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DYNAMICS OF SOIL NUTRIENTS AND ECTO-MYCORRHIZAL SYMBIONTS IN DISTURBED AND UNDISTURBED STANDS OF TROPICAL DRY DECIDUOUS FOREST OF CENTRAL INDIA

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ABSTRACT

The present investigation has been designed to study the influence of nutrients on formation and growth of ecto-mycorrhiza in disturbed and undisturbed stands of Tropical Dry Deciduous Forest of Central India with respect to soil moisture, pH, total organic carbon, organic matter, available Nitrogen and Available Phosphorus. Moisture content, pH, total organic carbon, organic matter, available Nitrogen and P decreased with increasing soil depth. All the soil parameters were higher in undisturbed site than the disturbed site, which is an indication of better productivity of the site. Negative correlation was found between soil depth and mycorrhizal count both for live and dead mycorrhiza. In most of the regression equations, r-values are significant ($p<0.01$) with a little error. Correlation between mycorrhizal counts (live and dead total) and available Nitrogen, organic matter and Phosphorus were highly significant. Occurrence of mycorrhizal roots is higher being in 5-10 cm depth (329±0.8) due to availability of optimum conditions for the development including higher organic matter percent. The rate of destruction of mycorrhizal roots increased with soil depth. Correlation coefficient value between soil depth and dead and live mycorrhizal roots are negatively significant. It may be due to low aeration, moisture content, organic matter and nutrient level.

KEY WORDS: (Ectomycorrhiza, destruction rate and productivity)

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INTRODUCTION

Ectomycorrhizal (ECM) fungal communities can be influence by a variety of factors including ECM tree species composition, forest structure (Villeneuve *et al*. 1989; Nanteland Neumann 1992; Ishida *et al.* 2007), stand age (Twieg *et al.* 2007), and soil nutrients (Avis *et al.* 2003). Diverse ECM communities can, in turn, have positive effects on host tree productivity (Baxter and Dighton 2001; Jonsson *et al.* 2001),probably because ECM fungi differ in functional attributes and occupy different environmental niches (Dickie *et al.*2002; Courty *et al.* 2005).Mycorrhizae have long been recognized as important symbioses in tropical forest interactions (McLean 1919, St. John 1980). Most plant species rely on mycorrhizae for uptake of nutrients and water; these associations are obligate for many tropical plants (Janos1980a). Janos (1980b) hypothesized that disturbance of lowland tropical forests reduces mycorrhizal fungal populations and inhibits forest regeneration. Soil infertility is a major constraint to plant productivity. The low productivity of these soil is often related to chemical constraints including deficiency of phosphorus, nitrogen, potassium, calcium and other nutrients. There are a number of factors which affect the development of mycorrhizal roots. Short roots die depending upon age and soil properties (Thaper and Rehill, 1984). Vertical distribution of ectomycorrhiza in good and poor sites (Marks *et. al.,* 1968) and their destruction rate (Thaper and Rehill, 1984) have been studied. However, soil characteristics get changed along the soil depth and therefore, govern the mycorrhizal development and its survival. The extent of root colonization varies with several soil and climatic factors apart from the host involved.(Kavatagi and Lakhaman,2012). The present investigation has been designed to study the mycorrhizal status and their rate of destruction in natural disturbed and undisturbed stands of Tropical Dry Deciduous Forest of Central India at various soil depth with respect to soil moisture, pH, total organic carbon, organic matter, available Nitrogen and available Phosphorus.

MATERIALS AND METHODS

The study area falls in Satpuda-Maichal range situated between $22^0$24' -$22^0$35' N latitude and $80^0$34'-$81^0$55' E longitude and elevation 262-721m above mean sea level in Tropical Dry Deciduous Forest of Chhattisgarh, Central India .The area is characterized by large tract of *Shorea* forest .The climate is tropical monsoon type, the temperature ranges from 10.9^{0}C -39^{0}C and average rainfall is 1322mm. The soil is red lateritic to clay loam. Based on repeated reconnaissance of the area, two site *viz* – undisturbed forest and disturbed forest sites representative of the region vegetation were selected .In the present study, 10 random sample plot were selected. In each sample plot 5 *Shorea* seedlings, poles and trees of the same diameter and comparable growth were selected in natural forest and field data were recorded as root length, shoot length, diameter etc.(Table-1) With the help of soil auger, five soil cores, each of 5 cm diameter and 25 cm length ,were taken around each tree at a distance of 45 cm around rhizosphere . Each soil core was than subdivided in to 5 composite sample of equal (5cm) which were analyzed separately for estimation of physico-chemical properties of soil , mycorrhizal count, spore count and percentage of infection. Each sub of soil was shaken vigorously in 500 ml water and poured in sieve to trap short roots which were further washed and cleaned with running tap water . The short roots observed under a magnifying glass to separate the healthy from dead ones (Ginwal *et.al.*1993). Destruction rate of mycorrhiza which may therefore, be used as one of the indirect attributes in assessing site productivity can be calculated by the following formula. Destruction rate = Live mycorrhizal count/ Total mycorrhizal count. The isolation of VAM spores from soil was done by wet sieving

and decanting method (Gerdemann, J.W. and T.W. Nicolson. 1963). The identification of VAM fungi was made by using the keys recommended by Gerdman and Trappe(1974). The percentage of infection in the root was studies by adopting the methods, recommended by Phillips and Hayman (1970) fine feeder roots were merged in 10% KOH at 90^0 C in water bath for 20-30 min decant KOH then roots are treated with alkaline H_2O_2 at 10-20 min and washed the roots in fresh H_2O shacked the root sample with 10% HCL and left it at least for 15 min . Decanted the HCL and taped the roots in a vial with a solution of 0.5% tryphan blue and lectoglycerol for 3-5 min staining to make a quantative estimation. The analysis of soil for Avi. Phosphorus (ppm)was done by using Olson's method (Jackson, 1973). The pH of the soil was tested by using pH meter after equilibrating the soil with water in the ratio of 1:2 soil-water suspension method, (Jackson, 1973). Organic C in soil was determined by Walkley and Black method, (Black, 1965), Organic carbon was converted to organic matter using factor 1.724. Soil moisture was estimated as per Mishra (1968). available Nitrogen was estimated as per alkaline permanganate method (Subbiah and Asija, 1956).

RESULTS AND DISCUSSION

The mycorrhizal symbiosis represents an unique system where two different organisms interact to form an entirely new organ mycorrhiza, which then becomes common to both organisms. Both root cells and fungal cells are integrated in this organ and function together to transport nutrients to each other.(Hiremath *et. al*,2013).In the present study growth characteristics viz-root length, shoot length diameter height and density were recorded to determine the status of growth of *Shorea* in different localities undisturbed and disturbed forest having different age groups. The growth records were higher in undisturbed site as compare to disturbed site due to the better productivity and mycorrhizal development. The growth characteristics of *Shorea* in both localities disturbed and undisturbed site are presented in Table – 1,Which remain slow growing with poorly developed root system, and also the colour of their foliage is pale green. Mycorrhization of forest tree species and its effects on biomass production is very well known (Karmanik, 1980 ; Bagyaraj *et. al*., 1989, Reena and Bagyaraj, 1990; Thaper *et. al*., 1992 ; Pilar *et. al*., 1993 ; Durga and Gupta, 1995). Plant mycorrhiza interactions play a very important role in survival, establishment and growth of forest tress in the natural environment the mycorrhiza protect roots from drought and pathogenic attack (Gerdemann, and Nicolson. 1963; Michelsen and Rosendahl, 1990). Mycorrhizal activity may be affected by edaphic and environmental factors too (Raman and Gopinathan, 1992). The ectomycorrhiza can be distinguished from the heterozoic root system comprising long roots of unlimited growth which remain uninfected and mycorrhizal roots of limited growth which are ephemeral and short lived. Infection restricts elongation of the absorbing roots but may stimulate branching and therefore, short roots become swollen when fresh and active it may become variously coloured due to the colour of the fungal symbiotic such roots become shriveled and black when they are dead. Total count of both live and dead mycorrhiza was highest in 5-10 cm soil layer following the decreasing trend down below with sudden fall alter 15-20 cm. The rate of live and dead mycorrhiza worked out to be 2:1 at 0-15 cm soil depth and after words it decreased at the soil depth so, there exists a negative correlation between soil depth and mycorrhizal count of both sites. However, the total count of ectomycorrhiza was higher in undisturbed site as compared to disturbed site. In general mycorrhizae are not equally distributed throughout the soil profile, In the upper humus layers root tips are transformed in to mycorrhizal roots. In the present investigation more mycorrhizal roots were recorded up to 20 cm depth and highest being in 5-10 cm depth. Because this region provides the optimum conditions for the mycorrhizal development, root

respiration and spore germination of mycorrhizal fungi. The rate of respiration of mycorrhizal roots has been reported higher that of non-mycorrhizal roots (Mikola, 1967 , Schweers and Meyer, 1970). O_2 diffusion from root may provide the initial stimulus for the physiological activity of mycorrhizal roots (Read and Armstrong 1972). Blume (1968) investigated the rate of O_2 diffusion in different soils and found the highest rate in the upper humus horizon and the lowest in the sub soil. Increasing Co_2 concentration with soil depth decreases mycorrhizal infection (Penningsfield, 1950) and makes mycorrhiza ineffectiveness to the deeper roots (Lyr. 1963). The study shows the rate of destruction of live and dead mycorrhiza increases with increase in soil depth . So, there exists a direct correlation between soil depth and destruction rate. The destruction rate of ectomycorrhiza is more in disturbed forest as compared to undisturbed forest (Figure-1). This is similar to findings of Marks *et.al.*1967. However, the total mycorrhiza decreased generally with decrease in site quality. It may be due to variation of soil type, aspects, biotic and abiotic factors which were not taken in to consideration in the present study. Another interesting feature was recorded during present study that the destruction rate was negatively correlated with growth stages of plant (Table - 2) the total count of live mycorrhiza was higher at seedling stage as compared to the mature trees. Observation indicates, that the soil contains higher organic carbon. Fassi *et. al.,* 1972 have also reported that high humified organic matter is beneficial for the establishment of mycorrhiza. Seedlings are more in contact with the organic matter than the mature trees. The present study showed that the roots of seedling harbors more mycorrhiza. The total count of dead mycorrhizal roots was higher as compared to the live mycorrhizal roots in mature trees. This may be due to the fact that with increasing soil depth O_2 diffusion rate is also reduced which in turns retards the development and survival of mycorrhiza in soil. Table-3 indicates that Moisture content, Total organic carbon, Organic matter, available Nitrogen and available Phosphorus decrease with increasing soil depth and so was pH. The observations are similar to the findings of Ginwal *et. al.*, (1993). But moisture content (%) Organic C(%), Organic matter (%),available Nitrogen (%) and Available Phosphorus (ppm) was higher in undisturbed site as compared to disturbed site, which is an indication of better productivity of this site. There exists a positive correlations between number of dead and live mycorrhiza and depth but a negative correlation between soil depth and mycorrhiza counts. In most of the regression equations, r values are significant ($p<0.01$) with a little error. Correlation between mycorrhizal counts (live, dead and total) and available Nitrogen, organic matter and available Phosphorus were highly significant. It is already recorded that mycorrhiza is highest being in 5-10 cm depth due to availability of optimum conditions for mycorrhizal development including higher organic matter (%) . The organic matter content has been reported to provide substrate for saprophytic survival of ectomycorrhization of short roots (Boullard, 1964). These findings support the theory of Melin, that is an evolutionary context. Mycorrhizal formation would have initially taken place in forest soils with mull and symbiosis would have resulted from continuous association (Marks and Kozlowski, 1973). Total mycorrhiza count shows significant ($P<0.05$) positive correlation with total organic matter. Moreover, available P is positively significant ($P>0.001$) with live, dead and total mycorrhiza counts. The amount of phosphorus in the soil has been reported as the decisive factor for establishment of mycorrhiza which did not act directly, but rather influences the carbohydrate metabolism of roots (Bjorkman, 1942). It is obvious from Table - 2 that the rate of destruction of mycorrhizal roots increased with soil depth. Correlation coefficient value between soil depth and live and dead mycorrhizal roots are negatively significant (Table-3). It may be explained that low aeration, moisture content, organic matter and nutrient level cause

reduction in mycorrhizal roots. Many interesting aspects of Dipterocarp ectomycorrhiza remain to be investigated. Results so far show that *Shorea* is obligatory ectomycorrhiza and that large variations in host growth occur with different ectomycorrhizal fungi. The data from the research in the Dry Deciduous Forest of Chhattisgarh,Central India showed that surprisingly few ectomycorrhizal fungi were symbiotic with large Dipterocarp host species. Mycorrhizal fungi are likely to be important in successful revegetation and regeneration of Dipterocarp in this forest.

Table 1
Distribution and growth charactioristics of different age groups of Shorea rabusta in different sites

Growth Stage	Undisturbed Forest				Disturb Forest			
	Root Length (cm)	Shoot Length (cm)	Dia (cm)	%of VAM Infection	Root Length (cm)	Shoot Length (cm)	Dia (cm)	%of VAM Infection
Seedling	1.5	1.4	0.2	Nil	1.1	1.1	0.1	Nil
	1.5	1.5	0.4	-	1.0	1.1	0.4	-
	1.4	1.5	0.6	-	1.1	1.3	0.2	-
	1.6	1.5	0.4	-	1.4	1.2	0.2	-
	2.0	1.6	0.4	-	1.6	1.7	1.7	-
Pole	23.0	12.0	<0.4	Nil	17.0	10.5	>0.4	Nil
	20.0	21.0	-	-	18.0	13.0	-	-
	21.0	18.0	-	-	12.0	11.0	-	-
	19.0	16.0	-	-	14.0	10.5	-	-
	13.0	17.5	-	-	13.0	12.0	-	-
Tree	137	45	<0.4	Nil	92	30	>0.4	Nil
	139	65	-	-	110	35	-	-
	210	70	-	-	123	39	-	-
	99	35	-	-	135	45	-	-
	289	72	-	-	119	35	-	-

Table 2
Quantification of Ectomycorrhizal infection in different age group of Shorea in different localities

G.Stage	Undisturbed Forest					Disturb Forest				
	Depth (cm)	Live	Dead	Total	Distraction Rate	Depth (cm)	Live	Dead	Total	Distraction Rate
Seedling	Do	196	99	295	0.66	Do	130	35	165	0.78
Pole	0-5	53.6±0.2	159±0.5	212.6±0.7	0.25	0-5	47.3±0.1	91.3±0.5	138.6±0.6	0.37
	5-10	71.6±0.1	177.6±0.6	249.2±0.6	0.28	5-10	68.0±0.8	98.3±0.1	166.3±0.9	0.40
	10-15	39.3±0.6	90.6±0.6	129.9±1.2	0.30	10-15	37.6±0.5	78.0±0.2	155.6±0.7	0.32
	5-10	7.0±0.3	41.0±0.4	48.0±0.7	0.14	15-20	17.0±1.0	61.3±0.3	78.3±1.3	0.21
	20-25	3.6±0.7	20.3±0.1	23.9±0.8	0.15	20-25	03.3±0.6	17.3±0.3	20.6±0.9	0.16
Trees	0-5	47.0±0.2	299.0±0.7	364.0±0.9	0.13	0-5	40.3±0.7	198±0.1	238.3±0.8	0.16
	5-10	69.0±0.7	260.6±0.1	329±0.8	2.20	5-10	54.6±0.4	171.3±0.3	225.9±0.7	0.24
	10-15	39.0±0.2	190.3±0.6	229.3±0.8	0.17	10-15	29.3±0.6	99.6±0.2	128.9±0.8	0.22
	15-20	23.6±0.1	110.0±0.7	133.6±0.8	0.17	15-20	9.0±0.2	68.6±0.6	77.6±0.8	0.11
	20-25	8.0±0.7	95.6±0.2	103. ±0.9	0.07	20-25	2.0±0.1	60.3±0.6	62.3±0.7	0.03

All data are Average of 10 plots.

Table - 3
Relationship between soil parameters and Mycorrhizal count of Shorea forest

S.No.	Variable	a+	b+	r	Syx	T
1.	Soil depth and LM	23.65	0.76	-0.92**	3.43	-4.66**
2.	Soil depth and DM	11.57	0.37	-0.94**	1.16	-6.59**
3.	LM and DM	0.81	0.43	0.96**	17.41	5.28**
4.	Organic matter and LM	-0.47	3.13	0.84*	4.77	2.91*
5.	Organic matter and LM	-0.51	1.50	0.80	1.99	3.48*
6.	Organic matter and TM	-2.073	4.64	0.86*	6.43	3.35*
7.	Total N and LM	1.021	37.09	0.71	6.16	1.99
8.	Total N and DM	-0.360	20.09	0.83*	2.25	2.96*
9.	Total N and TM	-0.048	57.18	0.75	8.21	2.31
10	Avai.P and LM	-22.22	1.087	0.97**	1.93	8.78**
11.	Avai.P and DM	-10.48	0.51	0.98**	0.69	11.57***
12.	Avai.P and TM	-33.69	1.59	0.99***	1.72	14.45***

*+component regression (Y=a+bx),r=correlation coefficient ; Syx=Std. deviation for regression; t=t test, *p<0.05, ** p<0.01,*** p<0.001; LM=Live Mycorrhiza,DM=Dead Mycorrhiza , TM=Total Mycorrhiza*

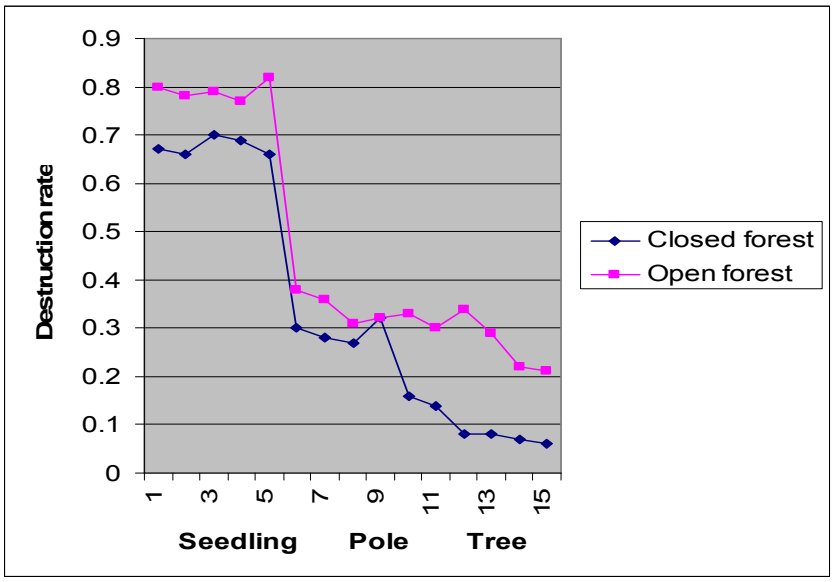

Figure1
Relationship between the Destruction rate of Ectomycorrhiza and Growth Stages

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