Arbuscular Mycorrhizal fungi in Lands Abandoned due to Shifting Cultivation in Karbi Anglong District of Assam (India)

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Abstract
Three places of the Karbi Anglong Hill District of Assam were screened for arbuscular mycorrhizae, in the lands abandoned after shifting cultivation. The number of AM fungal spores, percentage of root colonized by the fungi and its diversity deteriorates after slashing and burning. The fungus populates and establishes itself in these abandoned lands ry slowly with increasing time. Similar trend in the development of the organism was observed in all of the three places under study. The time period of abandonment and number of fungal spores / the fungal diversity / the percentage root colonization were highly positively correlated. The early colonizers and profusely growing AM fungi in the lands abandoned were mostly the species of Glomus such as *G. aggregatum, G. multicaule, G. ambisporum*, *G. fulvum*.

Kew Words: Shifting Cultivation; Lands abandoned; A M fungi; Colonization

Introduction

The shifting cultivation is widely practiced in the hilly regions of North Eastern States of India. In Assam, the shifting cultivation is widely practiced in Karbi Anglong and North Cachar Hill Districts (between 25^{o} 33$^{'}$ N to 26^{o} 35$^{'}$ N Latitude and 92^{o} 10$^{'}$ to 93^{o} 50$^{'}$ E Longitude). In early days, a long term shifting cultivation ("Jhum Kheti") cycle of 20 – 30 years was followed but because of shortage of space with increasing population the cycle is reduced to 3 - 5 years only.

It is well known that the AM fungi, occurs in almost all types of soils (Mosse et al., 1981; Daniels Hetrick, 1984). The few instances where these fungi may be absent include eroded soil, fumigated soil, soil disturbed by mining etc. The wider occurrence may be attributed to its ability to disperse through wind (Warner et al., 1987) and soil transportation (Abbott and Robson, 1991) and extensive host range (Smith, 1980; Harley and Smith, 1983). The association of the AM fungi with the plant is necessary for the growth and development of the plants. This fungal community contributes in manifold ways for the growth and development of the plants - basically by supporting inherent phosphorus nutrition to them (Reeves et al, 1979; Allen et al, 1981; Harley and Smith 1983), enhancing nitrogen fixation and increasing the uptake of micronutrients such as Zn, Cu, etc (Swaminathan & Verma 1979; Li et al 1991), supporting the plant survivability under adverse conditions such as draught, salt injury, toxicity of heavy metals and pathogens attack (Reed et al, 1976; Hirral and Gerdemann, 1980; Harley and Smith, 1983; Kothari et al, 1991).

Many studies world wide have been made on various aspects of AM fungi in natural ecosystems and agricultural ecosystems (Sturmer et al., 2006; Hayman, 1982; Mosse and Bowen, 1968; Abbott and Robson, 1977; Johnson et al., 1991; Kucey and Paul, 1983; Schenck and Kinloch, 1980). However, very little is known about the AM fungi in the lands abandoned due to shifting cultivation. The land for shifting cultivation is prepared by slashing and burning of the natural vegetation. This probably results in degradation of fragile ecosystem and may lead to severe loss of top soil by erosion, loss of organic matter and A M fungi including other microbes. This paper therefore attempts to illustrate the status of the AM fungi in a land disturbed by shifting cultivation based on its spores population, diversity as well as the extent to which the fungi colonizes the roots of the plants.

Material and Methods

Three places from Karbi Anglong District of Assam were selected for the investigation namely Amtreng (P1), Hamren (P2) and Dilai (P3), where shifting cultivation is extensively practiced.

The plots for investigation were categorized as 0^{th} year (plots just after slashing and burning of the natural vegetation), and 1^{st}, 2^{nd}, 3^{rd}, 4^{th} and 5^{th} year on the basis of the year of abandonment. A simple random method was adopted for the investigation of the vegetation in these lands left abandoned. Each land was divided into equal blocks of 1 sq m. Some of the plants that are profusely growing in these blocks were uprooted and collected for observation of their root colonization by the AM fungi. Similarly soil samples were also collected in triplicate from each block at random, by digging the soil by approximately 15 inch wide and 20 inch depth, for the isolation of the AM fungal spores. For comparative analysis of the spore status, root colonization and diversity of the fungi the samples were also collected from the adjacent undisturbed areas.

The spores of AM fungi were isolated according to the method proposed by Gerdemann and Nicolson (1963) i.e. wet sieving and decanting method. The soil samples were air dried and 100g of soil was kept wet overnight. This was then decanted passing through a series of sieves 180 m to 53   m. The leftover in these sieves were observed under stereoscopic microscope for mycorrhizal spores.

The spores found were separated on the basis of morphology color and shape for identification. The identification of the fungi was based on the spore morphotypes as described by Schenck and Perez (1988).

The diversity index for each land of different year of abandonment is calculated according to the formula proposed by Shannon (1948)

$$H' = -\sum_{i=1}^{S}(p_i \ln p_i) - [(S-1)/2N]$$

Where

- n_i The number of individuals in species i; the abundance of species i.
- S The number of species. Also called species richness.
- N The total number of all individuals
- p_i The relative abundance of each species, calculated as the proportion of individuals of a given species to the total number of individuals in the community: $\frac{n_i}{N}$

For assessment of root colonization the method suggested by Philip and Hayman (1970) was followed. The roots of the plants were stained by using LGTB (Lectoglycerol Trypane Blue) stain for clear observation. The percentage of root infection was calculated by observing the presence or absence of internal AM fungal structures in the root segments under compound microscope. The calculation was done according to the formula described as below.

$$rc = \frac{\sum S^{+}}{\sum S^{+} + S^{-}} x100$$

Where *rc* = Percentage of root colonized by AM fungi S^{+} = segment of the root with AM fungal structures in it and S^{-} = segment of the root without any AM fungal structure.

Results

The lands on the hillocks those were used for cultivation, was prepared by slashing and burning of the vegetations (Pic. 1 & 2). Thus these lands became deserted, and thus did not host any vegetation. After one or two cultivations the lands were left abandoned for at least 3 to 5 years. During these fallow periods the lands were colonized by some of the herbs and shrubs. Mostly the plants those were growing in these abandoned lands belonging to the families of Asteraceae, Amaranthaceae, Leguminosae. The land abandoned for one year usually contained plants such as *Blainvillea latifolia, Erechthites valarianaefolia, Grangia madaras, Eclipta alba, Tridax procumbens, Cassia hirsute, Ageratum conyzoides* and *Eupatorium odoratum.* These plants therefore probably were the early colonizers in the lands left abandoned. More of the plants were seemed to be added to these lands with the increasing time of abandonment (Table 1 (+) for presence of the plants and (-) for the absence of the plants in the lands). An interesting consequence was also noted that from the 3rd year of abandonment, mostly the plants remained covered by *M. scandens,* which probably prevented all other herbs from growing. All those plants recorded in the abandoned plots were present in the undisturbed adjacent to the abandoned lands besides others.

Pic1. Land prepared for cultivation.

Pic2. Land prepared for cultivation.

Table 1. Presence or Absence of the plants from lands abandoned due to shifting cultivation. (P1, P2 and P3 = the three different places; 1-5 = years of abandonment; + = present and - = absent)

Plants	P1					P2					P3				
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Eupatorium odoratum	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Ageratum conyzoides	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+

Eclipta alba	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Cassia sofera	-	+	+	+	+	+	+	+	+	+	-	+	+	+	+
C. tora	-	-	+	+	+	-	-	+	+	+	-	-	+	+	+
C. occidentales	-	-	-	+	+	-	-	-	+	+	-	-	-	-	+
Vernonia sp.	-	-	-	+	+	-	-	+	+	+	-	-	+	+	+
Mikenia scandens	-	-	+	+	+	-	+	+	+	+	-	-	+	+	+
Lantana camera	-	-	-	-	+	-	-	-	+	+	-	-	-	-	+
Pespelum sp	-	+	-	+	+	+	+	+	+	+	-	+	+	+	+
Elephantopus scaber	+	+	+	+	+	+	+	+	+	+	-	+	+	+	+
Clerodendrum	-	-	-	+	+	-	-	+	+	+	-	-	+	+	+
Justicia simples	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Erechthites	+	+	+	+	+	+	+	+	+	+	-	-	+	+	+
Balinvillea latifolia	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Grangia madaras	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Tridax procumbens	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Cassia hirsute	-	-	+	+	+	-	-	+	+	+	-	-	-	+	+
Dryophylla sp.	-	+	+	+	+	+	+	+	+	+	-	-	-	-	-
Achranthus aspera	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Sida cordifolia	+	+	+	+	+	-	-	-	-	-	-	-	-	+	+
Urena lobata	+	+	+	+	+	-	-	-	-	-	-	-	-	-	-

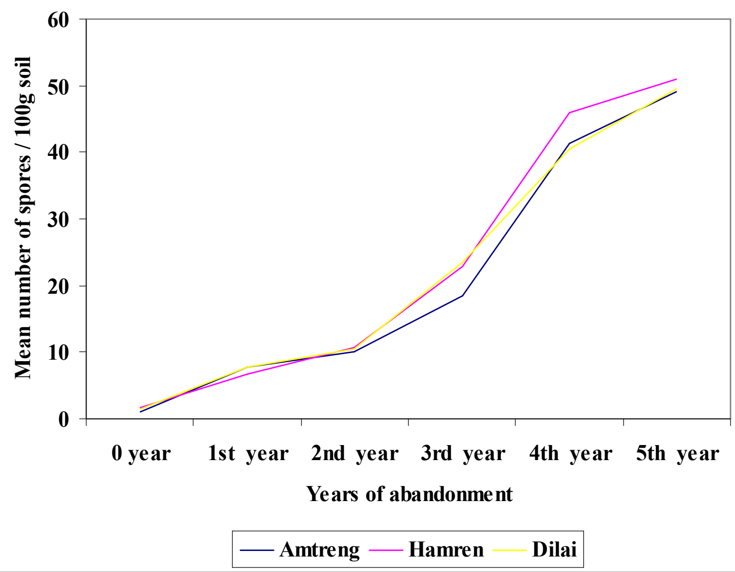
The result of AM fungal spore number is as shown in table 2, the values are the arithmetic average of 50 samples of soils each weighing 100g (grams) from every year of abandonment and also the adjacent undisturbed lands. A very poor number of spores were recorded from the soil samples of plots after slashing and burning (0^{th} year), which subsequently increasing in the fallow period. But the mean spores accounted in the fifth years abandoned land was significantly smaller than that of the undisturbed lands adjacent to it. The pattern of increment in all the three places under investigation was almost similar (Fig 1).

Plots Category	Places		
	Amtreng (P1) Avg. Spores/100g soil	Hamren (P2) Avg. Spores/100g soil	Dilai (P3) Avg. Spores/100g soil
0 year	1.00	1.67	1.53
1^{st} year	7.71	6.68	7.71
2^{nd} year	10.09	10.67	10.52
3^{rd} year	18.52	22.81	23.52

4th year	41.43	45.86	40.48
5th year	49.14	51.05	49.57
CC (r) =	0.95	0.96	0.97
Undisturbed	83.27	84.33	90.73
CC Correlation Coefficient			

There were 22 different species of AM fungi isolated and identified. All these 22 species were present in the lands undisturbed adjacent to the lands affected by shifting cultivation. Out of 22 species 17 species were encountered in the abandoned lands.

Fig. 1. Showing the pattern of increment in the number of AM fungal spores along the year of abandonment



The diversity index of the organism in the 1st year abandoned land was only 1.69 which is low species richness and species evenness than that of the undisturbed lands which was 2.58 according to the Shannon index range (1.5 low species richness and evenness to 3.5 high species richness and evenness). The three places shows similar pattern of the species richness and evenness. Although the diversity index was growing with time but even after of the fifth year of abandonment it didn't equals to that of the undisturbed adjacent lands.

Table 3. AM fungal spore identified in lands disturbed and undisturbed due to shifting cultivation.

AM species	Abandoned plots					Undisturbed Land
	1	2	3	4	5	
Ambispora apendicula	0	0	0	15	33	71
A. bireticulata	0	0	0	0	29	62
A. denticulate	0	0	19	34	63	100
A. foveata	0	0	17	25	26	57
Gigaspora decipens	0	0	0	0	0	30
Glomus ambisporum	15	68	97	236	316	387
G. constrictum	0	0	0	0	0	32
G. deserticola	6	23	20	43	46	77
G. fulvum	17	76	98	233	570	478
G. aggregatum	12	73	114	256	589	388
G. australe	0	0	0	0	0	37
G. borale	0	0	0	0	0	20
G. botryiodes	0	0	0	10	17	40
G. multicaule	14	65	87	121	134	249

G. microcurpum	0	23	0	0	0	41
G. radiatum	0	0	0	12	56	82
G. mossae	0	0	0	14	45	69
G. rubiforme	0	21	19	28	29	48
Scutellospora nigra	5	17	47	49	96	115
S. perisca	0	0	0	0	56	69
S. reticulate	0	0	0	0	19	44
Diversity Index	**1.69**	**1.91**	**1.95**	**2.01**	**2.07**	**2.58**

Root colonized by the AM fungi was based on the presence or absence of the fungal structures inside the root. Almost all of the plants in the abandoned lands were colonized by the AM fungi. However, some plants in the 1st year abandoned land were growing without the fungal association. But in the subsequent year the fungi establishes symbiosis with these plants. The total root colonized by the fungi was very poor 2-4% but gradually in the subsequent year of abandonment it increases (Table 4).

Table 4. Showing percentage of root colonization in plants growing in areas abandoned for 1 – 5 years. of all three places (P1-P3) (UL = Undisturbed land; - = plant absent)

	Percentage of root colonized																	
Plants	1st			2nd			3rd			4th			5th			UL		
	P1	P2	P3	P1	P2	P3	P1	P2	P3	P1	P2	P3	P1	P2	P3	P1	P2	P3
Eupatorium odoratum	0	0	0	5	3	0	10	8	0	21	16	4	28	23	10	70	65	70
Ageratum conyzoides	0	2	0	2	10	3	8	19	6	14	28	16	31	32	23	65	60	65
Eclipta alba	2	0	0	8	6	0	10	10	4	20	12	10	32	18	21	68	58	62
Cassia sofera	-	3	-	5	0	0	11	8	3	23	10	6	32	22	15	59	65	70
Cassia tora	-	-	-	-	-	-	12	9	0	20	16	7	35	25	18	70	68	70
Cassia occidentalis	-	-	-	-	-	-	-	-	-	13	10	10	28	18	22	60	59	56
Vernonia sp	-	-	-	-	-	-	-	5	-	12	8	-	25	18	10	55	60	58
Mikenia scandens	-	-	-	-	6	-	10	9	9	28	14	18	98	20	38	78	70	76
Lantana camera	-	-	-	-	-	-	-	-	-	-	8	-	42	23	20	80	75	70
Pespelum sp	-	6	-	4	12	0	-	15	3	9	22	8	26	35	19	59	68	72
Elephantopus scaber	3	2	-	0	3	0	8	10	7	10	23	14	19	38	22	56	62	72
Clerodendrum infortunata	-	-	-	-	-	-	-	8	6	19	15	12	33	29	24	75	68	68
Bambusa arundinacea	-	-	-	-	-	-	-	-	-		-	-	-	-	20	80	76	64
B.baccifera	-	-	-	-	-	-	-	-	-		-	-	-	-	-	76	82	75
Justicia simplex	0	3	0	3	5	3	8	14	8	22	28	15	38	40	38	72	71	80
Erechthites valarianaefolia	4	0	-	9	4	-	18	10	6	29	17	21	35	26	30	68	59	72
Blainvillea latifolia	0	0	0	0	2	0	5	8	0	12	15	9	15	22	18	56	61	62
Grangia madaras	0	0	0	6	6	2	16	11	0	22	18	11	35	25	22	64	65	56
Tridax procumbens	6	7	0	8	15	4	18	23	8	27	39	15	42	42	28	67	80	71
Cassia hirsute	-	-	-	-	-	-	0	10	-	6	28	10	22	40	16	79	76	78
Dryophylla sp	-	0	-	0	10	-	13	20	-	31	29	-	38	36	-	62	60	72
Achyranthus aspera	0	5	0	7	9	0	15	14	8	32	18	15	39	28	28	66	68	60
Sida cordifolia	0	-	-	12	-	-	15	-	-	29	-	12	35	-	21	59	65	55
Urena lobata	0	-	-	5	-	-	16	-	-	18	-	-	29	-	-	57	54	65
Solanum torvum	-	-	-	-	-	-	-	-	-	20	-	-	38	-	-	80	78	70
Total S^+	15	28	0	74	91	12	193	211	68	437	374	213	795	560	463	1681	1673	1689
No of .pants. colonized	12	13	8	15	14	11	17	18	15	22	20	15	23	20	21	25	25	25
no. of Obs.=$S^+ + S^-$. X 100 segment each plant	1200	1300	800	1500	1400	1100	1700	1800	1500	2200	2000	1500	2300	2000	2100	2500	2500	2500
Total % of root colonized	1.2	2.1	0	4.9	6.5	1.0	11.3	11.7	4.5	19.8	18.7	14.2	34.5	28	22.0	67.2	66.9	67.5

Discussion

Cultivation of edible crops although is an unavoidable need to the human beings. The degrading account of the AM fungi in the abandoned land may be attributed to the desrting phenomenon because of the slashing and burning for the preparation of the lands for cultivation. Although there are no much evidence regarding the effect of fire on AM fungi, however the study of Klopatek and coworkers 1988, had shown that the burning in controlled condition of three sources of litter above either wet or dry soil lead to loss of mycorrhizal infectivity which was because of the soil temperature reached during combustion. In shifting cultivation similar condition arise therefore, probably the 0^{th} year of the present study, there was insignificant occurrence of AM fungal spores. Further it is possible that due to the exposure of the top soil after denudation, downpour washed away the AM fungal propagules with the top soil. The possibility cannot be denied because literatures revealed that the AM fungal spore usually occurs in the top 20 cm of the soil profile (Sutton and Barron, 1972; Redhead, 1977). The poor extent of mycorrhizal formation in these land probably is also an indication regarding the soil erosion, because the studies of Hall and Armstrong, 1979; Powell 1980; Habte, 1989 suggests that soil erosion by means of water decreased markedly both the number of propagules of AM fungi and the extent of mycorrizae formation.

The increasing number of AM fungal spores, may be because of the migration of the AM fungal propagules from the adjacent undisturbed lands through, wind, water and animals as was been describe by Walker, 1987 and Warner, 1987 that these are the agents for AM fungal dispersal.

The study revealed that the number of spores as well as the root colonization correlates to that of the increasing time of abandonment. However, even after fifth year of abandonment the number of spores, species diversity, and mycorrhizae formation remained significantly low compared to that of undisturbed adjacent areas. This may be because of the alteration of an ecosystem to an agro-ecosystem resulted change in the incidence of AM fungal species and their potential. Similar result were suggested many authors Schenck and Kinloch, 1980; Jhonson and co-workers 1991 that changes occur in the incidence of AM species during conversion of natural ecosystem to agro ecosystem. The lower number of AM fungi in agricultural lands than in adjacent was also recorded by Mosse and Bowen 1968; Abbott and Robson 1977a. However, Molina and coworkers; Rose, 1981 recorded that nonetheless small numbers of spores may be associated with extensive root infection, but present study reveals that both the spore number and mycorrhizae formation are comparative low than that of the adjacent undisturbed lands.

Conclusion

The study reflects AM fungi are disturbed because of slashing and burning for cultivation resulting poor mycorrhizae formation and spore population. The succession of AM fungi to these lands found to be correlating to that of time of abandonment, the more the fallow period more is the mycorrhizae. The mycorrhizae formation may also be dependent on the plant communities successed to these lands. The repeated conversion of the undisturbed lands to an agroecosystem is exerting stress on the AM fungal incidence and growth. Agro-ecosystems are generated by different methods, no doubt all of the agro-ecosystems do exert pressure on the growth of the AM fungi, a comparative study may reveal the degree to which slashing and burning for shifting cultivation is responsible for the alteration of AM fungi.

Acknowledgement

The author is grateful to Dr. R.N. Bhattacharjee, for providing support in various ways for the present work and Dr. M.P. Barmon for his valuable guide to work out the statistics of the study. I thank Mr. N. Bharali, Mr. T. Rongpi for their kind help in interaction and in sample collection from the fields.

References

Abbott, L.K. and Robson, A.D., 1977. The distribution and abundance of vesicular arbuscular endophytes in some western Australian soils. *Aust. J. Bot.,* 25: 515 – 522.

Abbott, L.K. and Robson, A.D., 1991. Factors influencing the occurrence of vesicular – arbuscular mycorrhizas. *Agriculture, Ecosystem and Environment.,* **35**:121-150

Allen, M.F., Sexton, J.C., Moore., T.S. and Chriestesen, M., 1981. Influence of phosphate source on vesicular – arbuscular mycorrhizae of *Boutelona gracillis*. *New Phytol.* **87**: 687 – 694.

Daniels Hetrick, B.A., 1984. Ecology of VA mycorrhizal fungi. In: C. Li. Powell and D.J. Bagyaraj (ED), VA Mycorrhizae. CRC Press, Boca Raton, Florida, pp. 35 – 55.

Gerdemann, J.W. and Nicolson, T.H., 1963. Spores of mycorrhizal *Endogone* species extracted from soil by wet sieving and decanting. *Trans. Br. Mycol. Soc.,* **46**: 235 – 244.

Habte, M., 1989. Impact of simulated erosion on the abundance and activity of indigenous vesicular-arbuscular mycorrhizal endophytes in as oxisol. *Biol. Fertil. Soils.* **I**: 164-167

Hall, I.R. and Armstrong, P., 1979. The effect of vesicular-arbuscular mycorrhiza on growth of white clover, lotus and ryegrass in some eroded soils. *N.Z.J. Agric. Res.*, **22**: 479-484

Harley, J.L, and Smith, S.E., 1983. Mycorrhizal Symbiosis Academic Press, London, pp 483.

Hayman, D.S., 1982. Influence of soils and fertility on activity and survival of vesicular – arbuscular mycorrhizal fungi. *Phytopathology,* 72: 1119 – 1125.

Hirral, C.M. and Gerdemann, J.W., 1980. Improved growth of onion and bell pepper in saline soil by two vesicular – arbuscular mycorrhizal fungi. *J. Soil Sci. Soc. Am.* **44**: 654 - 665

Johnson, N.C., Zac, D.R., Tilman, D. and Pfleger, F.L., 1991. Dynamics of vesicular – arbuscular mycorrhizae during old field succession. *Oecologia.* 86: 349 – 358.

Kothari, S.K., Marschner, H. and Romheld, V. 1991. Effect of a vesicular – arbuscular mycorrhizal fungus and rhizosphere microorganism on manganese in the rhizosphere and manganese concentration in maize (*Zea mays* L.). *New Phytol.* **117**: 649 - 655

Klopatek, C.C., Debano, L.F. and Klopatek, J.M., 1988. Effects of simulated fire on vesicular-arbuscular mycorrhizae in pinyon-juniper woodland soil. *Plant Soil.* **109**: 245-249

Kucey, R.M.N. and Paul, E.A., 1983. Vesicular – Arbuscular mycorrhizal spore population in various Saskatchewan soils and the effect of inoculation with *Glomus* *mosseae* on faba bean growth in green house and field trials. *Can. J. Soil Sc.,* 63:87 – 95.

Li, X. L., Marschner, H. and George, E., 1991. Acquisition of phosphorus and copper by VA mycorrhizal hyphae and root – to – shoot transport in white clover. *Plant Soil.* **136**: 49 – 57.

Mosse, B., Sribely, D.P. and LeTacon, F., 1981. Ecology of mycorrhizae and mycorrhizal fungi. *Advances in Microbial Ecology* **5**: 137 – 210.

Mosse, B. and Bowen, G.D., 1968. The distribution of *Endogone* spores in some Australian and New Zealand soils and in an experimental field soil at Rothamsted. *Trans. Br. Mycol. Soc.,* 51: 485 – 492.

Molina, R.J., Trappe, J.M. and Strickler, G.S., 1978. Mycorrhizal fungi associated with *Festuca* in the western United States and Canada. *Can. J. Bot.,* **56**: 1691-1695.

Philips, J.M., and Hayman, D.S., 1970. Improved procedures for clearing and staining parasitic and vesicular – arbuscular mycorrhizal fungi for rapid assessment of infection. *Trans. Br. Mycol. Soc.,* 55: 158 – 161

Powell, C.L., 1980. Mycorrhizal infectivity of eroded soil. *Soil. Biol. Biochem.,* 12: 247 – 250.

Redhead, J.F., 1977. Endotropic mycorrhizas in Nigeria: species of Endogonaceae and their distribution. *Trans. Br. Mycol. Soc.,* 69: 275 – 280

Reeves, F.B., Wagner, D., Moorman, T. and Keil, J., 1979. The role of endomycorrhizae in regeneration practices in the semi-arid west. I. A comparison of incidence of mycorrhizae in severely disturbed vs natural environments. *Am. J. Bot.,* **66**: 1-13.

Reed, D.J., Koucheki, H.K. and Hodgson, J., 1976. Vesicular – arbuscular mycorrhiza in natural vegetation systems. I. Occurrence of infection. *New phytol.,* **77**: 641 – 653.

Rose, S.L., 1981. Vesicular – arbuscular endomycorrhizal associations of some desert plants of Baja. California. *Can. J. Bot.,* 59: 1056 – 1060.

Schenck, N.C. and Kinloch, R.A., 1980. Incidence of mycorrhizal fungi on six field crops in monoculture on a newly cleared woodland site. *Mycologia.,* 72: 445 – 456.

Schenck, N.C. and Perez, Y., 1988. Mannual for the identification of VA mycorrhizal fungi. University of Florida, Gainesville, Fl, 244pp.

Shannon, C.E., 1948. A mathematical theory of communication. *Bell System Technical Journal* **27**: 379–423 and 623–656.

Smith, T.F., 1980. The effect of season and crop rotation on the abundance of spores of vesicular – arbuscular (VA) mycorrhizal endophytes. *Aust. J. Soil Res.* **16**: 359 – 369**.**

Sturmer, S. L., Filho, O.K., Queiroz, M.H. and Mendonca, M.M., 2006. Occurrence of arbuscular mycorrhizal fungi in soils of early stages of a secondary succession of Atlantic Forest in South Brazil. *Acta bot. bras.* 20(3): 513-521

Sutton, J.C., and Baron, G.L., 1972. Population dynamics of *Endogone* spores in soil. *Can. J. Bot.,* 51: 2487 – 2493.

Swaminathan, K and Verma, B.C. 1979. Response of three crop species to vesicular – arbuscular mycorrhizal infection of zinc deficient Indian soil. *New Phytol.,* **82**: 482 – 487.

Warner, N.F., Allen, M.F. and MacMahem, J.A., 1987. Dispersal agent of vesicular – arbuscular mycorrhizal fungi in disturbed arid ecosystem. *Mycologia.* **79**: 721 – 730.

Walker, C., 1987. Formation and dispersal of propagules of Endogonaceae fungi. In: G. Pegg and P.G. Ayres, (ED), Fungal infection of plants. Cambridge Univ. Press, Cambridge, UK. pp. 269 – 284.