Gmelina arborea Roxb.	+	+
Kydia calycina Rob.	–	+
Manglieta caveana HK. f. & Th	+	+
Phoebe goalparensis Hutch	–	+
Pterospermum acerifolium Willd.	–	+
Tectona grandis Linn. f.	+	–
Toona ciliata Roem.	–	+

Presence (+) or absence (–) of VAM fungi species used for further cultivation of crops since last jhum fallow cultivation practiced in 1993 due to lower crop productivity and is lying currently as an abandoned fallow land. Luxuriant growth of ferns and weeds such as *Mikania mikranthes, Gleichenia* sp., *Lantana camara, Boreria boralis, Oplismanus* sp., etc. and various species of *Cyperus* covers the soil surface during summer rainy period while dried residues of these vegetation covers the soil surface in dry winter season. The tree density of the jhum fallow is 21 trees 100 m^{-2}.

The natural forest site has not been used for cultivation according to the records available with forest department for the last 50 years. The forest floor in natural forest site is covered with thick layer of litter, weeds and grasses throughout the year. The tree density in natural forest site was 174 trees 100 m^{-2}. This site consists of naturally growing trees only.

Soil sampling and laboratory analysis

Three sampling plots of 100 m^{-2} were selected in each site. Soil sampling was done in the month of October 1998 after the seasonal rain had stopped in September. Soil samples were collected in sterile polythene bags using thin metal sheet soil sampler (10 cm diameter and 30 cm height) at a depth of 0-30 cm from 15 random locations and at least 5 m distance between two locations in each replicate plot. The samples were collected both from the rhizosphere of trees and other plants and from bulk soil and finally mixed to get a homogenous mixture of soil for each replicate plot. Separate soil samples were collected in triplicate for determination of bulk density from all locations of the two sites.

Soil moisture was determined by drying 10 g fresh soil at 105°C for 24 h in a hot-air oven. The soil temperature was measured with the help of a soil thermometer by inserting up to 20 cm below the topsoil. Soil pH was determined at 1:2.5 soil: water suspension using a digital pH meter (Systronics-335). Organic carbon, total nitrogen and phosphorus were determined following the methods given by Okalebo *et al.* (1993).

Isolation and identification of VAM fungi

The VAM fungal spores were isolated by wet sieving and decanting method of Gerdemann & Nicholson (1963) and Singh & Tiwari (2001). The spores were identified up to species level with the help of VAM fungi identification manual of Schenck & Perez (1987) under stereo-zoom microscope.

The species composition of VAM fungi were assessed using the methods for study of trophic structure of ecosystem. VAM fungi species and propagule populations (100 g^{-1} dry soil) were measured and described. The variations in the VAM fungal population and number of species between jhum fallow and natural forest sites were tested statistically by calculating standard deviation (SD). Pearson's correlation coefficient (*r*) was calculated between spore and species number of VAM fungi and organic C, total N and P contents of the soils. Using the data obtained, the following indices of species structure were assessed:

(1) Percentage frequency of individual species

$$= \frac{\text{No. of locations in which individual VAM species occurred x 100}}{\text{Total no. of VAM fungi species in all location}}$$

(2) Index of general diversity (H'); Shannon & Weaver (1949) cited in Odum (1971).

$$H' = \Sigma\ (n_i / N \log_e n_i / N)$$

where, n_i is the importance value of each species and N is the total importance value.

(3) Index of dominance (C) (Simpson 1949).

$$C = \Sigma\ (n_i / N)^2$$

where n_i is the number of individuals of each species and N is the total number of individuals in that location.

Results and discussion

The important physico-chemical properties of soil are given in Table 3. The bulk density was

Table 3. Parameters studied in jhum fallow and natural forest sites.

Parameters	Jhum fallow site	Natural forest site
Bulk density (g cm^{-3})	1.36	1.04
Soil temperature (°C)	25	23
Moisture (%)	14	21
pH (water)	4.9	6.2
Organic C (%)	1.2	3
Total N (%)	0.23	0.54
Total P (%)	0.06	0.09

Values given are means of 15 replicates

Table 4. Pearson's correlation coefficient (*r*) values between VAM fungi spore and species numbers with organic C, total N and total P contents of natural forests and jhum fallow sites.

Soil properties	Natural forest		Jhum fallow	
	Spore	Species	Spore	Species
C	0.453**	-0.388*	-0.514**	-0.407**
N	0.465**	-0.545**	-0.669**	-0.588**
P	0.256	0.385*	-0.147	0.305*

*P<0.05, **P<0.01.

higher in jhum fallow site than natural forest site. The moisture content, organic carbon, total nitrogen and total phosphorus contents were higher in the natural forest site while these values were lower in the jhum fallow site. The pH of the jhum fallow was strongly acidic (4.9) whereas it was slightly acidic (6.2) in the natural forest site (Table 3). The Pearson's correlations coefficient (*r*) values between VAM fungi spore and species numbers and other soil properties are given in Table 4.

VAM fungal population was higher in the natural forest site while it was comparatively lower in the jhum fallow site (Fig. 1a). The spore density in this study is higher than those of grassland soils (232-296 spores 100 g^{-1} dry soil) in Wyoming (Stahl & Christensen 1982) but lower than that of the forest soil (271-1285 spores 100 g^{-1} dry soil) in South India (Visalakshi 1997). The number of VAM fungi species was higher in the natural forest site than in the jhum fallow site (Fig. 1b). The average number of VAM fungi species varied from 9 species 100 g^{-1} dry soil in jhum fallow site to 13 species 100 g^{-1} dry soil in the natural forest site respectively. Altogether, 44 VAM fungi species belonging to six genera namely, *Acaulospora* (6), *Enterophospora* (1), *Gigaspora(3), Glomus* (25), *Sclerocystis* (2) and *Scutellospora* (7) were recorded from both study sites with different percentage frequency occurrences of each individual species (Table 5). The natural forest contained 42 species while jhum fallow contained only 34 species. The VAM fungi spore population was positively correlated (P<0.01) to the organic C and total N while no significant correlation was seen with total P content of the soil in the natural forest site. However, the number of species was positively correlated (P<0.05) to the total P content despite negative correlations to the organic C and total N contents. On the other hand, spore population as well as the species number of VAM fungi was negatively correlated (P<0.05) to the organic C and total N contents of the soils but the species number was positively correlated (P<0.05) to the total P

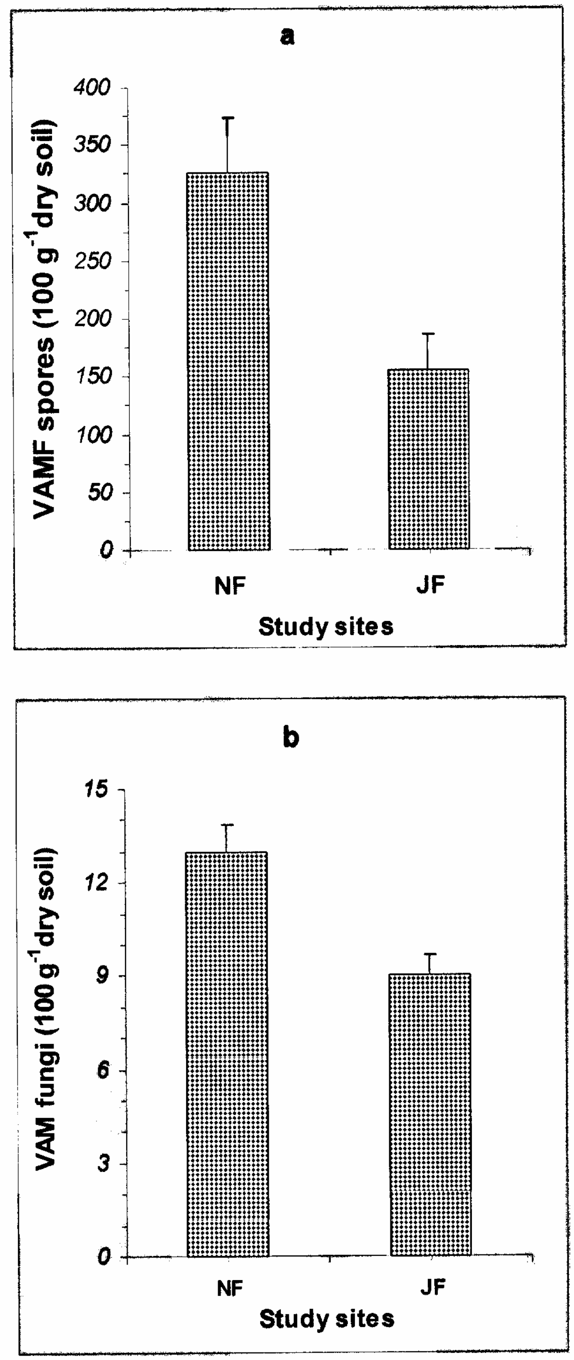

Fig. 1. VAM fungi spore population (a) and species number (b) in jhum fallow (JF) and natural forest (NF) sites. Bars on the histogram represents SD.

content of the soil in the jhum fallow. These results clearly suggests that species diversity of VAM fungi was influenced by the total P content of the soil irrespective of the study sites.

Maximum number of VAM fungi species were *Glomus* while only one species was recorded for *Enterphospora* genus in the study. *Scutellospora hetrogama* followed by *Scutellospora gregaria* and *Glomus fasiculatum* in the natural forest whereas *Acaulospora denticuata, A. delicate, Gigaspora albidum, Glomus clarum, G. fasiculatum, G. microaggregatum* and *G. mossae* in the jhum fallow were VAM fungi species with highest percentage frequency occurrences. The reason for higher frequency occurrences could be attributed to the favourable soil environmental conditions of the natural forest site and jhum fallow to these species in which the native VAM species had established a permanent symbiosis with their host plants for regeneration. VAM fungi species occurring in these sites would have favourable conditions for completing their life cycle in presence of their host roots. On the contrary, the jhum fallow site being an abandoned land, the top soil had been repeatedly disturbed for 13 years with a short jhum fallow cycle of every 1-3 years.

Since the jhum fallow site was cleared and uncontrolled burning was done for every time prior to cropping, the continuity of the life cycle of VAM fungi must have been affected by removal of the host plants. Further, the repeated slash and burning practices and simultaneous rainfall, insolation and erosion in this site might have caused compaction and hardening of the soil as evidenced by increased value of bulk density of jhum fallow site (1.36 g cm^{-3}) over the natural forest site (1.04 g cm^{-3}). This could have caused restricted propagule movement, growth and colonization of host plant roots by VAM fungi propagules. This results in delay of interaction between VAM fungal propagules and plant roots and subsequent establishment of symbiosis. Ahmad (1996) reported that there was a reduction of VAM propagules by 30-50% when a forest soil is severely disturbed through heavy soil mechanical compaction, exposure and erosion. Reduction in the rate of host root infection, formation and colonization of VAM fungi have been reported from disturbed soils (Bellgard 1993; Jasper *et al.* 1987; Mc Gonigle *et al.* 1990). All the VAM fungi species recorded from jhum fallow site were recorded from the natural forest site

Table 5. Percentage frequency occurrence of VAM fungi species in jhum fallow and natural forest sites.

Species	Jhum fallow	Natural forest
Acaulospora delicata Walker *et al.*	40	47
A. denticulata Sicverding & Toro	47	47
A.elegans Trappe & Gerd.	20	20
A. foveata Trappe & Janos	33	40
A. lacunosa Morton	33	27
A. spinosa Walker & Trappe	20	7
Enterophospora infrequens Hall	–	13
Gigaspora albida Schenck & Smith	40	7
G.candida Bhattacharjee *et al.*	27	40
G. decipiens Hall & Abbott	–	20
Glomus albidum Walker & Rhodes	40	20
G. boreale (Thaxter) Trappe & Gerd.	33	40
G. canadense (Thaxter) Trappe & Gerd.	27	40
G. claroideum Schenk & Smith	–	27
G. clarum Nicolson & Schenck	47	47
G. constrictum Trappe	27	13
G. diaphanum Morton & Walker	–	20
G. fasciculatum (Thaxter) Gerd. & Trappe emend. Walker & Koske.	40	53
G. fulvum (Berk & Broome) Trappe & Gerd.	27	20
G. globiferum Koske & Walker	7	–
G. glomerulatum Sieverding	7	13
G. heterosporum Smith & Schenck	–	33
G. intraradices Schenck & Smith	7	13
G. lacteum Rose & Trappe	–	13
G. maculosum Miller & Walker	–	27
G. microaggregatum Koske *et al.*	40	47
G. microcarpum Tul. & Tul.	27	47
G. monosporum Gerd. & Trappe.	7	7
G. mosseae (Nicol. & Gerd.) Gerd. & Trappe	40	47
G. multicaule Gerd. & Bakshi	–	40
G. pulvinatum (Henn.) Trappe & Gerd.	13	20
G. reticulatum Bhattacharjee & Mukerjee	33	–
G. tenebrosum (Thaxter) Berch	7	33
G. tenerum Tandy emend. Mc Gee	33	20
G. tortuosum Schenck & Smith	7	53
Sclerocystis rubiformis Gerd. & Trappe	20	7
S. sinuosa Gerd. & Bakshi	20	20
Scutellospora aurigloba (Hall) Walker & Sanders	20	27
S. coralloidea (Trappe *et al.*) Walker & Sanders	–	40
S. gregaria (Schenck & Nicol.) Walker & Sanders	20	53
S. heterogama (Schenck & Nicol.) Walker & Sanders	20	73
S. pellucida (Nicol. & Schenck) Walker & Sanders	13	40
S. persica (Koske & Walker) Walker & Sanders	–	27
S. reticulata (Koske *et al.*) Walker & Sanders	7	20

Absence of species is denoted by dash (–)

except for two species namely, *Glomus globiferum* Koske & Walker and *G. reticulatum* Bhatacharjee & Mukerjee. Ten VAM fungi species (*G. heterosporum* Smith & Schenck, *Enterophospora infrequens* Hall, *G. claroideum* Smith & Schenck, *G. decipiens* Hall & Abbott, *G. diaphanum* Morton & Walker, *G. lacteum* Rose & Trappe, *G. macaulosum* Miller & Walker, *G. multicaule* Gerdemann & Bakshi, *S. coralloidea* Walker & Saunder and *S. persica* Koske & Walker) were recorded to be disappeared from the jhum fallow though these species were noted only from the natural forest site. Roldan *et al.* (1997) also reported that agriculture use of soil reduces soil fertility and lowers VAM fungi propagules as compared to the soil which is kept in its natural state. The loss of these VAM fungi species in the jhum fallow site shows the long-term detrimental effect of soil disturbance due to slash-and-burn agriculture practices on species diversity of VAM fungi. Another reason for decreased VAM populations and species diversity in the jhum fallow site could be that the fungal propagules were killed as a result of uncontrolled burning of dried slash on the soil surface during the preparation of field for cultivation of crops.

The lower index of dominance (0.13) for VAM fungi in the natural forest site indicates shared dominance of many VAM fungi species while the higher value of 0.16 indicates dominance by a few species of VAM fungi in the jhum fallow site (Fig. 2). Species dominance was shared by a maximum of 17 VAM fungi out of a total of 42 species in the natural forest site as revealed by higher percentage frequency occurrences of the species which accounts for more than 40% of the total species occurred. However, species dominance was found with 8 VAM fungi species representing only 25% of the total species occurred in the jhum fallow. In case of general diversity indices the result was in contrast to the indices of dominance, a value of 0.99 for natural forest and 0.85 for jhum fallow sites suggesting a greater diversity of VAM fungi species in the natural forest site than in jhum fallow site. There was a decline of about 20% VAM fungi species diversity in the jhum fallow site in comparison to the natural forest site. This is in conformity with the higher number of VAM fungal species and propagules in natural forest than in jhum fallow.

Miller & Jastrow (1992) had reported that mycorrhizal hyphae are involved as an important cementing agent in forming soil aggregate and its stability. Another important role of mycorrhizal hyphae may be to bridge the annular space, producing a physical connection between the plant

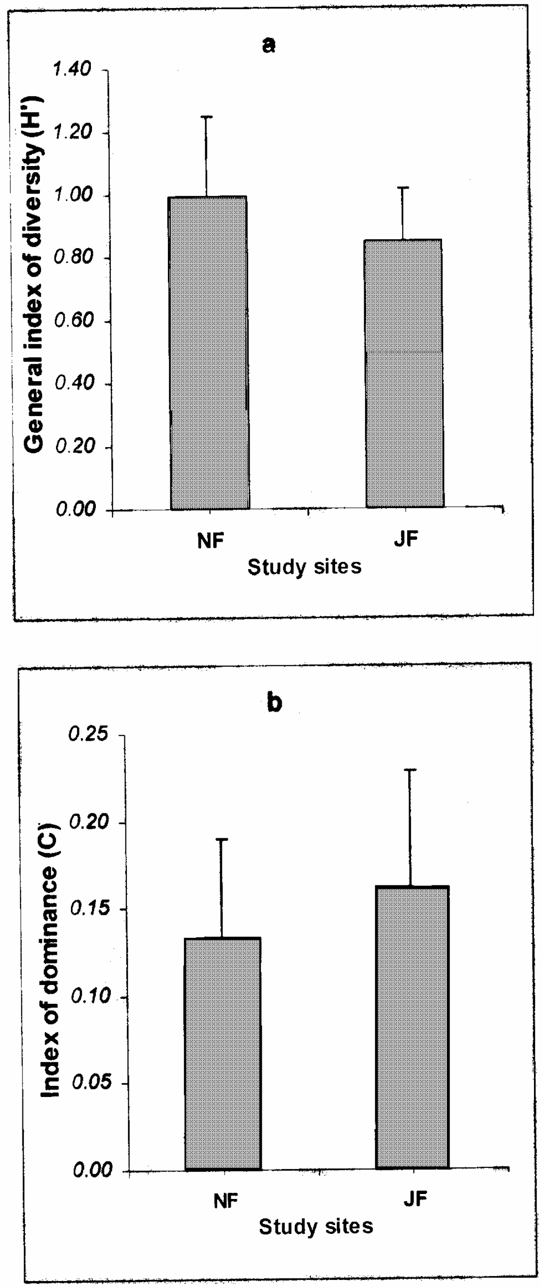

Fig. 2. Shanon & Weavers index of general diversity (a) and index of dominance (b) of VAM fungi in jhum fallow (JF) and natural forest (NF) sites. Bars on the histogram represents SD.

root surface and surrounding soil particles (Miller 1987; Ravarkar *et al.* 2000). This important function of the hyphae of mycorrhizal fungi might have been lost when the soil was used for cultivation continuously for a long period of time without proper nutrient input based on either organic or inorganic fertilizers. Such soils with reduced soil aggregation are poor in conserving nutrients, moisture and organic matter contents which are essential for germination, growth and development of plants and fungal propagules in the abandoned lands. Since the herbaceous and woody plant grows during the fallow period they are the main agents of restoring soil fertility (Pieri 1991). It is necessary to improve the re-establishment of these vegetation (Duponnois *et al.* 2001) by enhancing the formation and re-colonization of plant roots by VAM fungi in jhum fallow lands. This may result in formation of soil aggregates and increased soil organic matter and thus soil fertility. This is because of the reason that arbuscular mycorrhizal symbiosis is one of the most effective biotic factors which can favour rapid plant establishment, faster plant growth, alleviates abiotic stress (Smith & Read 1997) and are important in successful re-establishment of plants in re-vegetation strategies (Duponnois *et al.* 2001).

Conclusions

The present study indicates that there was a significant decrease in propagule populations, species abundance and diversity of VAM fungi in the jhum fallow site even after five years of regeneration period as fallow land after slash-and-burn agriculture in comparison to natural forest site. There was a long term adverse effect of slash-and-burn agriculture system on the distribution and survival of vesicular-arbuscular mycorrhizal fungi which in turn influences the poor vegetal cover recovery and restoration of soil fertility in the jhum fallow site. The decreased diversity of VAM fungi species in jhum fallow might be due to (i) repeated slash-and-burn agriculture in the past destroying the VAM fungi propagules, (ii) lost of host plants and (iii) unfavourable edaphic conditions for regeneration of VAM fungi in the jhum fallow land. There was loss of ten VAM fungi species in the jhum fallow site as a consequence of shifting cultivation. Whether these species have been eliminated permanently from the jhum fallow site or are unable to regenerate due to the absence of the host plants and other soil conditions need further investigation.

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References

Ahmad, N. 1996. An assessment and enumeration of vesicular-arbuscular mycorrhizal propagules in some forest soils of Jengka. *Journal of Tropical Forest Scinece* **9**: 137-146.

Bellgard, S.E. 1993. Soil disturbance and infection of *Trifolium repens* root by vesicular-arbuscular mycorrhizal (VAM) fungi. *Mycorrhiza* **3**: 25-29.

Bellgard, S.E. 1994. The bi-functional nature of the mycelial network associated with plants colonized by vesicular-arbuscular mycorrhizal fungi. *Mycorrhiza News* **6**: 1-5.

Duponnois, R., C. Plenchette., J. Thioulouse & P. Cadet. 2001. The mycorrhizal soil infectivity and arbuscular mycorrhizal fungal spore communities in soils of different aged fallows in Senegal. *Applied Soil Ecology* **17**: 239-251.

Gerdemann, J.W. 1968. Vesicular-arbuscular mycorrhizae and plant growth. *Annual Review of Phytopathology* **6**: 397-418.

Gerdemann, J.W. & T.H. Nicolson. 1963. Spores of mycorrhizal *Endogone* extracted from soil by wet-sieving and decanting. *Transactions of British Mycological Society* **46**: 235-244.

Greenland, D.J. & P.H. Nye. 1959. Increase in carbon and nitrogen contents of tropical soils under natural fallow. *Journal of Soil Science* **10**: 284-299.

Janos, D.P. 1980. Mycorrhizae influence tropical succession. *Biotropica* (Suppl.) **12**: 56-64.

Jasper, D.A., A.D. Robson & L.K. Abbott. 1987. Effect of surface mining on the infectivity of vesicular-arbuscular mycorrhizal fungi. *Australian Journal of Botany* **35**: 641-652.

Loyanachan, T.E. 2000. Mycorrhizae and their role towards natural resource management *In*: *Extended Summary*. *International Conference on Managing Natural Resources for Sustainable Agriculture Production in the 21st Century,* New Delhi, India, Feb. 14-18, 2000, **1**: 70.

Mc Gonigle, T.P. D.G. Evans & M.H. Miller. 1990. Effect of degree of soil disturbance on mycorrhizal colonization and phosphorus absorption by maize in growth chamber and field experiments. *New Phytologist* **116**: 629-639.

Miller, R.M. 1979. Some occurrence of vesicular-arbuscular mycorrhiza in natural and jhum fallow ecosystems of the Red Desert. *Canadian Journal of Botany* **57**: 619-623.

Miller, R.M. 1987. The ecology of vesicular-arbuscular mycorrhizae in grass and shrublands. *In*: G.R. Safir (ed.) *Ecophysiology of VA Mycorrhizal Plants*. CRC Press, Boca Raton, Finland.

Miller, R.M. & J.B. Jastrow. 1992. The application VA Mycorrhizae to ecosystem restoration and reclamation. pp. 437-439. *In*: M.F. Allen (ed.) *Mycorrhizal Functioning: An Integrative Plant Fungal Process.* Chapman & Hall, London.

Okalebo, J.R., K.W. Gathua & P.L. Woomer. 1993. *Laboratory Methods of Plant and Soil Analysis: A Working Manual.* Technical Bulletin No. 1 Soil Science Society East Africa.

Odum, E.P. 1971. *Fundamentals of Ecology.* Third Edition. W.B. Saunders and Co, Tokyo.

Pieri, C. 1991. Les bases agronomiques de l'amelioration et du maintein de la ferilite des terres due savanes au sud sahara. pp. 43-74. *In*: *Savanes d'Afrique, terre fertile? Actes des Rencontres internatinales,* Montepellier (France), 10-14 December 1990.

Ravarkar, K.P., N.G. Juma & W.B. Mc Gill. 2000. Vesicular-arbuscular mycorrhiza hyphal bridges and N-transfer from legume to non-legume plant. *In*: *Extended Summary International Conference on Managing Natural Resources for Sustainable Agriculture Production in the 21st Century,* New Delhi, India, Feb. 2000 **1**: 657-658.

Roldan, A., C. Garcia & J. Albadalejo. 1997. AM fungal abundance and activity in chronosequence of abandoned fields in a semi arid Mediterranean site. *Arid Soil Research and Rehabilitation* **11**: 211-220.

Schenck, N.C. & Y. Perez. 1987. *Manual for the Identification of VA Mycorrhizal Fungi.* Second Edition. International Culture Collection of VA Mycorrhizal Fungi (INVAM), University of Florida, Gainesville, Florida.

Simpson, E.H. 1949. Measurement of diversity. *Nature* **163**: 688.

Singh, S.S. & S.C. Tiwari. 2001. Modified wet-sieving and decanting technique for enhanced recovery of spores of vesicular-arbuscular mycorrhizal (VAM) fungi in forest soils. *Mycorrhiza News* **12**: 12-13.

Smith, S.E. & D.J. Read. 1997. *Mycorrhizal Symbiosis*. 2nd Edition Academic Press, San Diego, California, USA.

Stahl, P.D. & M. Christensen. 1982. Mycorrhizal fungi associated with *Bouteloua* and *Agropyron* in Wyoming sagebrush grasslands. *Mycologia* **74**: 877-885.

Surendra, S. 1999. *A Resource Atlas of Arunachal Pradesh.* Department of Planning, Govt. of Arunachal Pradesh, Itanagar, India.

Visalakshi, N. 1997. Dynamics of Vesicular-arbuscular mycorrhizae in two tropical dry evergreen forests, South India. *International Journal of Ecology & Environmental Sciences* **23**: 25-36.