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PLANTATION ON UNPRODUCTIVE FALLOW LAND AND ITS CONSEQUENCES:A STATISTICAL APPROACH

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ABSTRACT

Three study plots (100' x 100') were established for the present investigation in which Plot-I was having one year old plantation, Plot-II having two years old plantation and third one was having three years old plantation. Each plot had 16 micro plots each of which was 20' x 20' and the gap between each micro plot was 5'. Plants were raised in 2'x 2' spacing both for mono crops and mixed crop. Vegetative slips of cultivated variety of aromatic grass *Cymbopogon winterianus* var.Jorlab-2(Java Citronella) and *Cymbopogon flexuosus* Stapf. Var.OD-19 were raised as Mono crop-I(M1) and Mono crop II(M2) respectively. Mixed crop was raised utilizing these two mono crops. Effect of plantation in coal mine fallow land showed a range of changes in soil physico-chemical, biological and biochemical properties in relation to plantation age and crop type Plantation cause significant changes in soil biological and biochemical properties enhance microbial activities and increased occurrence and distribution of Vesicular-arbuscular mycorrhiza (number of chlamydospores in the soil) in coal mine fallow land. Changes with plantation age revealed that maximum magnitude of increment was occurred for all the characteristics under mixed crop plantation with age. Soil of 3 years old plantation showed a high tune of increment for soil fungal biomass, density of total acarina population and oribatid mite, soil microbial biomass – C content, rate of soil respiration, number of VAM fungi spore except in density of collembola. Collemobolan density slightly decline under 3 years old plantation than that of 2 years old plantation. Humus component analysis revealed that volume of herbaceous litter remained high in coal mine fallow land than any of the plantation plots. It was minimum under 3 years old plantations of mixed crop. Fragmented litter component was maximum in 2 years old plantation under mixed crop and then decline to some extent in the 3 years old plantation crops. Results showed that for all the yield related components and yield of the plant mixed crop plantation provided the best performances than any of the two mono crops. Performance of crops was increased with the increased age for all the crops. The two mono crops (M1andM2) showed almost similar trend of performance for all the characters. However, for certain characteristics and yield M2 showed better performance than M1.

Key Words: Fallow land, *Cymbopogon* Plantation, Soil Respiration Plant Yield,Correlation and Regression

Introduction

Disturbed ecosystems like coal mine fallow land, degraded land, non-arable land etc. provide harsh conditions for plant and microbial growth because of high soil erosion rates, low organic matter, nutrient supply or compact structure (**Meyer,1973**). Soil erosion increase loss of nutrients like C,N,P by 'leakage' from the ecosystem leading to reduction in soil fertility, carbon fixation and organic matter accumulation. Under these conditions only a few non-demanding but aggressive species invade open areas and establish themselves. However, natural vegetation succession in such habitats is slow and complete protections from all sorts of biotic disturbances are required. In order to hasten vegetation recovery in such sites it is often necessary to artificially introduce suitable tree and grass species that will allow natural recovery processes to begin. Several studies have indicated that plantations adapted to harsh condition of degraded sites, reverse the process of degradation by stabilizing soils, increasing organic matter, moderation of physico-chemical properties and improvement of soil fertility **(Singh et al.,1990; Raizada et al.1996a).**Through their localized effects on microclimate and biotic conditions, these plantations facilitate recruitment, survival and growth of native plant species and thus acting as 'foster ecosystems'**(Lugo, 1988).**The effect of plantations on plant biodiversity was discussed by **Parrotta (1993)**.Vegetation change is expected to affect soil fauna **(Gonzales and Seastedt, 2000)** and degraded lands generally undergo a decrease in soil fauna density and diversity **(Tian, 1998).** Plantation determines the structure, composition, distribution and diversity of the vegetation of a particular area and these are associated with differences of site conditions dynamics of regeneration, growth and succession of biotic impact and this plantations can alter the microclimate and soil property which in turn may affect species diversity **(Pande et al., 1988).**Soil organic matter accumulation and quality were among the main ecological changes found to occur when savanna was planted with trees, and determined the development of undergrowth and changes in soil characteristics**(Wardle and Lavelle,1997).**

The differences in litter quality and quantity of plantations resulted in major differences in soil micro fauna and fungal density and biomass, and suggested that litter quality of the above ground crop took precedence over plant biodiversity in controlling soil biota. Presence of higher number of VAM fungi, faunal and microbial density and diversity under plantation may be due to enhance fertility status of soil **(Rathore and Singh,1995)**.During the investigation made by **Adhikari et al.(1998)** in the Iron ore mines of semiarid India revealed that soil and water conservations through Bioengineering technique was a prerequisite for natural succession to begin. Species like *Acacia catechu*, *Cymbopogon martini* etc began to appear in reclaim sites six to seven years after a protection was enforced.

In India, the state of West Bengal with 23 districts in its fold present a complex ecological set up in different geographical zones. Asansol is a semi-arid zone in the district of Burdwan once famous for industry and mining as major economic resources, now severely affected by its declining socio-economical scenario. In this area huge uncultivable fallow lands are available which are characterized with high porosity and contaminated with industrial pollutants. These characters are reflected by the distribution patterns of above ground standing vegetation and below ground biological diversity **(Bandyopadhyay and Chatterjee, 2005)**.In the present context, seeking for alternative socio-economic resources land management is one of the primary options for this area. For proper utilization and management of these fallow lands the necessity of soil reclamation through plantation and vegetation recovery is well understood.

The aim of the present work was to determine the effects of interactions between soil micro-arthropods (Collembola And Acarina) and mycoflora on soil fertility and crop productivity with the objective to investigate the responses of some selected soil characteristics (both physico-chemical and biological) to plantation in unproductive fallow land and their relation to crop productivity.

Site description

The present study was undertaken at **Kalajharia**(Ward No-37), Burnpur under Asansol Municipal Corporation of Burdwan district in West Bengal, India.It is situated at a distance of about 12 km(approx) in the south –west of Asansol Rail way station. This area falls between $86^0$15'14''N latitude and $23^0$30'15''E longitude at an altitude of 100m above sea level. Kalajharia is characterized by coal mine fallow land zone (**considered as site of plantation in the present study**). The soil characteristics of the studied area are sandy loam to lateritic with high porosity.

Material and methods

RBD Layout of Plantation

Three study plots (100' x 100') were established for the present investigation in which Plot-I was having one year old plantation, Plot-II having two years old plantation and third one was having three years old plantation. Each plot had 16 micro plots each of which was 20' x 20' and the gap between each micro plot was 5'. Plants were raised in 2'x 2' spacing both for mono crops and mixed crop. For mixed crop, mono crops were raised in alternate rows. In each plot out of 16 micro plots 4 each for mono crops, mixed crop and open fallow land were allocated (Fig:1).All the plantations were raised on Coal mine fallow land of the same location in the month of June, 2018.

Planting Materials:

Vegetative slips of cultivated variety of aromatic grass *Cymbopogon winterianus* var.Jorlab-2(Java Citronella) and *Cymbopogon flexuosus* Stapf. Var.OD-19 were raised as Mono crop-I(M1) and Mono crop II(M2) respectively. Mixed crop was raised utilizing these two mono crops. All the slips were procured from Madhya Pradesh, India.Plantings were raised in previously dug pits of 40cm x 40 cm x 40 cm size. No fertilizers and irrigations were made.

For the analysis of edaphic factors, soils were collected from each site. Several soil factors such as moisture, pH, organic carbon, nitrogen, potassium, phosphates and electro-conductivity were quantitatively analysed by means of some standard laboratory methods (Bandyopadhyay, 2006).Extraction of Soil organisms(Acarina,Collembola, Soil fungi and VAM were also made following the standard procedure. In the present study Tullgren Funnel as by Murphy (1962) was used for exteaction of the arthropods. Soil samples for fungi population study were collected separately from the non-rhizosphere and rhizosphere of the dominant species of both the study sites. The fungal population was assessed by inoculating the soil solution of 10^{-3} and 10^{-4} dilutions. The conventional dilution plate method was followed, using potato dextrose agar (PDA) media. The fungal population was recorded after 3-4 days of incubation at 25ºC. From this, number of fungal colony forming unit (CFU) per gm of soil was calculated. Estimation of VAM fungi following flotation method (Daniels and Skipper,1982);Estimation of Soil Microbial Biomass-C **:**Fumigated and non-fumigated soils were extracted with 0.5M K_2SO_4 for 30 min (1:5 Soil: Extractant ratio), filtered, and then an aliquot was analyzed for organic carbon by the acid dichromate oxidation method. The additional C and N obtained from the fumigated soils were taken to represent the microbial -C flush and converted to microbial biomass-C using the following relationship **(Sparling and West, 1998).**

Biomass -C = C flush /0.35.

Fumigation of soil was made by ethanol-free Chloroform in the fumigation Chamber.

Measurement of Soil Respiration

100 gm of soil sample was transferred into a sterile flask (1 litre capacity) and mixed with distilled water to adjust soil moisture to be 33% of water holding capacity. 10 ml of freshly prepared N/10 NaOH solution was taken into two test tubes and the mouth of test tubes were tied with a thread. Then the test tubes were hung into the two flasks (the second one devoid of soil acts as control) in such a way that the free end of thread remains out of the flask. The mouth of the flasks were closed with rubber stopper and sealed with molten wax to make them air-tight. The flasks were incubated at 30^0C. At weekly intervals

test tubes were taken out from each flask.2-3 drops of Phenolphthalein indicator was added and the colour of NaOH solution turns to pink. Then it titrates against N/10 HCl solution pouring in a burette to measure the residual amount of NaOH unturned to Na_2CO_3. Volume of HCl was measured through end point when pink colour turns to colourless. The amount of CO_2 evolved was calculated following the formula of **Jenkinson and Powlson (1976).**

Humus analysis:Replicate samples were taken at plantation sites during 2002-2004 according to the method of **Bernier and Ponge (1994**).Blocks of 25cm^2 surface area and 9 cm depth that included the whole organic layer **(Zaitsev et al.2002)** were prepared directly in the field with a sharp knife. Each block was then separated into different horizons. Thick horizons (more than 1.5 cm) were subdivided into several layers. Each layer was separately fixed in 95 % ethanol in the field and then transferred to the laboratory. A total of 85 humus samples were available.All layers were carefully spread out in a Petri dish filled with 95 % ethanol. The different solid humus components were identified under a dissecting microscope (x 40) and their relative volume was quantified using the point-count method **(Roze, 1989).** To do so, a transparent film with a 300-point grid was placed above each of the humus samples and all components falling below grid nodes were identified. Results were expressed as percentages of the volume ratio of each solid element. A total of 35 humus components were identified.

Sampling, Growth parameters study, Extraction and quantification of oil yield:

Sampling were made from one year old plot(Plot-I),two tears old plot(Plot-II) and three years old plot(Plot-III) during 2018-2019,2019-2020 and 2020-2021 respectively.

Sampling of soil physico-chemical, biological parameters and humus structure were made (three replications from each respective micro plots) in every three month intervals i.e. in 90,180,270 and 360 days after plantation.

Plant growth parameters were measured from three randomly chosen plants from each micro plots under plantation in every three month intervals for mono crops and six (three of each mono crop) for mixed crop. Plant fresh herbage yield was measured after harvest in six month intervals from three randomly chosen plants of mono crops and six (three of each mono crop) of mixed crop.Extraction and quantitative estimation of oil were performed following hydrodistillation method proposed by **Guenther(1972).**
All the statistical analysis was made using Windows Microsoft Excel and SPSS version 10.00

Results and discussion

In the present study on the effect of plantation in coal mine fallow land showed a range of changes in soil physico-chemical, biological and biochemical properties in relation to plantation age and crop type. Humus component analysis (Table 1) revealed that volume of herbaceous litter remain high (36.33±3.45) in coal mine fallow land than any of the plantation plots. It was minimum under 3 years old plantations of mixed crop (16±1.25). Fragmented litter component was maximum in 2 years old plantation under mixed crop and then decline to some extent in the 3 years old plantation crops. Recently litter component was remained high in coal mine fallow land and minimum 3 years old plantation of mixed crop. Contribution of faeces and fungi in the humus was gradually increased significantly under 3 years old plantation. Yield of M1 (C*ymbopogon winterianus)* and M2 (C*ymbopogon flexuosus)* and mixed crop (M1+M2) directly related to vegetative growth as the stalks and the vegetative leaves are the main component for yield. Hence yield of these crops were determined by the plant height (cm.) ,leaf number per plant ,leaf area(cm^2),tiller per clump, tiller diameter (cm) ,plant fresh herbage yield (kg/clump) and oil content(w/w) which were in highly influenced by the soil genetic and environmental factors as well as crop management practice.

Table 1:Mean values with ± S.E. of different humus components(% contribution) under plantations and in adjoining fallow land during the period 2018-2021.

Parameter	Fallow land	M1	M2	M1+M2
Herbaceous litter	36.33±3.45	19±3.56	18.66±2.5	16±1.25
Recent litter	36.33± 2.5	24±2.5	23±2.5	20± 1.5
Fragmented litter	21.66±3.25	32.66±3.25	32.33±2.89	34.66± 3.15
Feces and Fungi	5.66±.84	24±1 .55	25.66±2.56	29.33± 2.89

Result from the Table-2 showed that for all the yield related components and yield of the plant mixed crop plantation provided the best performances than any of the two mono crops. Regarding plant height plant height (cm.) ,leaf number per plant ,leaf area(cm^2),tiller per clump, tiller diameter (cm) ,plant fresh herbage yield (kg/clump) and oil content(w/w) and oil yield per plants these were124.75±3.56, 8.4±1.45, 119.83±7.56, 114.66±3.56, 8.33±1.2, 1.74±0.39, 1.34±0.68 and 25±1.24 respectively for mixed crops. Performance of crops was increased with the increased age for all the crops. The two monocrops showed almost similar trend of performance for all the characters. However, for certain characteristics and yield M2 showed better performance than M1.

Table2 :**Mean values with ± S.E. of different Plant growth and Yield related Characters during the period 2018-2021.**

Parameter	M1	M2	M1+M2
Plant height (cm)	107.26± 5.66	110.96± 4.59	124.75± 3.56
Leaf No/Plant	7.23± 2.3	7.5± 1.2	8.4± 1.45
Leaf Area (cm^2)	103± 12	101.66±9.5	119.83±7.56
Tiller/Clump	89.5± 2.56	98.66± 3.68	114.66±3.56
Tiller diameter(mm)	7.26± 1.25	7.01± 2.3	8.33± 1.2
Plant herbage yield (kg/Clump)	1.113±.95	1.23± .56	1.74±.39
Oil Content (w/w)	1.12± .45	1.25± .65	1.34±.68
Oil yield (gm/Plant)	15.33± 3.4	19± 4.6	25± 1.24

Statistical analysis:

Statistical analysis was made on the basis of pooled data from plots as well as from different crops. Results from correlation matrix between soil physico-chemical parameter plant herbage yield and oil yield showed significant relationship (Table 3A). Plant herbage yield showed significant correlation ($p<0.05$) with moisture organic carbon and potassium. Plant oil yield showed significant correlation ($p<0.05$) with moisture organic carbon and potassium.

Table3B revealed that plant herbage yield showed significant correlation with fungi, Acarina, oribatida, collembola, soil microbial biomass carbon , soil respiration and VAM. Oil yield per plant also showed significant relationship with all those characters.The correlation matrix (Table 3C) showed significant relationship between plant growth parameter, plant herbage yield and oil yield. Plant herbage yield showed significant correlation between plant height, leaf number per plant leaf area, tiller per clump, tiller diameter and with oil content of the plant. Oil yield also showed similar significant relationship with all those growth parameters as well as with plant herbage yield.

Table 3A:Correlation Matrix between Soil Physico-Chemical parameters,Plant herbageYield and oil yield.

	Moisture	*Organic carbon*	*Nitrogen*	*Phosphate*	*Potassium*	*pH*	*EC*	*Herbage yield*	*Oil yield*
Moisture	1								
Organic carbon	0.988***	1							
Nitrogen	0.928***	0.904***	1						
Phosphate	0.868**	0.856**	0.978***	1					
Potassium	0.974***	0.954***	0.936***	0.895***	1				
pH	0.347	0.384	0.202	0.094	0.339	1			
EC	0.321	0.342	0.355	0.287	0.344	0.411	1		
Herbage yield	0.768*	0.777*	0.562	0.515	0.807**	0.472	0.174	1	
Oil yield	0.759*	0.790*	0.577	0.553	0.804**	0.464	0.265	0.978***	1

Table 3B : Correlation Matrix between Soil Organisms,Soil Microbial Biomass-C,Soil Respiration,VAM,Faeces& Fungi, Plant herbage Yield and oil yield

	Fungi	*Acarina*	*Oribatida*	*Collembola*	*SMB-C*	*Soil Respiration*	*VAM*	*Faeces &Fungi*	*Oil yield*	*Herbage yield*
Fungi	1									
Acarina	0.887***	1								
Oribatida	0.912***	0.988***	1							
Collembola	0.581	0.767**	0.724*	1						
Soil Microbial biomass-C	0.905***	0.895***	0.873***	0.749*	1					
Soil Respiration	0.938***	0.917***	0.944***	0.700*	0.855**	1				
VAM	0.944***	0.892***	0.912***	0.668*	0.934***	0.958***	1			
Faeces & Fungi	0.939***	0.762*	0.784**	0.585	0.908***	0.878***	0.940***	1		
Oil Yield	0.825**	0.925***	0.939***	0.679*	0.728*	0.887***	0.789**	0.644	1	
Herbage yield	0.785**	0.887***	0.892***	0.714*	0.715*	0.821**	0.728*	0.613	0.978***	1

Table 3C : Correlation Matrix between Plant Growth,Plant herbage yield and oil yield

	Plant Height	Leaf No/Plant	Leaf Area	Tiller/Clump	Tiller diameter	Herbage yield	Oil content/Plant	Oil yield/Plant
Plant Height	1							
Leaf No/Plant	0.853**	1						
Leaf Area	0.921**	0.742*	1					
Tiller/Clump	0.920**	0.818*	0.861**	1				
Tiller diameter	0.847*	0.748*	0.885**	0.833**	1			
Herbage yield	0.940***	0.789*	0.892**	0.952***	0.800*	1		
Oil content/Plant	0.844**	0.765*	0.784*	0.953***	0.760*	0.895**	1	
Oil yield/Plant	0.931***	0.815*	0.868**	0.983***	0.801*	0.978***	0.964***	1

***Significant at 1%, ** Significant at 5% and * Significant at 10%.

Table 4A,B and C reveals the allometric relationship between soil organic carbon(as dependable variable) and soil physico-chemical, soil biological, bio chemical parameters, plant growth, as well as yield and yield related parameters respectively. It is obvious from the result that positively highly significant correlation ($p<0.001$) was found between moisture available N and P. All the biological characters (Fungi,Acarina , oribatida) soil microbial biomass C, soil respiration VAM and faeces and fungi of humus component except Collembolla which showed positive significant correlation($p<0.05$). Among the growth parameter plant height showed highly significant positive correlation ($p<0.001$). Positive significant correlation ($p<0.05$) was estimated between organic carbon content and leaf area as well as tiller diameter

Table4A:Showing simple Regression equation between soil Organic Carbon Contentand Soil Physico-Chemical properties

Parameters	Regression equation (y=a+bx)	R^2
Y= Organic Carbon		
Moisture	y= - 1.2762+0.4463x	0.9479***
pH	y= -21.752+3.965x	0.4514
Electro conductivity(EC)	y=0.0322+57.981x	0.3546
Nitrogen	y=0.462+0.0155x	0.775***
Phosphate	y=0.3395+0.200x	0.7145**
Potassium	y=-1.198+0.0244x	0.9162***

Table4B : Showing simple Regression equation between soil Organic Carbon Contentand Soil Fungi, Fauna,Soil Microbial Biomass-C, Soil Respiration,VAM and Feces and Fungi in humus.

Parameters	Regression equation (y=a+bx)	R^2
Y= Organic Carbon		
Fungi	y=0.1499+0.2219x	0.8412***
Acarines	y= -1.1461+0.1325x	0.8138***
Oribatida	y=-0.1043+0.1542x	0.8485***
Collembola	y=-1.251+0.2598x	0.6209**
Soil Microbial Biomass-C	y=-1.0423+0.6603x	0.8733***
Soil Respiration	y=-2.049+0.7263x	0.7021***
VAM	y=-1.0609+0.006x	0.8613***
Feces & Fungi	y=-0.6002+0.137x	0.8658***

*** Significant at 1% level ** Significant at 5% level * Significant at 10% level

Table4C: Showing simple Regression equation between soil Organic Carbon Content and Plant growth, Oil content, Herbage yield and Oil yield.

Parameters	Regression equation (y=a+bx)	R^2
Y= Organic Carbon		
Plant height	**y=-10.284+0.1161x**	**0.8846*** **
Leaf No./Plant	**y= -9.7719+1.6548x**	**0.5502**
Leaf area	**y=-5.2169+0.0759x**	**0.7186** **
Tiller No/Clump	**y=-3.2174+0.061x**	**0.6713***
Tiller diameter	**y=-5.2028+1.0869x**	**0.71** **
Oil content(W/W)	**y=-4.8618+6.3321x**	**0.5347**
Plant herbage yield (kg/Plant)	**y=-0.4083+2.495x**	**0.6048***
Oil yield (gm/Plant)	**y=-0.3906+0.1709x**	**0.6254***

*** Significant at 1% level ** Significant at 5% leve * Significant at 10% level

Table 5 A, B and C reveals that Soil respiration showed highly significant correlation ($p<0.001$) with Potassium, Organic carbon, all the biological parameters (except Collembola), Tiller No./ Clump, Tiller diameter, Oil content . Positively significant correlation ($p<0.05$) was estimated between soil respiration, moisture, Nitrogen, Plant height, Leaf area and with oil yield.

Table5A: Showing simple Regression equation between soil Respiration an Soil Physico Chemical properties

Parameters	Regression equation (y=a+bx)	R^2
Y= Soil Respiraton		
Moisture	**y= 3.6225+0.3591x**	**0.6595** **
pH	**y= -12.11+3.0893x**	**0.263**
Electro conductivity(EC)	**y=1.9796+97.643x**	**0.478**
Nitrogen	**y=5.2443+0.0118x**	**0.5899** **
Phosphate	**y=5.1632+0.1534x**	**0.5586***
Potassium	**y=1.105+0.327x**	**0.7836*** **
Organic Carbon	**y=2.7336+1.3319x**	**0.8432*** **

Table5B:Showing simple Regression equation between soil Respiration and Soil Fungi, Fauna,Soil MicrobialBiomass-C, Soil Respiration,VAM and Feces and Fungi in humus.

Parameters	Regression equation (y=a+bx)	R^2
Y= Soil Respiration		
Fungi	**y=4.4925+0.208x**	**0.8814*** **
Acarines	**y= 2.3567+0.1499x**	**0.8419*** **
Oribatida	**y=2.1972+0.2309x**	**0.9041*** **
Collembola	**y=1.822+0.3197x**	**0.4907***
Soil Microbial Biomass-C	**y=0.9457+0.9582x**	**0.8743*** **
VAM	**y=0.6458+0.0091x**	**0.9618*** **
Feces & Fungi	**y=1.4677+0.2045x**	**0.9172*** **

Table 5C : Showing simple Regression equation between soil Respiration and Plant growth, Oil content, Herbage yieldand Oil yield.

Parameters	Regression equation (y=a+bx)	R^2
Y= Soil Respiration		
Plant height	**y=-7.1674+0.1234x**	**0.7334** **
Leaf No./Plant	**y= -8.1055+1.9507x**	**0.5744**
Leaf area	**y=-2.643+0.0886x**	**0.7358** **
Tiller No/Clump	**y=-1.0412+0.079x**	**0.8333*** **
Tiller diameter	**y=-3.3089+1.3594x**	**0.8344*** **
Oil content(W/W)	**y=-4.3323+9.0879x**	**0.8276*** **
Plant herbage yield (kg/Plant)	**y=2.7941+3.0435x**	**0.6756***
Oil yield (gm/Plant)	**y=2.5632+0.2211x**	**0.7868** **

*** Significant at 1% level ** Significant at 5% leve * Significant at 10% level

Statistical data showed allometric relationship of plant herbage yield and oil yield on soil physico-chemical, biological and plant growth related parameters respectively. Simple regression line along with scattered diagrams of Plant herbage yield and oil yield

on the different parameters were drawn All the statistical estimation reveals that Plant herbage yield and oil yield was highly significantly depended on different soil physico-chemical, biological and plant growth parameters.
The present results suggested that plantations cause significant changes in soil physico-chemical and biological characteristics of coal mine fallow land. The changes were occurring with age of plantation. The changes were much more prominent for biological characteristics particularly in decomposer assemblage, soil microbial biomass-C, activity of soil organisms (soil respiration), acceleration of humus formation and distribution as well as abundance of VAM fungi. Among the physico-chemical characters moisture and soil organic carbon content change significantly. This enhancement may be due to accumulation of litter and the resulting soil organic matter accumulation **(Wardle and Lavelle,1997).** Accumulation of soil organic matter, through its influence on physical, chemical, biological processes in soil, is widely recognized as an important indicator of soil quality **(Tissen et al.1994; Pankhurst,1994).** Accumulation of soil organic matter through litter fall might have regulated organic matter decomposition and the formation of stable and labile soil organic matter pool **(Vitousek and Sanford,1986).** Low organic carbon content in the coal mine fallow land might be due to less litter accumulation because of scanty vegetation over it.

In this study organic carbon was found highest in three years old rehabilitated plots under mixed crop and lowest in coal mine fallow land. A significant increase was recorded in soil moisture percentage which was very low in coal mine fallow land (control plots) and high in 3 years old rehabilitated plots. The increment of soil organic carbon content and soil moisture content may be resulted in soil texture improvement. Soil moisture depends on the annual precipitation, evaporation, soil texture, organic matter, soil depth and the vegetation cover **(Ototzky, 1905, Jha and Singh, 1992).** The maximum moisture content under 3 years old mixed crop plantation may further be explained due to the dense vegetation. Vegetation provides shade to reduce evaporation and the organic matter and clay are capable of retains higher amounts of moisture. Coal mine fallow land with patchy vegetation cover contains very low organic matter and clay and therefore, is not able to hold sufficient moisture as in the case of rehabilitated plots.

Coalmine fallow land soils were suffering from poor available N,P and K with pH and EC of 5.7±2.5 and 0.023±0.003 respectively. Plantation may significantly result in raising soil pH, total soluble salts and available nutrients The number of Acarina and Collembola were increased to a high magnitude of 26.33±4.5 and 16.33±1.25 in M1, 29.33±3.5 and 13.66±2 in M2, 36.00±2.5 and 18±2 in M1+M2.respectively. High number of micro arthropods in soils of plantation plots may be associated with high moisture and organic matter content in the soil **(Klironomous and Kendrick, 1995).**Fungal biomass increased upto15±2.25 CFU/gm.soil in the soils under mixed crop plantation. The higher population of fungi in soils of plantations may be ascribed to nutrient status, organic matter and moisture regime.The number of VAM fungi spores was 628±63, 682±38 and 776.54±46 in M1, M2 and M1+M2 respectively which were higher than that of coalmine fallow land soil (174±13). High number of VAM fungi spores under plantations may be due to enhanced fertility status of soil (**Rathore and Singh,1995).**Among the acarines oribatid mite showed significantly higher in number under plantations and reached its maximum in the soils 3 years old mixed crop plantation plots. Increment of this oribatid mite group which are strongly fungivorous, can enhance decomposition process and leading to formation of humus structure. Presence of high number of oribatid mite in the soil indicates increasing fertility status of the soil. The fungal-micro arthropod interactions in the soil food web, presence of high organic matter and moisture regime enhance microbial activity in the soil under plantations and thereby increasing rate of soil respiration. There is considerable evidence that microbial biomass measurements, either alone **(Powlson et.al, 1997**) or in connection with total organic carbon contents and related biological parameters (such as population of micro arthropods**) (Yeates, 1996)** which change rapidly, could be used to evaluate the influence of land-use change on soils. Results of humus component analysis exhibited that contribution of herbaceous litter, recent litter, fragmented litter and faeces and fungi in the humus structure in the plots of mono crops as well as in mixed crop showed a significant change from that of coalmine fallow land. The portion of herbaceous litter and accumulation of recent litter found higher in coalmine fallow land may be due to the depletion of surface dwelling decomposer organisms which delayed the process of humus formation **(Ponge, 2000).**The accumulation and increment of fragmented litter and faeces particles in the plantation plots reflects the stimulation of consumer activity with plant growth and age. The joint increase of invertebrates faeces and fungal components under plantations of mono crops and mixed crop thus points to an important feed back loop among different groups of soil biota postulated by several authors, with invertebrate consumers opening of new surfaces for microbial colonization and fungal preconditioning of litter increasing the accessibility of the organic resources for primary decomposers**(Heal et al.,1997).**The accumulation of fragmented litter along with faeces and fungi in the humus definitely indicative of acceleration of humus formation under plantation plots**(Schulze et al.2000, Law et al.2001).**

The statistical analysis revealed that soil organic carbon was positively highly correlated with the moisture content, available nutrients i.e. N,P and K and with all the biological characteristics (Fungi, Acarina, Collembola,Oribatid mite),biochemical characteristics (Soil microbial biomass-C and Soil respiration),VAM fungi as well as faeces and fungi of humus component (Table 4A,B). Soil respiration also showed significant relationship with these parameters (Table 5A, B).

Among the plant growth parameters plant height, leaf area, tiller no/clump, tiller diameter showed positively significant correlation with the soil organic carbon content (Table 4C).Soil respiration also showed highly positive significant relationships with tiller no./clump, tiller diameter, oil content and positive correlation with plant height and leaf area.These positive significant correlations of soil organic carbon content and soil respiration with the available nutrients, biological parameters and plant growth parameters exhibited that soil fertility and crop productivity highly related with soil organic carbon content and microbial activity of the soil under plantations.The results of allometric relationship and correlation matrix on plant fresh herbage yield and oil yield/plant also supported these findings.

The results and findings of this study were highly corroborated with the findings of **Gonzales and Seastedt (2000), Lavelle et al. (1994, 1997), Pankhurst et al. (1997), O'Connell and Sankaran (1997), Adhikari et al. (1998), Jha and Singh (1991),Raizada and Samara (2000)** and others.

Conclusion

It can be concluded from the present investigation that plantation on coalmine fallow land may cause significant changes in soil physico-chemical, biological properties particularly moisture content, organic matter accumulation, enrichment of available nutrients along with the fungal and microbial biomass as well as micro arthropods population. The positive and significant interactions between them enhance fertility status of the soil and can promote crop productivity with time and management practices. Thus more and more suitable plantations should be raised on degraded land like coalmine fallow land in order to increase native biological diversity and improve the soil quality of coalmine fallow land. Soil biological parameters have the potential to be early and sensitive indicators of stress on key populations or productivity. There is considerable evidence that microbial biomass, microbial activity in combination or along with total organic carbon and related biological parameters (Oribatid mite), which change rapidly, could be used to evaluate the influence of land-use changes in soils.

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