CHAPTER 4:

RESULTS AND DISCUSSION

4. Results and discussion

This chapter contains the explanations of the tables and figures containing the data or the projections of the data. The objectives of the methodology have also been explained in details. The reasoning of the results is provided as the discussion which refers to related and new work in the relevant field.

4.1. Meteorology of Jharia

The climate is tropical monsoon with annual average rainfall is 1169 mm. The mean monthly maximum and minimum temperature during initiation of the study were 19.8-45°C in summer, 8.5-33.5°C in winter and 24-37.8°C in monsoon season (Fig. 4.1, 4.2). The relative humidity varied from 15-98%. The wind speed was low and ranged from 2.6-4.5 km/hr throughout the year. The meteorological data was collected from Department of Environmental Science and Engineering, Indian School of Mines, Dhanbad.

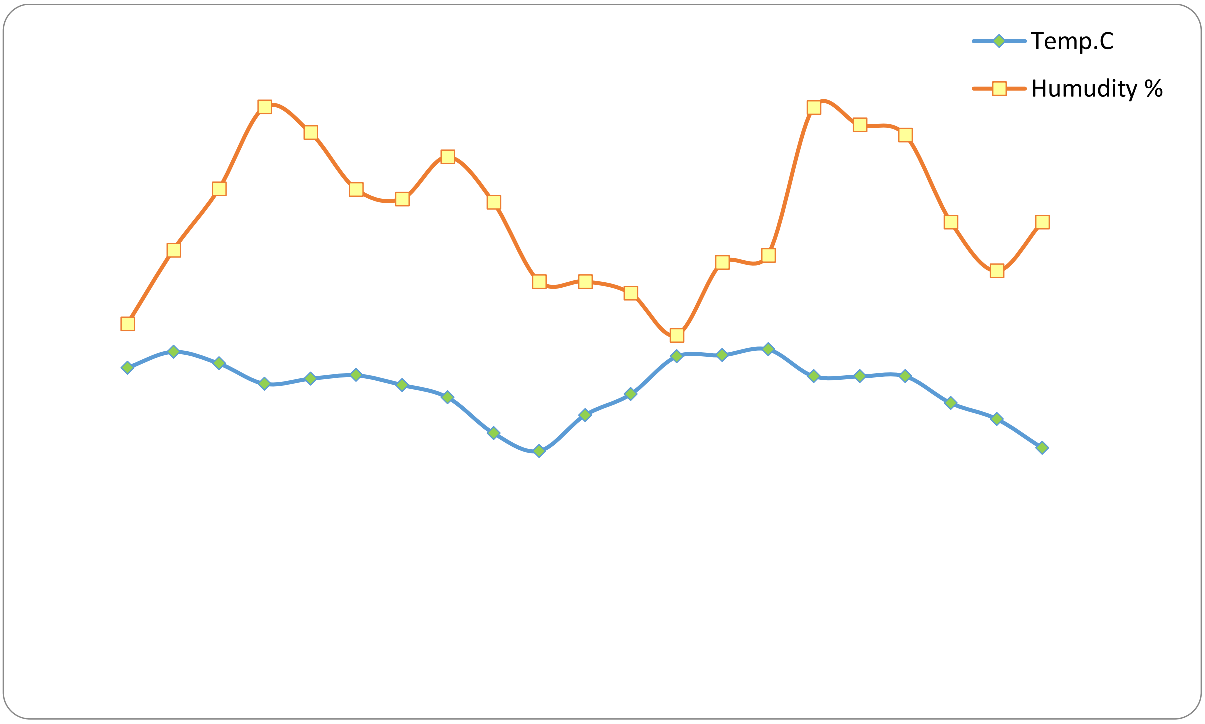

Fig. 4.1. Temperature and Humidity in Jharia from April 2013 to December 2014.

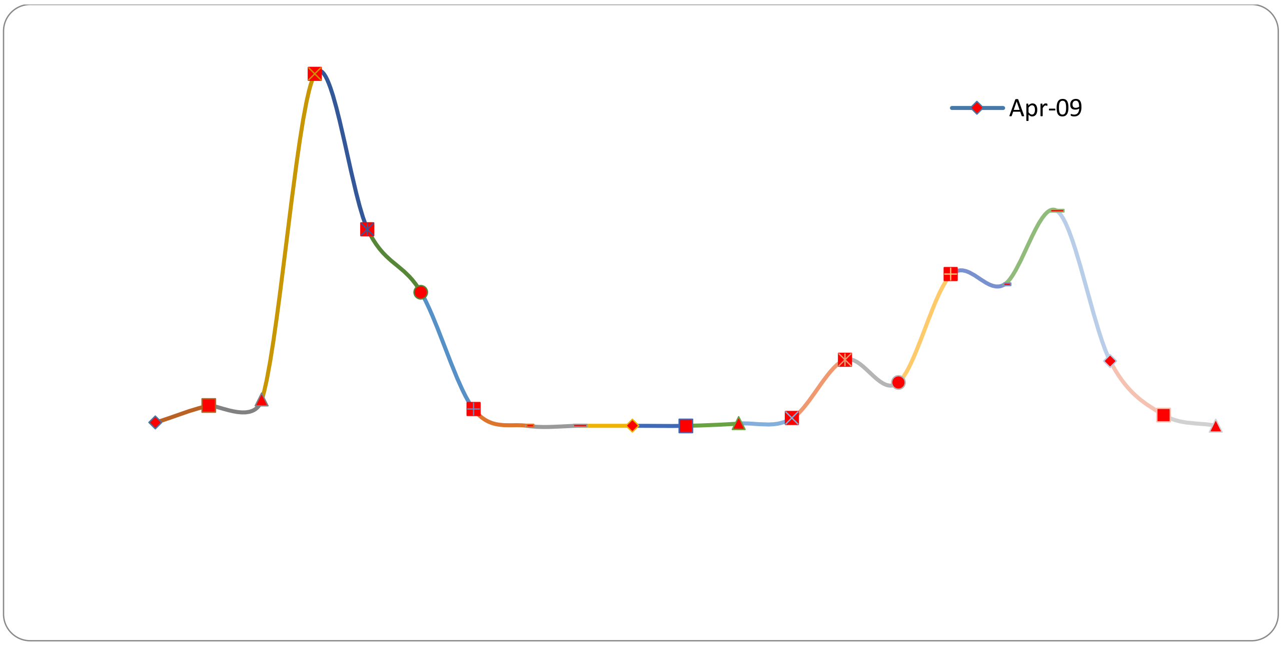

Fig.4.2. Total rainfall (mm) in Jharia from April 2013 to December 2014.

4.2. Experimental design

Figure 3.7 depicts the stepwise detailed of the plot design followed in this study. Herein, pot experiments were not preferred, as such experiments are a long way from field experiments in respect of realism and can have very high errors owing to the few plants which can be placed in a pot and their rhizosphere are restricted to a certain area. Thus in our study, the plot was preferred to be more suitable than the pot. The plots were designed in such a way that it had one set of control plots and three sets of experimental plots. Each plot had triplicates. The reason for taking replicates is that higher replication enhances the accuracy of estimates of mean response. It also increases the probability of significant statistical detection of any experimental response because it allows the response distribution to be determined more accurately. True replication refers to the number of identical plots, i.e. plots with exactly the same set of planted species. This was followed in the present experiment. The word “control” refers to the control of error, while “Error” means variation.

Another aspect is plot size. Big plots, as big as 1 hectare or more is usually required for biodiversity studies. However, for decomposition studies and effects on soil quality (which is also the objective of the present study), smaller plot sizes are preferred (Lorenzen et al., 2005). Small plots were designed for this short-term study as already described above in section 3.1.3 (Preparation of plot). The randomized block design was implemented and special distribution of individual trees within the plot was in a regular pattern which is a common practice in silviculture (Fig. 4.3).

Figure 4.3 Randomised Block Design of the Plots. A, B, C, D and E are the five individual plant species namely *Dendrocalamus strictus, Phullanthus emblica, Saraca asoca, Ficus religiosa and Azadirachta indica.*

A	B	D
D	C	E
C	A	D
E	C	B
B	E	A

The mixed plantation was preferred than monoculture as it is well known that mixtures improve economic status through greater individual-tree growth rates and provision of multiple commercial or subsistence products, as a long-term goal of the current study. Piotto et al. (2004) conducted experiments on pure and mixed forest plantations with native species of the dry tropics of Costa Rica. When they compared the growth and productivity of mixed and pure plantation, it was observed that mixed plantations with native species contributed more to sustainability because they provided a greater range of goods and services than pure species plantations. Since our aim was ecological restoration so in such studies mixtures are always preferred (Kelty, 2006). Mixed cultures are also resistant to pest attacks thus lowering the risk of experimental failure during the study period. Consequently, the performance of any treatment plot could greatly be influenced by three factors: (1) the number of species; (2) the species that are present; and/ or (3) the soil conditions at the site location of that plot. These factors may be interpreted in different ways as per the objectives of the study.

The control plot was designed with the objective to find out the plant species which could survive with minimum care in the stressful condition. Then the next treatment was the addition of VAM in OBV plot. This was done in order to know how the plants responded to the addition of VAM. The dumps were devoid of naturally occurring VAM spores, thus it was mandatory to add VAM to hasten the restoration. The soil addition is a particular trend of reclamation activity in the mining area but how far it is practically feasible for such short term and quick reclamation process in the fire affected coal mines is yet to be established. So in OBS plot agriculture soil collected from the vicinity of the colliery was added. The most easily available and cheap source of organic manure was cow dung. Hence the fourth treatment plot, OBM was designed to know the growth response of the plants.

The agriculture soil and manure were mixed in the ratio 1 part (soil or manure) + 4 parts spoil material (Singh and Juwarkar, 2014). While designing the plots, the economy was always given priority as these dumps are unstable and will be removed after 3-4 years to explore the coal seam underlying the dumps. Hence, quick economic restoration was the objective of plot design. Usually, furrows are made for treatment separation as practiced in agriculture. Furrow is actually, not applicable for plant apecies, it is applicable for crops. But in this study, the exact practice of plantation process was followed, as observed by the authors, in the Jharia Coalfields. Thus a new idea was applied in plot design. It was made as simple as possible.

The soil properties were altered after introducing treatments, which were soil amendments. Table 4.3 shows the fertility status of the various plots with and without the addition of soil amendments. The three years of study brought some changes in the physicochemical nature of the soil in the plots which are shown in table 4.4. The soil samples analyses show that since no soil amendment was added in OBC and OBV plots hence parameters like bulk density, organic carbon and nutrients, did not change. However, due to the influence of agriculture soil and cow dung in some treatment plots, bulk density and nutrients changed a lot in OBM and OBS plots. Organic carbon was maximum in OBM plot i.e., 3.89%.

The soil samples from the control and treatment plots were collected with an objective to know the changes taking place after plantation. Also whether changes were significant or not, was verified. The nutrients like calcium, magnesium decreased in the preceeding year. This might be due to uptake by the plants. Some nutrients increased later which may be due to the addition of litter during the litter bag experiments. Actually, in the initial stages, it is very difficult to establish any correlation between nutrient release and uptake because of the dynamism of the system. Also in very disturbed or stressful conditions established correlations are difficult to exist. The last sampling was done in the summer. This may be one of the reasons for fewer uptakes of nutrients from the soil as this is not a growing season for the plants.

4.3. Physicochemical properties of the soil and the amendments used

The data show the impoverished status of the mine spoil material in comparison to the soil amendment like agriculture soil and cow-dung manure (Table. 4.1). Bulk density being 1.47 g/cc, showed the utmost need of addition of amendments as such OB material are so heavy that the plant root growth and penetration are obstructed. The organic carbon was poor being 1.66% and pH, slightly acidic. Texture analyses showed that the soil consisted of unweathered soil portions such as sand. The soil also lacked the macro and micro nutrients. On the other hand, the physicochemical properties of the soil amendments, which were added as treatments to the plots, like agriculture soil and cow dung manure, were obviously much better than the spoil material of the overburden dump. The cow dung was as expected the best soil amendment as observed in table 4.2. The pH being neutral (7.44), such amendment provides favourable condition for soil biodiversity. No heavy metal toxicity was found in the spoil material. In fact, the metals were very less in quantities.

Table 4.1 Physico-chemical parameters of the coal mine spoil, agricultural soil, and cow dung manure

Parameters	Mine Spoil (Avg ± Sd)	Agriculture soil (Avg ± Sd)	Cow dung manure (Avg ± Sd)
pH	5.67±1.36	5.84±0.11	7.44±0.05
Electrical Conductivity (mmhos/cm)	0.07±0.34	0.08±0.01	3.07±0.01
Bulk Density(g/cc)	1.45±0.02	1.29±0.04	0.75±0.01
Moisture Content (%)	2.07±1.30	3.21±0.32	6.02±0.24
Water Holding Capacity (%)	16.28±4.25	40.03±0.64	47.54±0.22
Organic Carbon (µg/g)	1.66±0.92	2.78±0.78	19.60±0.07
Organic Matter(µg/g)	2.87±1.60	4.78±1.34	33.94±0.93
Nitrogen (µg/g)	16.67±9.20	66±4.97	171.12±0.98
Phosphorus (µg/g)	1.80±0.47	12.48±1.75	20.32±0.23
Magnesium(µg/g)	8.22±4.91	78.43±4.60	93.62±1.12
Calcium (µg/g)	191.95±8.34	1114.18± 6.86	2179.20±2.05
Sodium (µg/g)	32.15±2.66	66.00±4.97	1019.80±1.30
Potassium (µg/g)	49.63±7.03	187.75± 10.54	8830.20±1.64
CEC (meq/100g)	6.89±1.76	22.87±4.17	28.80±0.07
%Sand (<2 –mm and > 0.05 mm)	73±6.20	43.81±1.20	-
%Silt (0.05 mm to 0.002mm)	21.4±3.66	29.40±1.25	-
%Clay(<0.002 mm)	6±2.17	26.71±1.63	-

In general, the total volume of the surface layer of the earth consists of about 50 percent solids, of which about 45 percent is soil particles and 5 percent or less is organic matter, rest 50 percent is pore space, which is filled with either air or water. The heaviness of the soil is determined by bulk density. Bulk density is also an indicator of soil compaction (USDA-NRCS, 2014). It affects infiltration, rooting depth, available water capacity, soil porosity and aeration, availability of nutrients for plant use, and activity of soil micro-organisms, all of which influence major soil processes and productivity. Bulk density is the oven-dry weight of soil per unit of volume at field moisture capacity or at specified moisture content. Sandy soils have relatively higher bulk density because they have less total pore space than silty or clayey soils. Bulk density typically increases with soil depth. The subsurface layers are more compacted and have less pore space because they have less organic matter, lesser aggregation, and hence less root penetration, than the surface layer. Since this is mainly the subsurface layer so it is bulky. Rai et al., (2010) reported bulk density as high as 1.7 g/cc in some mining area of Jharia Coalfields. Since bulk density is closely related to moisture content and texture, our findings indicate the same. Sandy spoil material and poor moisture content as obvious in overburden dumps (Rai et al., 2011). There was poor organic content, as typically seen in the unreclaimed site, owing to no plant cover.

It is worth to mention that the organic matters originate naturally from the decay of plant leaves, stems roots. Such findings have also been reported by Makdoh and Kayang (2015). Due to the poor organic carbon, no holding of essential nutrients was observed. Therefore, the whole scenario depicts an impoverished soil condition. It also depicted that unless soil amendments were added, plant growth was not possible. The soil amendments were added to the treatment plots and the experimental plots were designed. The changes that took place in the soil characteristics after the addition of amendment were analyzed periodically. The characteristics of the soil in the plots are summarized in Table 4.2. As expected, the amendments gave favorable nutrients to the mine spoil material.

Table 4.2. Physico-chemical parameters of the control and treatment plots in three years of study (DTPA extractable metals are depicted)

Parameters	Values ± Standard Deviation			
	OBC	OBV	OBS	OBM
pH	6.21±0.39	6.02±0.07	6.55±0.73	6.69±0.20
EC(mmhos/cm)	0.17±0.05	0.51±0.09	0.70±0.10	1.46±0.42
BD(g/cc)	1.45±0.02	1.45±0.01	1.33±0.06	1.30±0.07
MC (%)	1.60±0.10	1.89±0.08	2.17±0.13	3.07±0.06
WHC (%)	18.20±0.43	18.61±0.47	25.63±0.345	29.67±0.22
OC (µg/g)	0.97±0.10	1.03±0.12	2.16±0.10	3.89±0.13
OM (µg/g)	1.68±0.17	1.79±0.20	3.74±0.17	6.74±0.23
Avai- N(µg/g)	23.23±1.50	23.29±2.34	34.98±0.93	60.10±1.37
Avai-P(µg/g)	1.95±0.80	2.38±0.62	8.23±0.79	15.64±0.54
C/N	0.04	0.04	0.061	0.24
Cu (ppm)	0.43±0.19	0.70±0.20	0.40±0.14	1.17±0.67
Mn (ppm)	3.24±0.74	3.75±0.81	9.76±0.13	59.70±1.67
Zn (ppm)	11.44±1.4	11.76±1.18	1.98±0.20	4.50±0.29
Ni (ppm)	0.13±0.06	0.16±0.04	0.53±0.14	0.44±0.07
Cd (ppm)	0.19±0.06	0.12±0.06	0.02±0.00	0.12±0.04
Pb (ppm)	0.82±0.08	0.84±0.03	0.66±0.07	1.34±0.41
Fe (ppm)	1.43±0.67	1.32±0.48	12.17±0.46	14.98±0.28

4.4. DTPA extractable metals

The DTPA extractable metals found in treatment and control plots have been depicted in Table 4.3.

Table 4.3. Physico-chemical parameters of the control and treatment plots in three years of study 2013, 2014, and 2015

Parameters	OBC (Avg±Sd)			OBV(Avg±Sd)			OBS (Avg±Sd)			OBM (Avg±Sd)		
	2013	2014	2015	2013	2014	2015	2013	2014	2015	2013	2014	2015
pH	6.21±0.39	6.19±0.31	6.78±0.15	6.02±0.07	6.36±0.32	6.53±0.32	6.55±0.73	6.31±0.81	6.44±0.52	6.69±0.20	6.87± 0.07	6.91±0.20
EC(mmhos/cm)	0.17±0.05	0.31±0.19	0.18±0.05	0.51±0.09	0.39±0.10	0.14±0.04	0.70±0.10	0.63±0.15	0.48±0.08	1.46±0.42	3.07± 0.51	1.16±0.06
BD(g/cc)	1.45±0.02	1.45±0.00	1.45±0.00	1.45±0.01	1.42±0.004	1.44±0.02	1.33±0.06	1.33±0.03	1.32±0.006	1.30±0.07	1.01±0.002	1.00±0.002
MC (%)	1.60±0.10	1.59±0.12	1.46±0.11	1.89±0.08	1.79±0.07	1.63±0.09	2.17±0.13	2.08±0.16	1.75± 0.09	3.07±0.06	2.96±0.06	2.00±0.08
WHC (%)	18.20±0.43	18.87±0.56	21.49±0.25	18.61±0.47	19.16±0.11	22.59±0.32	25.63±0.345	26.83±0.13	27.41±0.38	29.67±0.22	30.15±0.26	31.99±0.76
OC (%)	0.97±0.10	1.34± 0.32	1.49±0.44	1.03±0.12	1.25±0.13	1.14±0.11	2.16±0.10	2.20±0.04	2.06± 0.12	3.89±0.13	4.00±0.16	2.99±0.21
OM (%)	1.68±0.17	2.31± 0.56	2.59±0.76	1.79±0.20	2.16±0.22	1.97± 0.18	3.74±0.17	3.81±0.06	3.56± 0.22	6.74±0.23	6.92±0.28	5.17±0.38
Avai-N(µg/g)	23.23±1.50	28.74±1.50	25.32±2.66	23.29±2.34	33.33±4.80	23.76±3.11	34.98±0.93	46.73±2.62	42.34± 0.34	60.10±1.37	74.85±6.2	43.46±6.95
Avai-P(µg/g)	1.95±0.80	5.18± 0.81	4.78±0.43	2.38±0.62	4.77±0.79	3.66±0.82	8.23±0.79	8.782±0.86	6.85± 2.93	15.64±0.54	12.57±1.11	9.13±2.77
Exch-Mg (µg/g)	18.48±1.05	25.77±15.0	23.1±5.08	30.64±0.62	39.88±5.59	26.54±2.37	54.47±4.41	58.36±5.15	49.48±5.82	81.72±2.77	89.49±8.13	77.56±4.77
Exch-Ca (µg/g)	265.18±13.22	446.6±11.5	612.26±11.0	253.26±11.91	344.28±10.02	506.23±10.55	674.48±7.15	722.6±7.28	598.58±3.61	967.64±5.85	445.4±3.11	966.84±4.14
Exch-Na(µg/g)	39.20±3.35	38.4±4.50	28.76±9.3	55.80±3.42	46.96±2.95	47.18± 2.98	47±4.06	139.2±8.11	137.6±6.02	145.20± 2.18	255.2±4.85	122.8±4.21
Exch-K(µg/g)	57.20±5.61	117.6±8.2	184.4±5.4	85.40±9.87	242.6±5.93	272.4±9.71	98.4±5.65	624.8±6.43	638.8± 9.97	911.80±6.41	1510.2±11.85	1180.6±5.60
CEC (meq/ 100g)	5.28±0.61	8.25±0.80	9.88±0.73	8.99±0.48	7.71±0.54	5.86±0.75	10.42±1.1	13.33±1.18	13.97±0.72	20.45±1.28	25.64±1.99	25.77±2.1