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RESEARCH ARTICLE

Arbuscular Mycorrhizal and Endophytic (DSE) Association in the Dominant Grasses of Melghat Forest (Phase -I), India

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ABSTRACT

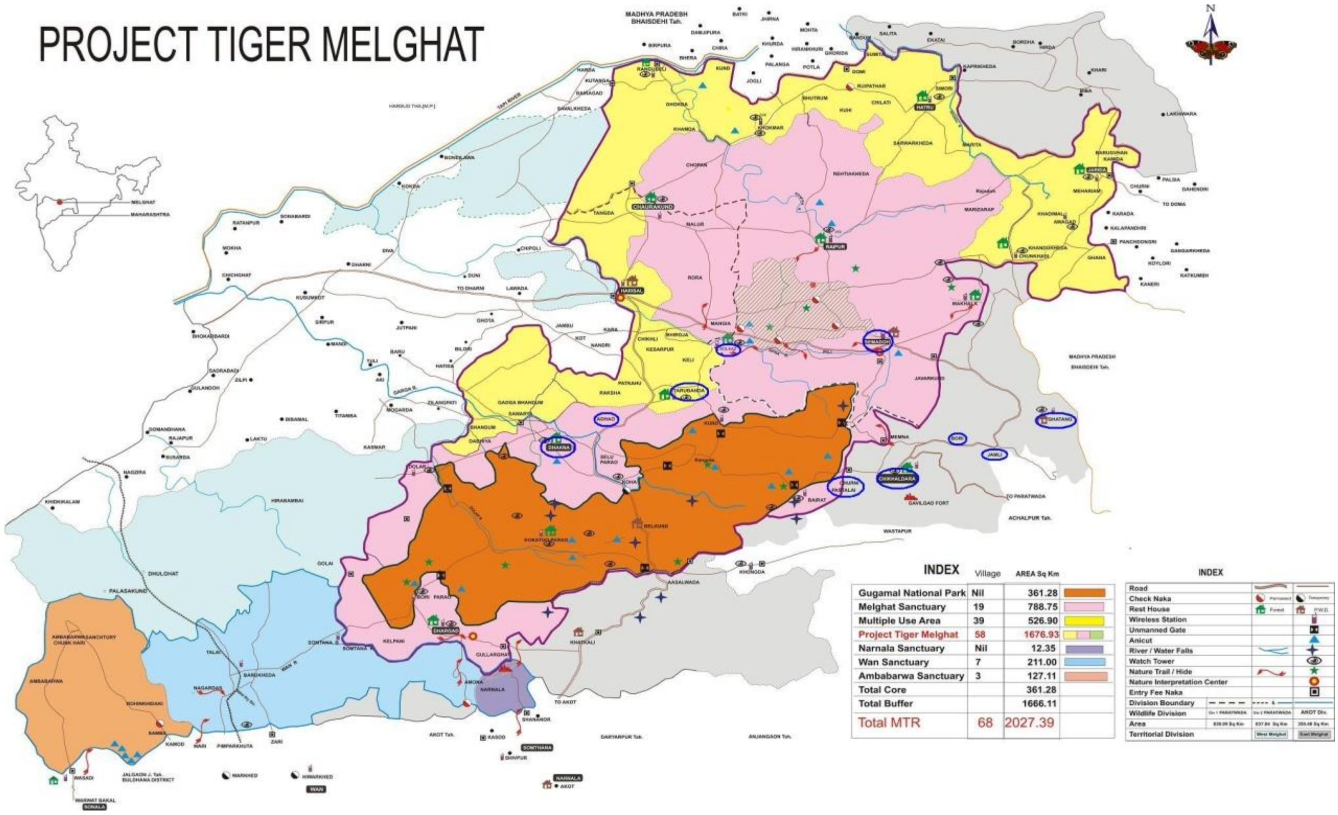
Investigations on arbuscular mycorrhizal fungi (AMF) and dark septate endophytic (DSE) association in some of the dominant grasses from Melghat forest (phase I) of Satpura terrain India, was carried out to examine their existence and symbiotic relationships with the host plants. This forest area was not surveyed earlier by anybody to evaluate the AMF status diversity hence it was decided to survey the buffer and core area. Rhizosphere soil of each sampled grass was analyzed for the AM fungal structures in the roots to study percent root colonization by AMF and AMF spore density in rhizospheric soils of respective samples. The composite soil sample was prepared for each site and used for physicochemical analysis by standard methods. In the first phase of the project, forty-eight dominant grass species from twenty-one different sites were collected along with roots and rhizospheric soil to find out AMF and DSE status of grasses. Both types of fungal associations was found in almost all the grass species collected during studies. All of them were found colonized by AMF hyphae along with moderate to poor development of mycorrhizal structures in roots. DSE colonization was also found in maximum forty-three species of grasses. Physicochemical characterization of all the soil samples were performed to find out its correlation with AM percent colonization and spore count. Mean AMF percent colonization was in between 1.33 to 52.85 and DSE in with 0.00 to 18.97. Viable AM spore count was in between 0 to 98 per 100g of soil. Altogether four AMF genera with its thirty-nine-different species were isolated and identified. A database of indigenous AM species richness for Melghat forest has been generated to plan and design the future management practices for grasses establishment and development especially in burnt and overgrazed areas.

Keywords: Grasses of Melghat, AMF, DSE, Diversity, Melghat Forest.

INTRODUCTION

Melghat forest is amongst the first nine tiger reserve declared and notified by the Indian government in 1974 as project tiger of Satpura terrain, spread in 2029 Km^2 area. The forest type is a southern tropical mixed dry deciduous with the dominance of finest teak (*Tectona grandis* Linn. f.). The forest is located at 21°26′45″N 77°11′50″E of northern part of Amravati district of Maharashtra state, India.

species (Wardle *et al.*, 2004). Bellgard (1993); Schwab and Reeves (1981) concluded that arbuscular mycorrhizal fungi (AMF) are mainly found in upper layer of soil and occur in high quantity in rhizosphere area and establish symbiotic association in almost all-natural ecosystems (Brundrett, 1991). On the global basis, mycorrhizae occur in 83% dicot and 79% of monocot plants and in all the gymnosperms (Wilcox 1991). AMF is associated with the roots of plant



Map I: Study Area Map

Grasses are monocotyledonous flowering plants belonging to family Poaceae formerly known as Gramineae are distributed widely throughout the world. They are ubiquitously found in almost all type of habitats and are helpful for growth of all plant communities (Mitra and Mukherjee, 2005). They are used as forage for domestic and wild animals, birds and for soil conservation. The Grains of grasses are provided as staple food for human (Gould, 1968) which satisfy about 80% of human nutrient requirement (Stebbin, 1972). They also play an important medicinal role (Mitra and Mukherjee, 2005; Jeeva *et al.*, 2006). Ecologically grasses are crucially important as their root system is very extensive and act as an effective soil binder (Skerman and Riveros, 1990); they consequently protect the erosion of banks of water tributaries (Saini *et al.*, 2007).

Soil microbes are effectively responsible for the health and productivity of plants (Bloemberg and Lugtenberg, 2001), hence the high level of soil microbial community is highly responsible for maintenance of high diversity of plant taxa and becoming an integral part of it, they occur in most of the ecosystems like dense rain forest, grasslands, sand dunes, savannas, woodlands, arid and semi-arid regions and are most common in different zones of the world and widely found in temperate, tropical and arctic regions of the earth forming broad ecological range.

Many researchers extensively studied the occurrence of AMF in tropical forests and subtropical forests (Mosse 1973; Janos 1980, Bagyaraj *et al.*, 2002). In India, distribution of AMF from semi-arid region was studied by Mukherji and Kapoor (1986); Rachel *et al.*, (1989).

Like AMF, Dark Septate Endophytes (DSE) which forms septate hyphae and microsclerotial structure in cortical region of roots are also capable to form mutual association (Jumpponen, 2001) and are common microbial community in tallgrass prairies (Mandyam and Jumpponen, 2005; 2008) and highly compatible with grasses and act beneficial to plant health in drought condition.

In the perusal of literature very scanty information is available about AMF and DSE association with grasses. The overall assessment of Melghat forest flora and fauna cannot be completed unless information available about this area is complete in all the respect. Therefore, the present investigation was undertaken to examine AMF and DSE relationship with dominant grasses of forest along with its colonization and diversity status of AM species in the Melghat forest for the first time.

MATERIALS AND METHODS

Studies were conducted in the Melghat forest of Satpura hill ranges from Amravati district, (Maharashtra), India. The forest is dry deciduous dominated by one of the best teak of India. The forest has rich biodiversity of different important medicinal plants along with various species of grasses. The grasses are considered to be a very important integral part of forest ecosystem and arbuscular mycorrhizae are one of the key components for the development and sustenance of forest ecosystems. In the first phase of survey, twenty-one different locations were selected for sampling. The samples were collected between September to December (2014). The photographic collection of grasses and its herbarium is maintained in the laboratory.

The top 2-3cm of soil around each grass species were removed and rhizosphere soils along with root systems from 4-15cm depth were collected in polyethene bags, labelled and brought to the laboratory for further processing. The soil and root samples in triplicate were maintained in refrigerator at 4^0C to find out physicochemical properties of soil, AMF spore count and taxonomic status of isolated AM spore.

Wet sieving and decanting technique of Gerdemann and Nicolson (1963) was used for the spore extraction and for spore count the method given by Gaur and Adholeya (1994) was followed. Only viable spores were counted and picked up by needle using Carl Zeiss semi DV 4 stereo zoom microscope. The mean spore density was expressed as spores in 100g soil. Permanent slides of these spores were prepared using polyvinyl alcohol. The detailed photography of these spores was done by Tucsen camera attached to Carl Zeiss Primostar Trinocular compound microscope under 10, 40 and 100x objectives. Morphotaxonomic identifications of extracted spores were carried out using the manuals of Schenck and Perez (1990) and INVAM.

All the permanent slides are deposited in Mycorrhizal biotechnology lab of Shri Shivaji Science College, Amravati

Data Analysis

The standard deviation of means was calculated. Pearson correlation coefficients were computed for soil physicochemical properties with AMF spore count and colonization. Ecological measures of diversity to describe AMF communities includes spore count, species richness, relative abundance, isolation frequency, Shannon-Winer index of diversity, Evenness and Simpson's index of dominance were used.

RESULTS

The soil physicochemical characteristics of the study sites of phase-I (buffer area) is presented in Table no 1. The soils were slightly acidic to alkaline in nature with pH ranged between 6.5 to7.8 and soil texture was mostly sandy clay loam. The range of other soil parameters such as EC ranged from 0.13 to 32.1 dsm^{-1}; phosphorus (P) 1.31 to 786.5 kg Ha^{-1} whereas some sites were P-deficient; potassium(K) 192.64 to 2723.84 kg Ha-1; Nitrogen (N) 109.76 to 517.44 kg Ha^{-1}; % Organic carbon 0.16 to 0.77. The micronutrients like Copper (Cu) ranged from 2.68 to 13.03 and Zinc (Zn) 0.52 to 4.23 ppm.

The site wise mean of AMF and DSE % colonization was found in between 1.33 to 52.85 and 0 to 18.97% respectively. The mean of spore count of AMF ranged from 0 to 98 per 100g of soil.

The grasses were collected from 21 different sites of phase-I and identified. In all 48 different grass species belonging to 37 genera were identified (Photo Plate-I) Highly dominant grasses from phase-I were found to be *Aristida hystrix* Thunb., nom. illeg., *Arthraxon lanceolatus* (Roxb.) Hochst., *Dichanthium pertusum* (L.) Clayton, *Digitaria stricta* Roth ex Roem. & Schult., *Setaria pumila* (Poir.) Roem. & Schult., *Sporobolus tenuissimus* (Mart. ex Schrank) Kuntze.

Intact viable AMF spores were isolated from all 21 sites of phase- I. In all 1430 AM spores were extracted and identified from all the sites from 100g soil of each site. As per morpho taxonomic characters 39 different AMF species belonging to 4 genera were recovered from different location (Table-2 and Photo Plate-II). Amongst 39 AM fungal species, *Glomus* represented by 29 different species, *Acaulospora* with 5 species, *Gigaspora* with 4 species and only one species of *Scutellispora*. *Glomus* found to be the most dominant genus with 74.35% species population followed by *Acaulospora* 12.82%, *Gigaspora* 10.25% and the least species that of *Scutellispora* with 2.56%.

Investigations were also carried out to observe presence or absence and types of arbuscular and intraradical AM spores in individual grassroots (Photo Plate No. III)

Apart from different types of arbuscules, other AMF structures such as hyphal penetration and appressorium, vesicles, H-connections and Y-junctions, hyphal coils, intraradical spores, extra-radical hyphae and spores have been observed (Photo Plate- IV). Dark Septate Endophytes (DSE) has formed septate hyphae and microsclerotia structure in cortical region of roots.

Statistical Analysis of correlation studies

Correlation studies between soil physicochemical properties, % AMF colonization, % DSE colonization and mean spore count from all sites of phase-I is presented in Table No.3.

In phase-I, % AMF colonization was found to be positively correlated with Potassium, Copper and Zinc, likewise % DSE colonization was found to be positively correlated with EC, Organic carbon, Nitrogen but % AMF was found to be negatively correlated with pH, Phosphorus, Potassium, Copper and Zinc. AMF spore count was found to be positively correlated with pH and Potassium but negatively correlated to EC, organic carbon, nitrogen, Phosphorus, Copper, Zinc, % AMF and % DSE.

In the present investigation, AMF % root colonization were in between 1.25 (*Coix aquatica*) to 86.53 % (*Rottboella cochinchinensis*); Root length with arbuscule ranged from 0 (in 15 grasses) to 53.33% (*Spodiopogon rhizophorus*);Root length with vesicle ranged from 0(in 6 grasses) to 34.11% (*Dichanthium pertusum*), root length with AMF hyphae ranged from 0 (in 3 grasses) to 71.78 % (*Rottboella cochinchinensis*); root length with hyphal coils ranged from 0 (in 35 grasses) to 12.22% (*Eleusine indica*). Whereas the DSE colonization in roots were in the range of 0 (in 10 grasses) to 38.90% (*Arthrason lanceolatus*). Root length with DSE hypha ranged from 0 (in 10 grasses) to 38.90% (*Arthrason lanceolatus*); root length with microsclerotia ranged from 0 (in 60 grasses) to 2.43 % (*Pseudanthistiria umbellata*). Table No.4.

DISCUSSION

The diversity of AM fungal species in Melghat forest associated with grass species was quite more than that of AM species reported by previous investigators. Choudhary et al., (2010) obtained 18 species belonging to 4 genera from marshy and shoreline vegetation of deeper beel Ramsar site of Assam, whereas Sathiyadash et al., (2010) reported only 11 species belonging to 3 genera from rhizospheric soil of south Indian grasses of Western Ghats. Chaudhry et al., (2006) was also isolated only 12 AMF species belonging to 3 genera from rhizospheric soils of perennial grasses from Cholistan desert, Pakistan. Thus, it can be said that the Melghat forest has more diversity of AMF species in compare to other studied area of the world and India.

Anjum *et al*., (2006) in their correlation studies reported that % mycelia and vesicular infection and number of vesicles were negatively correlated with all root and shoot growth parameters. Similarly, it was also reported by Baylis (1974) and Janos (1980).

CONCLUSION

The present investigation, moderate to very good AMF association along with DSE in different grasses were traced out. It can also make emphasis on the fact that mycorrhizal and DSE symbiosis was controlled by various edaphic factors. Moderate to high level of AMF colonization was an indication of better hyphae and root contact amongst different grasses of monocot plant species for increased benefits of AMF symbiosis and better adaptation to soil. Though there was less number of viable AMF spores in the rhizosphere soil of grasses there was high biodiversity of AM fungal species in the Melghat forest in comparison to previous studies on grasses.

From the present studies, it can be concluded that AMF diversity was high in compared to other regions of world. *Glomus* was recovered as the most dominant genus throughout the forest. An expanded AMF study from Melghat forest may be needed to determine relationships between AMF and DSE colonization. With the proper knowledge of mycorrhizal diversity in the rhizosphere of grasses, we can ensure better mycorrhizal inoculation programmes for sustainable availability of grass resources.

The selection of native dominant AMF, mass multiplication and its incorporation as biofertilizer is an important need for future technical development, restoration of burnt and destroyed grasses in the long-term sustenance of forest ecosystem in view to safeguarding the existence of wild animal life.

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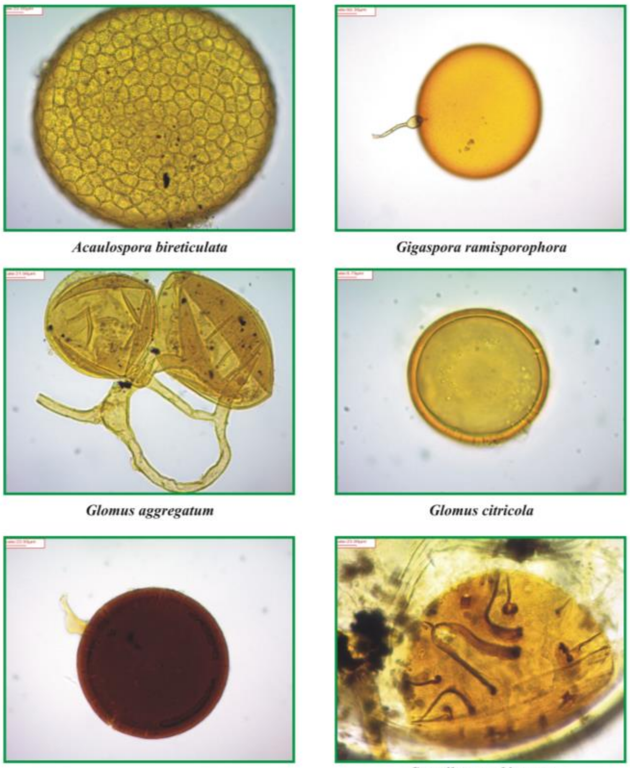
Website:
http://invam.caf.wvu.edu/myc.intor/Taxonomy/species.htm
http://melghattiger.gov.in/

PHOTO PLATE - I

Aristida hystrix — *Arthraxon lanceolatus* — *Dichanthium pertusum*

Digitaria stricta — *Setaria pumila* — *Sporobolus tenuissimus*

PHOTO PLATE - II



Acaulospora bireticulata — *Gigaspora ramisporophora*

Glomus aggregatum — *Glomus citricola*

Glomus constrictum — *Scutellospora biornata* (Germination Shield)

PHOTO PLATE - III

Type of Arbuscule

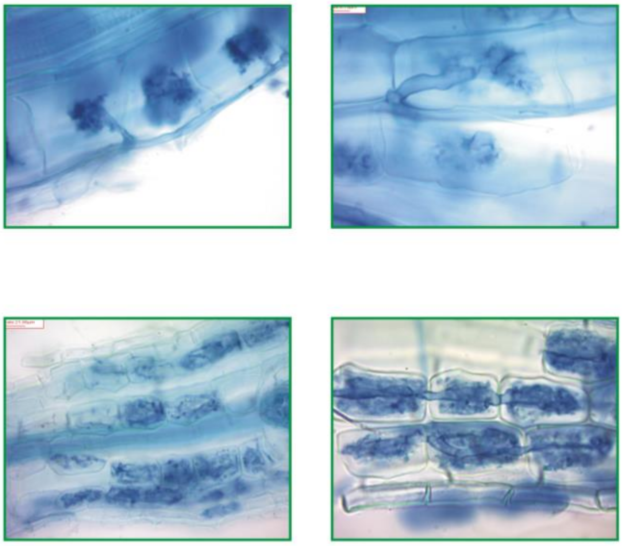
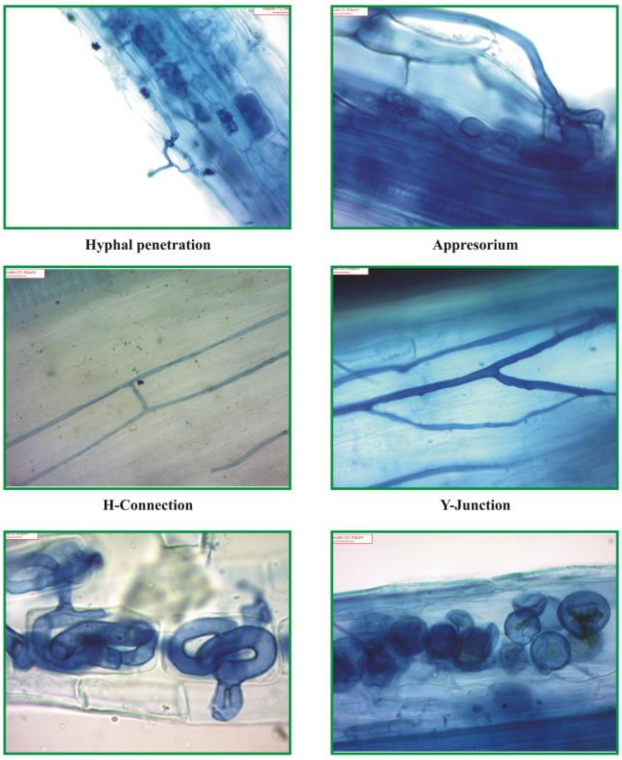


PHOTO PLATE - IV



Hyphal penetration — Appresorium

H-Connection — Y-Junction

Hyphal coils — Intraradical Spores

TABLE NO.1: SOIL PHYSICOCHEMICAL ANALYSIS

Site No.	Name of Spot	Soil Texture	pH	EC (dSm^{-1})	Organic Carbon (%)	Nitrogen ($Kg\ ha^{-1}$)	Phosphorus ($Kg\ ha^{-1}$)	Potassium ($Kg\ ha^{-1}$)	Copper (ppm)	Zinc (ppm)	% AMF Mean	% DSE Mean	Spore Count Mean
S_1	Bori (open ground)	Sandy loam	7.80	9.31	0.77	517.44	12.92	1302.56	13.03	1.01	7.19	1.82	0.00
S_2	Bori (on slope)	Sandy clay loam	7.36	27.80	0.77	517.44	145.98	2723.84	4.41	4.04	3.97	4.72	24.00
S_3	Gawilgad	Sandy clay loam	7.13	11.50	0.37	250.88	19.66	351.68	4.79	4.23	32.05	0.76	24.00
S_4	Devi point (open ground)	Sandy loam	6.57	11.60	0.44	297.92	7.74	472.64	3.64	0.52	31.07	10.80	1.20
S_5	Devi point (on slope)	Sandy loam	7.30	22.90	0.37	250.88	25.88	556.64	2.68	3.14	39.17	10.24	7.00
S_6	Dhamangao gadi (from roadside)	Sandy clay loam	7.52	30.70	0.56	376.32	1.31	535.36	5.94	3.03	35.14	10.06	30.75
S_7	Manbhang (on slope from roadside)	Sandy clay loam	7.16	14.70	0.23	156.80	786.50	377.44	3.26	1.76	28.30	5.17	7.50
S_8	Madaki (on slope)	Loamy sand	7.55	14.10	0.74	501.77	147.17	300.16	5.56	0.86	46.93	17.22	8.00
S_9	Madaki (on roadside plane)	Sandy clay loam	7.22	21.00	0.16	109.76	28.00	295.68	3.45	0.97	34.13	18.06	7.00
S_{10}	Madaki (on slope)	Loamy sand	7.73	0.13	0.35	235.20	1.48	320.32	8.81	1.37	36.33	1.79	44.00
S_{11}	Motha (on plane land)	Sandy loam	7.33	19.90	0.67	454.72	29.37	771.68	7.47	0.82	29.47	10.76	15.00
S_{12}	Churani (before churani roadside)	Sandy clay loam	6.73	24.90	0.77	517.44	2.93	622.72	6.71	1.61	20.60	7.49	11.42
S_{13}	Pastalaee	Sandy clay loam	7.66	9.61	0.35	235.20	12.92	505.12	9.39	1.46	3.21	2.21	0.00
S_{14}	Mariumpur (on slope)	Sandy clay loam	6.56	29.08	0.53	360.64	3.15	775.04	4.02	0.71	33.64	18.97	51.14
S_{15}	Semadoh road	Loam	6.94	32.10	0.35	235.20	31.72	461.44	5.94	1.61	50.32	7.48	8.00
S_{16}	Tetu (near rice field)	Sandy loam	7.78	8.77	0.23	156.80	4.70	421.12	10.54	1.31	27.33	11.20	23.60
S_{17}	Tetu (soyabean field)	Sandy loam	7.36	5.07	0.36	241.42	11.26	271.04	7.09	0.67	52.85	7.04	38.66
S_{18}	Bori (in cultivated land)	Sandy loam	7.11	14.90	0.46	313.60	4.82	229.6	6.51	0.75	34.34	12.96	18.66
S_{19}	Jamli (Marshy condition)	Sandy clay loam	7.86	14.30	0.39	266.56	19.54	192.64	8.05	0.64	40.74	10.20	0.00
S_{20}	Ghatang (on roadside)	Sandy clay loam	7.13	11.50	0.37	250.88	19.66	351.68	4.79	4.23	28.08	0.00	8.00
S_{21}	Chikhaldara Garden	Sandy Loam	7.86	11.60	0.44	297.92	7.74	472.64	3.64	0.52	1.33	0.67	98.00

TABLE NO.2: GRASS WISE AND SITE WISE DISTRIBUTION OF AMF SPECIES

Sr. No.	Name of Grass	Site No.	Identified AMF Species
1	*Alloteropsis cimicina*	S14	*Glomus ambisporum, Glomus etunicatum, Glomus fasciculatum*
2	*Andropogon pumilus*	S6	*Glomus heterosporum, Scutellospora erythropa*
3	*Apluda mutica*	S7	*Glomus geosporum*
4	*Apluda mutica*	S12	*Acaulospora scrobiculata, Acaulospora spinosa*
5	*Apocopis vaginata*	S7	*Gigaspora ramisporophora,*
6	*Aristida hystrix*	S6	*Glomus caledonium, Glomus fistulosum, Glomus geosporum, Glomus heterosporum*
7	*Aristida hystrix*	S18	*Scutellospora erythropa*
8	*Aristida hystrix*	S20	*Acaulospora scrobiculata, Scutellospora erythropa*
9	*Arthraxon hispidus*	S11	*Glomus geosporum*
10	*Arthraxon hispidus*	S14	*Gigaspora gigantia, Gigaspora margarita, Glomus aggregatum, Glomus albidum, Glomus arborence, Glomus cerebriforme, Glomus dimorphicum, Glomus etunicatum, Glomus fasciculatum, Glomus fistulosum, Glomus geosporum, Glomus macrocarpum, Glomus microaggregatum*
11	*Arthraxon lanceolatus*	S3	*Acaulospora scrobiculata, Acaulospora laevis, Glomus mosseae*
12	*Arthraxon lanceolatus*	S5	*Acaulospora laevis, Glomus fasciculatum, Glomus mosseae*
13	*Arthraxon lanceolatus*	S8	*Glomus clarum, Glomus geosporum*
14	*Arundinella pumila*	S12	*Glomus aggregatum, Glomus glomerulatum*
15	*Arundinella pumila*	S15	No Spore Found
16	*Chloris virgata*	S9	*Glomus geosporum*
17	*Coix aquatica*	S18	No Spore Found
18	*Cynodon barberi*	S20	*Acaulospora laevis*
19	*Dichanthium filiculme*	S7	*Glomus fasciculatum, Glomus geosporum*
20	*Dichanthium hugelii*	S12	*Glomus manihot*
21	*Dichanthium pertusum*	S6	*Acaulospora scrobiculata, Glomus albidum, Glomus fistulosum, Glomus heterosporum*
22	*Dichanthium pertusum*	S12	*Scutellospora erythropa*
23	*Dichanthium pertusum*	S18	*Glomus aggregatum, Glomus botryoides, Glomus constrictum, Glomus geosporum, Glomus intraradices, Glomus tenerum*
24	*Digitaria ciliaris*	S16	*Acaulospora scrobiculata, Gigaspora albida*
25	*Digitaria stricta*	S4	*Acaulospora scrobiculata*
26	*Digitaria stricta*	S14	No Spore Found
27	*Digitaria stricta*	S16	*Acaulospora scrobiculata, Gigaspora albida, Gigaspora ramisporophora, Glomus caledonium*
28	*Dimeria ornithopoda*	S14	*Gigaspora ramisporophora, Glomus citricola, Glomus geosporum, Glomus fasciculatum, Glomus fistulosum, Scutellospora erythropa*
29	*Echinochloa colunum*	S1	No Spore Found
30	*Echinochloa colunum*	S11	*Acaulospora laevis*
31	*Eleusine indica*	S9	*Gigaspora ramisporophora, Glomus geosporum*
32	*Eleusine indica*	S18	*Acaulospora scrobiculata, Glomus albidum*
33	*Eragrostiella biferia*	S4	No Spore Found
34	*Eragrostiella biferia*	S14	*Glomus aggregatum, Glomus arborence, Glomus fasciculatum, Glomus etunicatum, Glomus geosporum*
35	*Eragrostis coarctata*	S2	*Acaulospora scrobiculata, Gigaspora ramisporophora, Glomus mosseae*

36	*Eragrostis japonica*	S11	*Scutellospora erythropa*
37	*Eragrostis pilosa*	S17	*Acaulospora scrobiculata, Gigaspora ramisporophora, Glomus tenebrosum*
38	*Eragrostis tenella*	S6	*Glomus fistulosum, Glomus geosporum, Glomus tenebrosum*
39	*Eragrostis* sp.1	S4	No Spore Found
40	*Eragrostis* sp.2	S17	*Acaulospora scrobiculata, Glomus albidum*
41	*Eriochloa procera*	S12	*Acaulospora scrobiculata*
42	*Heteropogon ritchiei*	S8	*Glomus tenebrosum*
43	*Ischaemum rugosum*	S16	No Spore Found
44	*Melanocenchris jacquemontii*	S6	No Spore Found
45	*Mnesithea granularis*	S18	*Gigaspora albida, Gigaspora ramisporophora, Glomus albidum*
46	*Oplismenus burmannii*	S7	No Spore Found
47	*Oryza sativa*	S16	*Acaulospora scrobiculata, Glomus fasciculatum, Glomus geosporum, Glomus microaggregatum, Glomus multicaule*
48	*Panicum psilopodium*	S11	*Acaulospora delicata, Acaulospora scrobiculata, Gigaspora albida, Glomus geosporum*
49	*Panicum psilopodium*	S16	*Acaulospora delicata, Acaulospora scrobiculata, Gigaspora ramisporophora, Glomus caledonium*
50	*Paspalidium flavidum*	S6	*Gigaspora ramisporophora, Glomus ambisporum, Glomus leptotichum, Glomus maculosum*
51	*Paspalidium flavidum*	S13	No Spore Found
52	*Pennisetum purpureum*	S19	No Spore Found
53	*Pseudanthistiria umbellata*	S14	*Acaulospora scrobiculata, Gigaspora ramisporophora, Glomus aggregatum, Glomus etunicatum, Glomus geosporum, Glomus macrocarpum, Scutellospora erythropa*
54	*Pseudoraphis spinescens*	S21	*Acaulospora scrobiculata, Glomus etunicatum, Glomus fasciculatum, Glomus fasciculatum, Glomus geosporum, Glomus leptotichum*
55	*Rottboellia cochinchinensis*	S17	*Acaulospora delicata, Gigaspora ramisporophora, Glomus claroides*
56	*Sehima nervosum*	S8	No Spore Found
57	*Setaria intermedia*	S11	*Acaulospora scrobiculata*
58	*Setaria pumila*	S4	*Acaulospora scrobiculata*
59	*Setaria pumila*	S5	No Spore Found
60	*Setaria pumila*	S6	No Spore Found
61	*Spodiopogon rhizophorus*	S10	*Acaulospora rehmii, Acaulospora scrobiculata, Gigaspora ramisporophora, Glomus geosporum*
62	*Spodiopogon rhizophorus*	S15	*Acaulospora scrobiculata, Gigaspora ramisporophora, Glomus aggregatum, Glomus geosporum*
63	*Sporobolus indicus* var. flaccidus	S18	No Spore Found
64	*Sporobolus tenuissimus*	S4	*Acaulospora scrobiculata*
65	*Sporobolus tenuissimus*	S13	No Spore Found
66	*Sporobolus tenuissimus*	S14	*Gigaspora ramisporophora, Glomus ambisporum, Glomus etunicatum, Glomus fasciculatum, Glomus fistulosum, Glomus geosporum*
67	*Themeda quadrivalvis*	S11	*Gigaspora ramisporophora, Scutellospora erythropa*
68	*Themeda quadrivalvis*	S12	*Acaulospora scrobiculata, Scutellospora erythropa*
69	*Urochloa reptans*	S12	*Acaulospora scrobiculata, Glomus mosseae*
70	*Urochloa supervacua*	S6	*Acaulospora scrobiculata, Glomus etunicatum, Glomus halon, Glomus geosporum, Scutellospora erythropa*

TABLE NO.3-PHYSICO-CHEMICAL CHARACTERISTICS WITH %AMF, %DSE COLONIZATION AND AMF SPORE COUNT FROM PHASE-I

	pH	EC	Organic Carbon	Nitrogen	Phosphorus	Potassium	Copper	Zinc	% AMF	% DSE	Spore Count
pH	1										
EC	-0.46	1									
Organic Carbon	-0.05	0.30	1								
Nitrogen	-0.05	0.30	1.00	1							
Phosphorus	-0.06	0.01	-0.17	-0.17	1						
Potassium	0.01	0.35	0.58	0.58	0.04	1					
Copper	0.54	-0.42	0.20	0.19	-0.29	0.04	1				
Zinc	-0.08	0.24	0.03	0.02	0.07	0.35	-0.27	1			
% AMF	-0.26	0.08	-0.29	-0.29	-0.02	-0.55	-0.19	-0.13	1		
% DSE	-0.33	0.42	0.02	0.03	-0.07	-0.17	-0.24	-0.43	0.49	1	
Spore Count	0.17	-0.08	-0.02	-0.02	-0.16	0.01	-0.20	-0.13	-0.19	-0.15	1

TABLE NO.4: STATISTICAL VALUES OF THE STRUCTURES OF AMF AND DSE WITH AMF SPORE DENSITY FROM PHASE-I

Sr. No.	Name of Grass	Site	% Arbuscular Mycorrhizal Fungi (AMF)										% Dark Septate Endophyte (DSE)						Spore Count (100gm-1soil)
			RLA (arb)		RLV (vesi)		RLH (hypha)		RLHC (coil)		AMF Total		RLDH (DSE hypha)		RL M (Microsclerotia)		DSE Total		
			Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
1	*Alloteropsis cimicina*	S14	14.71	9.24	5.54	5.06	18.54	2.28	1.77	1.58	39.04	7.43	11.60	9.50	0.00	0.00	11.60	9.50	20
2	*Andropogon pumilus*	S6	0.37	0.64	11.74	11.02	16.14	8.57	0.74	1.28	28.99	7.20	17.57	16.48	0.00	0.00	17.57	16.48	40
3	*Apluda mutica*	S7	3.78	3.28	0.00	0.00	8.78	1.33	4.34	2.79	16.89	0.67	0.00	0.00	0.00	0.00	0.00	0.00	4
4	*Apluda mutica*	S12	0.00	0.00	0.68	1.18	10.91	3.31	2.08	3.61	13.68	6.20	13.93	13.75	0.00	0.00	13.93	13.75	10
5	*Apocopis vaginata*	S7	2.00	3.46	1.71	1.59	38.68	20.70	0.00	0.00	42.38	19.10	0.00	0.00	0.00	0.00	0.00	0.00	18
6	*Aristida hystrix*	S6	0.00	0.00	0.00	0.00	5.07	1.16	0.00	0.00	5.07	1.16	0.00	0.00	0.00	0.00	0.00	0.00	36
7	*Aristida hystrix*	S18	0.00	0.00	1.13	1.96	1.69	2.93	0.00	0.00	2.82	4.89	0.00	0.00	0.00	0.00	0.00	0.00	2
8	*Aristida hystrix*	S20	0.00	0.00	0.67	1.15	1.33	2.31	0.54	0.93	2.54	3.11	0.00	0.00	0.00	0.00	0.00	0.00	14
9	*Arthraxon hispidus*	S11	1.15	1.99	2.47	2.71	19.23	6.13	0.60	1.03	23.44	3.50	12.25	6.61	0.00	0.00	12.25	6.61	8
10	*Arthraxon hispidus*	S14	5.32	2.39	24.11	8.94	32.24	6.97	0.71	1.23	62.39	7.02	16.15	10.24	0.00	0.00	16.15	10.24	60
11	*Arthraxon lanceolatus*	S3	4.08	3.87	8.71	6.56	19.26	10.24	0.00	0.00	32.05	17.97	0.76	1.31	0.00	0.00	0.76	1.31	24
12	*Arthraxon lanceolatus*	S5	16.28	5.67	0.69	1.20	30.53	5.02	0.00	0.00	47.50	9.55	19.29	18.66	1.20	1.08	20.49	17.59	14
13	*Arthraxon lanceolatus*	S8	0.00	0.00	6.09	5.80	33.21	8.22	0.47	0.81	39.76	10.14	38.90	2.00	0.00	0.00	38.90	2.00	18
14	*Arundinella pumila*	S12	1.71	1.57	2.78	1.60	6.23	2.20	1.76	0.26	12.48	2.65	0.00	0.00	0.00	0.00	0.00	0.00	8
15	*Arundinella pumila*	S15	0.62	1.07	4.52	2.19	14.07	7.06	1.90	1.85	20.49	9.57	1.28	1.11	0.00	0.00	1.28	1.11	0
16	*Chloris virgata*	S9	0.00	0.00	6.44	4.21	37.99	6.31	0.00	0.00	44.44	3.47	36.13	9.86	0.00	0.00	36.13	9.86	6

17	*Coix aquatic*	S18	0.00	0.00	0.61	1.05	0.64	1.11	0.00	0.00	1.25	1.08	1.28	2.22	0.00	0.00	1.28	2.22	0
18	*Cynodon barberi*	S20	0.00	0.00	16.46	5.75	37.17	13.52	0.00	0.00	53.63	10.19	0.00	0.00	0.00	0.00	0.00	0.00	2
19	*Dichanthium filiculme*	S7	1.06	1.83	0.48	0.83	19.56	4.27	0.00	0.00	21.10	2.76	13.25	6.63	0.48	0.83	13.73	5.82	8
20	*Dichanthium hugelii*	S12	1.26	2.18	4.46	0.75	37.54	6.69	1.75	3.04	45.02	4.39	13.54	8.05	0.00	0.00	13.54	8.05	4
21	*Dichanthium pertusum*	S6	0.69	1.20	13.88	7.16	53.71	7.26	4.43	1.13	72.71	11.36	2.02	2.09	0.00	0.00	2.02	2.09	46
22	*Dichanthium pertusum*	S12	1.99	0.35	1.44	1.26	9.29	8.17	0.00	0.00	12.73	9.47	13.17	7.67	0.00	0.00	13.17	7.67	10
23	*Dichanthium pertusum*	S18	0.00	0.00	34.11	7.70	20.06	6.30	0.00	0.00	54.17	12.53	18.02	6.16	0.00	0.00	18.02	6.16	80
24	*Digitaria ciliaris*	S16	11.18	3.91	0.65	1.13	12.08	6.77	0.00	0.00	23.26	9.85	1.31	2.26	0.00	0.00	1.31	2.26	4
25	*Digitaria stricta*	S4	32.64	4.06	1.15	1.99	12.73	6.39	1.19	1.03	47.71	3.96	10.45	4.32	0.00	0.00	10.45	4.32	2
26	*Digitaria stricta*	S14	5.39	3.86	0.56	0.96	4.65	4.49	0.56	0.96	11.15	1.14	9.12	6.31	0.00	0.00	9.12	6.31	0
27	*Digitaria stricta*	S16	15.98	18.90	0.00	0.00	8.04	1.38	1.48	2.56	25.50	19.60	9.46	5.59	2.02	2.25	11.48	5.80	24
28	*Dimeria ornithopoda*	S14	17.45	7.92	4.57	3.78	10.07	9.88	0.00	0.00	32.09	14.81	19.86	10.30	0.00	0.00	19.86	10.30	76
29	*Echinochloa colunum*	S1	4.69	6.60	1.89	1.82	0.00	0.00	0.61	1.05	7.19	7.15	1.82	3.15	0.00	0.00	1.82	3.15	0
30	*Echinochloa colunum*	S11	4.52	2.59	15.74	5.08	25.19	4.23	0.00	0.00	43.76	4.81	13.31	9.17	0.00	0.00	13.31	9.17	6
31	*Eleusine indica*	S9	3.23	2.31	3.56	2.60	16.93	6.35	0.65	1.13	23.83	9.09	0.00	0.00	0.00	0.00	0.00	0.00	8
32	*Eleusine indica*	S18	2.39	2.86	5.77	1.05	36.31	10.75	12.22	5.43	56.68	4.72	18.33	1.45	0.00	0.00	18.33	1.45	16
33	*Eragrostiella biferia*	S4	1.80	1.62	7.95	5.21	0.00	0.00	0.00	0.00	9.76	5.57	9.84	4.84	0.00	0.00	9.84	4.84	0
34	*Eragrostiella biferia*	S14	8.05	12.31	5.66	5.56	14.63	2.78	6.91	6.03	35.25	21.53	5.15	6.01	1.87	1.85	7.03	4.93	56
35	*Eragrostis coarctata*	S2	1.97	1.96	0.67	1.15	1.33	2.31	0.00	0.00	3.97	4.00	4.72	1.32	0.00	0.00	4.72	1.32	24
36	*Eragrostis japonica*	S11	0.65	1.13	0.65	1.13	5.07	0.91	0.68	1.18	6.41	1.31	5.09	6.04	0.00	0.00	5.09	6.04	8
37	*Eragrostis pilosa*	S17	7.85	2.60	7.52	2.18	52.04	14.37	0.00	0.00	67.41	11.53	11.70	6.00	0.00	0.00	11.70	6.00	62
38	*Eragrostis tenella*	S6	0.62	1.07	10.91	9.46	25.65	19.72	3.76	0.22	40.94	29.47	8.53	8.34	0.00	0.00	8.53	8.34	60
39	*Eragrostis sp.1*	S4	7.37	3.05	1.77	1.79	20.34	13.38	1.92	0.26	31.41	11.74	13.12	3.83	0.00	0.00	13.12	3.83	0
40	*Eragrostis sp.2*	S17	2.32	2.69	0.56	0.98	1.73	1.76	0.00	0.00	4.62	4.40	0.56	0.98	0.00	0.00	0.56	0.98	12
41	*Eriochloa procera*	S12	3.40	4.51	0.64	1.11	2.62	1.42	5.54	6.55	12.20	11.74	4.54	1.61	0.00	0.00	4.54	1.61	2
42	*Heteropogon ritchiei*	S8	0.00	0.00	14.59	2.38	24.87	1.01	0.00	0.00	39.45	1.38	10.84	2.89	0.00	0.00	10.84	2.89	6
43	*Ischaemum rugosum*	S16	0.00	0.00	2.98	2.61	2.53	2.43	0.00	0.00	5.51	4.98	19.14	7.96	0.54	0.93	19.68	8.20	0
44	*Melanocenchris jacquemontii*	S6	0.00	0.00	15.32	4.72	15.77	2.19	0.00	0.00	31.10	4.96	19.00	2.03	0.00	0.00	19.00	2.03	0
45	*Mnesithea granularis*	S18	0.00	0.00	0.52	0.90	65.78	7.99	5.69	3.41	71.99	9.78	13.78	12.10	0.00	0.00	13.78	12.10	14
46	*Oplismenus burmannii*	S7	1.15	1.99	1.15	1.99	30.55	24.63	0.00	0.00	32.85	21.15	5.65	8.34	1.32	1.16	6.97	9.03	0
47	*Oryza sativa*	S16	3.66	4.65	0.00	0.00	6.52	5.34	0.00	0.00	10.18	4.94	6.26	8.21	0.00	0.00	6.26	8.21	30
48	*Panicum psilopodium*	S11	14.61	8.02	6.11	4.39	15.05	2.32	1.28	1.11	35.77	4.75	8.62	4.35	0.00	0.00	8.62	4.35	42
49	*Panicum psilopodium*	S16	50.24	28.89	6.30	4.64	9.71	6.05	1.90	2.04	68.15	19.26	7.39	1.80	0.00	0.00	7.39	1.80	60
50	*Paspalidium flavidum*	S6	0.00	0.00	0.72	1.24	23.25	12.27	0.36	0.62	24.33	13.27	17.44	15.61	0.00	0.00	17.44	15.61	34
51	*Paspalidium flavidum*	S13	1.13	1.96	1.13	1.96	2.01	2.19	0.00	0.00	4.27	4.24	1.45	2.51	0.00	0.00	1.45	2.51	0
52	*Pennisetum purpureum*	S19	29.85	19.53	3.76	5.07	7.54	10.13	1.18	1.02	40.74	30.70	10.20	8.53	0.00	0.00	10.20	8.53	0
53	*Pseudanthistiria umbellata*	S14	3.65	6.33	10.43	3.52	26.26	2.92	0.68	1.18	41.02	4.09	34.21	12.34	2.43	1.45	36.65	11.82	74
54	*Pseudoraphis spinescens*	S21	0.67	1.15	0.00	0.00	0.67	1.15	0.00	0.00	1.33	2.31	0.67	1.15	0.00	0.00	0.67	1.15	98
55	*Rottboellia cochinchinensis*	S17	0.00	0.00	14.75	7.57	71.78	5.84	0.00	0.00	86.53	5.96	8.87	7.78	0.00	0.00	8.87	7.78	42
56	*Sehima nervosum*	S8	0.53	0.92	0.53	0.92	60.54	20.72	0.00	0.00	61.60	19.02	1.93	1.70	0.00	0.00	1.93	1.70	0
57	*Setaria intermedia*	S11	2.81	3.26	7.44	6.07	32.19	18.49	0.00	0.00	42.43	17.83	2.07	2.04	0.00	0.00	2.07	2.04	18
58	*Setaria pumila*	S4	10.35	7.16	24.06	7.53	10.25	7.53	4.48	4.18	49.14	8.88	5.93	7.20	0.00	0.00	5.93	7.20	2
59	*Setaria pumila*	S5	5.70	1.91	9.47	1.91	15.68	2.17	0.00	0.00	30.85	2.11	0.00	0.00	0.00	0.00	0.00	0.00	0
60	*Setaria pumila*	S6	0.83	1.44	20.04	13.50	25.57	5.57	0.83	1.44	47.28	12.87	9.15	5.37	0.00	0.00	9.15	5.37	0
61	*Spodiopogon rhizophorus*	S10	6.06	10.50	6.48	2.63	23.79	14.19	0.00	0.00	36.33	23.22	1.79	3.09	0.00	0.00	1.79	3.09	44
62	*Spodiopogon rhizophorus*	S15	53.53	12.53	2.57	2.23	21.53	1.01	2.52	2.82	80.15	14.81	13.06	8.32	0.62	1.07	13.68	8.58	16

63	*Sporobolus indicus* var. flaccidus	S18	13.52	6.51	3.95	6.85	1.13	1.96	0.56	0.98	19.17	10.49	26.35	13.53	0.00	0.00	26.35	13.53	0
64	*Sporobolus tenuissimus*	S4	6.03	8.99	2.15	3.72	9.18	14.43	0.00	0.00	17.36	14.43	12.98	10.24	1.72	2.98	14.70	10.44	2
65	*Sporobolus tenuissimus*	S13	1.61	2.79	0.54	0.93	0.00	0.00	0.00	0.00	2.15	3.72	2.98	3.63	0.00	0.00	2.98	3.63	0
66	*Sporobolus tenuissimus*	S14	4.83	6.87	0.64	1.11	8.58	3.75	0.53	0.92	14.58	10.81	31.79	5.73	0.60	1.03	32.39	5.59	72
67	*Themeda quadrivalvis*	S11	0.81	1.41	5.64	3.41	15.13	3.78	3.45	2.37	25.03	0.97	23.23	12.74	0.00	0.00	23.23	12.74	8
68	*Themeda quadrivalvis*	S12	0.65	1.13	2.59	2.25	41.25	17.82	0.00	0.00	44.49	18.08	7.27	7.63	0.00	0.00	7.27	7.63	34
69	*Urochloa reptans*	S12	0.64	1.11	0.00	0.00	2.98	1.90	0.00	0.00	3.62	1.67	0.00	0.00	0.00	0.00	0.00	0.00	12
70	*Urochloa supervacua*	S6	0.52	0.90	0.52	0.90	29.67	15.35	0.00	0.00	30.71	14.14	6.83	2.33	0.00	0.00	6.83	2.33	30