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Effect of Tree Species and Organic Manures on Physio-Chemical Properties of Coal-Mine Soil and Seed Germination

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Abstract: The present study was attempted to document the influences of three tree species viz., *Dalbergia sissoo* (shisham), *Gmelina arborea* (ghamari) *and Acacia nilotica* (babul) and organic manures such as vermicompost, farm yard manure and poultry manure on physico-chemical properties of coal mine soil. Coal mine soil amendment mix was prepared and used as top layer in all treatments. The organic amendments viz. vermicompost (VC), farm yard manure (FYM) and poultry manure (PM) were applied uniformly @ 0, 20, 40 and 60 kg as a top layer. Top soil amendment was also used as one of treatments along with species and organic manures. Treatments were studied as individual and different combinations of treatments. Ninety viable seeds of each test species were sown in each treatment and each treatment replicated three times. The tree species, top soil and organic manures had significant positive effect on physico-chemical properties of coal soil. Highest seed germination of all test species was in control and *D. sissoo* had highest germination percent. Organic amendments and tree species had significant effect in coal mine soil amelioration and re-vegetation on it.

Keywords: Coal-mine, Vermicompost, Reclamation, Soil, Revegetation

The coal industry alone converts about 500 ha of land as biologically unproductive in 1994-95, which rose to 1400ha by 2000AD in India (Chari et al 1989). During opencast mining, the entire existing vegetation is uprooted (Kundu and Ghose 1997). Mining causes several changes in physical, chemical and microbiological properties of mine soils and are unsuited for plant and microbial growth because of low organic matter content, unfavorable pH, and drought arising from coarse texture of oxygen deficiency due to compaction (Dutta and Agarwal 2000). It is universally known that the plants produce many beneficial interactions with the surroundings in which they grow and vice-versa. The mine soil is influenced greatly by plant species in many ways. Addition of organic manures help plants to bio-rejuvenate by themselves. It also promotes microbial activity and release organic acids through litter decomposition which improve physical properties such as porosity, field capacity, bulk density and aeration of coal mine soil. Organic matter is the most capable and potent substance that greatly influences mine soil composition due to humus deposition in a man-made forest. The tree species may speed up reclamation and bio rejuvenate process in a relatively short period of time. Therefore, self-sustainability and regenerative capacities of abandoned mining areas should be developed for the proper functioning of the ecosystems through re-vegetation. Addition of organic manure plays vital role in increasing the organic C content, CEC and t soil fertility in mine soil and also macro nutrient fertilizer (N, P, K) is required at high doses reclamation and enhancing productivity (Pranayama et al 2019). During open cast mining, topsoil stripping and stockpiling are important practices since topsoil is critical element for the successful restoration of mine soil (Ghose 2001). Topsoil cannot always be placed directly onto mined out land. Therefore, it may be necessary to stockpile the resource for future use (CMSACRA, 2007). Poor management of topsoil and stockpiles will lower the rehabilitation potential of the soils and increase rehabilitation costs. Restoring the soil productivity and re-vegetation are primary objectives of mine soil reclamation (Mushia et al 2016). The present study was aimed to study the combined effect of tree species and organic manures on physical and chemical properties of coal mine soils and to find out the promising tree species for revegetation in coal mine dumps.

MATERIAL AND METHODS

Study area: A study was conducted during in the month of March – June, 2011 at Forest Research Centre, Mandar, Jharkhand (23^0 27' 41.3" N and 085^0 05' 57.0"N) at an altitude of 703m above mean sea level, having an annual average rainfall of 1400mm; humid to sub humid tropical type of climate. Annual temperature ranges from maximum 42 to 20^0C during summer and 25 to 4^0C during winter season. Soil of study site is lateritic in nature.

Experiment details: On the cemented platform (1.0 m height from ground level), eight rectangular shape nursery beds with size 3.40 X 1.36 m were made with bricks lining. The beds were filled uniformly with coal mine soil @ 150 kg per bed. Then each bed was divided into 4 equal sub- plots with dimensions of 1.36 X 0.75 X 0.17 m. Stone chips (2mm jelly) was spreaded uniformly at base of bed up to about 30 cm thickness prior to filling of amended coal-mined soil treatment. Above this layer, another layer was formed with coal- mine-soil - amendment mix which includes 50,10 and 10 % municipal waste, saw dust and bio-char of coal mine soil (w/w). Then, three organic amendments viz. vermicompost (VC), farm yard manure (FYM) and poultry manure (PM) were applied uniformly @ 0 (T1), 20 (T2), 40 (T3) and 60 kg (T4) as a top layer. Each dosage represents as a treatment and each treatment replicated thrice. Influences of three tree species viz., *Dalbergia sissoo* (Shisham)*, Gmelina arborea* (Ghamari) *and Acacia nilotica* (Babul) and organic amendments on physico-chemical properties of coal mined soil at end of 3- month period. Representative soil samples were collected randomly two times from each the treatment, i.e., at time of seed sowing and at three-month-old end of experiment. The collected samples were processed and subjected to analysis of physical and chemical properties (bulk density, soil pH, EC, organic carbon, avail N, P, K were determined with standard methods (Black 1963).

RESULTS AND DISCUSSION

Physical properties of coal mine soil: The soil physical properties viz. bulk density, particle density, porosity, maximum water holding capacity and volume expansion were changed significantly with species, top- soils and addition of organic manures such as VC, FYM and PM (Table 1). The physical properties of coal mine soils were significantly changed with influence of species planted, organic manures and combination of both. The bulk density of treated coal mine soil under all tree species was lower than that of control. The highest bulk density was in *D. sissoo* and lowest in *A. nilotica*. The particle density was high (2.03) in *G. arborea* and low in *A. nilotica*. The porosity of all species plots was significantly higher than that of control. The porosity, water holding capacity and volume were higher in *G. arborea*. The tree species and top-soil had combined influences the soil physical properties of coal mine soil significantly. The bulk density of all top-soil incorporated plots had higher value than that of control. The highest bulk density was in top-soil added *D. sissoo* plot whereas top-soil added *G. arborea* plot had lowest bulk density. Similarly, the particle density of top-soil added plots had shown higher values than that of control. On other hand, the porosity, water holding capacity and volume were found low in all top-soil added plots.

Similarly, both organic manures and species had shown significant effect on physical properties of coal mine soils. The bulk density and particle density of organic manures added coal mine soils were found lower than that of control under *D. sissoo*. The bulk density of organic manure- added coal mine plots followed the order viz. vermicompost plot > FYM plots > Poultry manure. The lowest bulk density was 0.50 found in PMD40 whereas highest was 0.92 in control followed by FYMD20 and VCD20. Both particle density and porosity of manured plots was FYM plots > Vermicompost > Poultry manures. The particle density was maximum in control and minimum in PMD20. The lowest porosity too was noted in PMD20. The highest porosity and maximum water holding capacity was in PMD60, whereas lowest volume expansion was in PMD60. As stray dogs were damaged some manured plots under *A. nilotica and G.arborea*, the results were interpreted with undisturbed treatments only. The data revealed that the bulk density was slightly increased with organic manures under *A. nilotica* when compare with control. The highest bulk density was observed in PMA60 and lowest was in PMA40. The particle density was lower than control in all manured plots except FYM60 and PMA60. Further, the porosity was decreased with increasing poultry manure. Both water holding capacity and volume expansion were high in PMA40. The lowest water holding capacity and volume expansion was in PMA60 and FYMA60.The bulk density of manured plots under *G. arborea* was ranged from 0.72 (PMG20) to 0.91 (control). The bulk density of manured plots was lower than that of control. The particle density too was shown similar trend as bulk density. The maximum porosity and water holding capacity was recorded in PMG20 and minimum of the same was in FYM20 and control, respectively. Besides, the highest volume expansion was in PMG40 and lowest in FYMG20 (Table 1). Thus, both plant species and organic manures had caused favorable effect on bulk density and water holding of coal-mine soil.

Chemical properties of coal mine soil: The plant species and organic manures caused significant changes in chemical properties of coal- mine soils. In general, plants raised pH level from acidity to near-alkalinity. The high pH was 7.10 in TSMD and low (5.7) in control. The EC changed with species. The EC of control and *A. nilotica* plots were same. The highest EC was 0.23 dS/m in TSMD. The organic content increased in all plots when compare with control. The OC content was high d in TSMA and low in TSMD. The available N content ranged from 106.8 to 422.55 ppm. The available N and K content had shown same trend. The high available N and K was noted in TSMG and low in control. The available P content had shown reverse trend of N and K.All top-soil plots were acidic in nature and pH ranged from 5.6 to 6.3. The EC

Table 1. Effect of species and organic manures on physical properties of coal-mine soil

Treatment	Treatment details	Bulk density	Particle density	Pore space	Maximum water holding capacity/100 g of soil	Volume expansion per 100 g of soil
TC00	Coal mine-amendment mixonly	1.2	1.96	42.13	34.78	2.01
Species effect						
TSMG	Coal mine-amendment + *G. arborea*	0.91	2.03	61.53	64.54	2.98
TSMA	Coal mine-amendment + *A .nilotica*	0.9	1.69	50.52	52.16	0.79
TSMD	Coal mine-amendment + *D. sissoo*	0.94	2.16	61.19	61.56	1.64
	Mean	0.9	2.0	57.7	59.4	1.8
Top soil effect						
TTSA	Coal mine-amendment + top soil + *A. nilotica*	1.22	2.03	42.61	34.43	1.54
TTSD	Coal mine-amendment + top soil + *D. sissoo*	1.26	2.1	41.66	32.09	0.35
TTSG	Coal mine-amendment + top soil + *G. arborea*	1.19	2.07	44.3	36.22	0.91
	Mean	1.22	2.07	42.86	34.25	0.93
Combined effect of species and organic manures(kg/1.1m^2)						
D. sissoo	VC -2O	0.9	1.4	50.4	60.9	6.1
	VC -4O Kg/1.1m2	0.8	1.1	48.5	68.5	13.0
	VC -6O Kg/1.1m2	0.9	1.5	53.8	69.6	5.6
	Mean	0.8	1.4	50.9	66.3	8.3
	FYM -2O Kg/1.1m2	0.9	1.8	57.1	61.1	1.7
	FYM -4O Kg/1.1m2	0.8	1.4	53.4	65.6	2.2
	FYM -6O Kg/1.1m2	0.8	1.2	52.9	80.1	11.8
	Mean	0.8	1.5	54.5	68.9	5.2
	PM -2O Kg/1.1m2	0.5	0.6	42.4	93.9	17.8
	PM -4O Kg/1.1m2	0.5	0.7	47.8	98.6	8.1
	PM -6O Kg/1.1m2	0.6	1.2	63.4	99.3	4.7
	Mean	0.5	0.8	51.2	97.3	10.2
A. nilotica	FYM 20kg /1.1m2	1.0	2.3	61.0	59.4	1.0
	FYM 60kg /1.1m2	0.9	1.7	55.9	59.6	3.7
	Mean	0.9	2.0	58.4	59.5	2.3
	PM 20kg /1.1m2	0.8	1.8	58.2	64.1	2.2
	PM40kg /1.1m2	0.8	1.5	57.1	71.9	6.6
	PM 60kg /1.1m2	1.1	2.2	54.5	47.9	1.5
	Mean	0.9	1.8	56.6	61.3	3.4
G. arborea						
	VC -4O Kg/1.1m^2	0.8	1.3	53.2	78.4	9.9
	FYM -2O Kg/1.1m^2	0.8	1.4	47.3	61.3	0.3
	FYM -4O Kg/1.1m2	0.9	1.5	52.9	62.5	2.4
	Mean	0.8	1.5	50.1	61.9	1.4
	PM -2O Kg/1.1m2	0.7	1.6	63.7	86.9	2.2
	PM -4O Kg/1.1m2	0.8	1.0	47.4	69.4	18.6
	PM -6O Kg/1.1m2	0.7	1.1	54.7	79.9	10.8
	Mean	0.8	1.3	55.3	78.7	10.5

of the top – soil added – plots were lower than that of control. The lowest EC was 0.06 dS/m in TTSD and highest in TTSG. The organic content of top-soil plots was higher than that of control and rest of the treatments. Available N content in top-soiled plots was influenced by top soil. The highest N content among top-soil added plots was 405.1ppm in TTSG and lowest in TTSD. The available P content was comparatively lower than that of control. The maximum P was inTTSA among top-soiled plots. The available K content was much lower than that of rest of treatments in top soil added plots. The high K was 26.4ppm in top-soil added TTSA and low K in TTSG.

Both vermicompost and tree species positively influenced the chemical properties of coal–mine soil equally. Soil pH was increased towards neutral pH from the acidic conditions under VC treated plots under *D. sissoo*. The range of pH under *D. sissoo* was 6.7-7.5. The highest pH in TFYMD2 and lowest in control followed by TVCD1. The pH of organic treated plots under *D. sissoo* exhibited the following order: VC< FYM < Poultry manure. EC of the all manured plots under *D. sissoo* was much higher than that of control. It was constantly increased with addition of organic manures. The highest EC was 1.07 dS/m in PMD and lowest was 0.2 dS/m in TFYMD1. The OC recorded decreasing trend with VC and FYM under *D. sissoo* whereas the OC of PM had increasing trend. The maximum OC was 19.82% in TPMD3 and lowest (4.48%) in TVCD2. The available N, P and K of the treated plots too were changed with organic manures and *D. sissoo*. Both N and K had shown increasing with addition of FYM while others did not any trend. The available nutrient content was higher in all treated plots when compare with control. The N, P and K ranged between 267.39 – 1572.8 ppm, 1.0 – 14.1ppm and 342.8ppm, respectively. The highest value of N, P and K was in TPMD2, TVCD1 and TPMD1, respectively. The TVCD1, TPMD2 and TPMD3 plots had shown low content of N, P and K, respectively (Table 2).

The pH of manured treated plots under *A. nilotica* was neutral when compare with control. The pH range of treated plots was between 6.7 in TVCA1and 7.2 in TPMA2. EC had significantly increased in all treated plots. The highest increase was in poultry manured plots (TPMA3) and low in TPMA1. The OC content ranged from 5.44 to 13.4%. The OC was high in FYM treated plots and low in TPMA1. The available N, P and K was between 100 – 305.5, 0.61 – 10.82 and 142.5 - 783.7ppm, respectively. The maximum N, P and K was in TPMA1, TVCA1 and TPMA3, respectively. The pH of all treated plots under *G. arborea* ranged from 6.57 to 7.4. Among treated plots, poultry manured had high pH values than in others. The highest and lowest pH was in TPMG1 and TVCG1, respectively. EC of organic manured plots were ranged from 0.17 to 0.69 dS/m. The highest EC was in TPMG3 and lowest in TVCG1. The OC also changed with addition of manures and was between 4.26-12.4%. The TFYMG2 had shown highest OC among the treated plots. In the *G. arborea* planted plots, the available N, P and K content varied from 277.48-586.81, 1.53-13.27 and 135.4-1033.5ppm, respectively. The highest P and K content were recorded in TPMG3, whereas available N was maximum in TPMG1 (Table 2).

The physical and chemical properties of mine soils tend to inhibit soil-forming processes and plant growth due to a lack of nutrients associated with SOM, nitrogen and phosphorus (Ussiri and Lal 2005). Soil amendments had significant effect on improvement on soil properties. Soil amendments had showed high-rate plant growth (Mohapatra and Goswami 2012).Organic manures contain humic substances with many functional groups viz., carboxyl and phenolic groups that are able to consume protons at their natural pH values (Stevenson and Vance 1989). Crop yield is maximum in poultry manure amended soil as it supplies more balanced nutrition especially Ca and Mg and adds large quantity of cations to the soil (Adediran et al 2005, Adediran and Ojeniyi 2006). Moreover, compost may increase the cation exchange capacity of soils, and also allow crops to utilize nutrients more effectively while reducing nutrient loss through leaching.

Germination: The germination percentage differ significantly among treatments and between tree species. The highest germination per cent of *D. sissoo* was in control and top-soiled coal mine. Among the vermi-composted coal mine soils, maximum germination was 30.4% in control whereas in FYM incorporated coal mine soil treatments, the germination was 43.3% in control. Among all treatments, top soiled coal mine soil had highest germination (44.4%). The mean germination per cent of *D. sissoo* followed the order: top – soil treated mine soil > FYM treated mine soils > poultry manures (PM) treated mine soils > VC treated soils. The highest germination of *Gmelina arborea* was 68.5% in TPM0 and lowest was 4.8% in TVC3. Maximum germination was in TVC0 and TPM0 under VC and PM treated mine-soils. The germination per cent of *Gmelina arborea* shown an increasing trend with addition of organic manures (FYM and PM) in coal mine soils. The germination of *Gmelina arborea* had shown the typical trend PM mine soils > FYM mine soils > VC mine soils. The germination of *Acacia nilotica* in amended coal mine that germination percent was decreasing trend in VC treated mine soils and increasing trend in PM treated mine soils. Among the three test tree species, the rate of germination of both *D. sissoo* and *G. arborea* was higher than that of *A. nilotica*. Over all, the highest germination per cent

Table 2 Chemical properties of organic manure treated coal mine under *Dalbergia sissoo*, *Gmelina arborea* and *Acacia nilotica*

Species	Treatment	Treatment details	pH (1:2.5) @ 30°C	EC (1:5) mS/cm	OC%	N (ppm)	P (ppm)	Avail K (ppm)
-	TC00	Soil mixture with no manure/top soil/spp.	5.7	0.2	3	107	12	44
Species effect								
G. arborea	TSMG	Soil mixture with no organic manure	6.9	0.2	6	423	8	221
A. nilotica	TSMA	Soil mixture with no organic manure	6.8	0.2	7	136	9	142
D. sissoo	TSMD	Soil mixture with no organic manure	7.1	0.2	3	149	2	330
	Mean		6.9	0.2	5	236	6	231
Top soil effect								
A.nilotica	TTSA	Soil mixture with top soil	5.6	0.1	3	152	8	26
D. sissoo	TTSD	Soil mixture with top soil	6.3	0.1	4	110	8	24
G. arborea	TTSG	Soil mixture with top soil	5.6	0.2	4	405	8	19
	Mean		5.8	0.1	4	222	8	23
Combined effect of species and organic manures (kg/1.1m^2)								
D. sissoo	TVCD1	VC @ 2O	7	0	6	267	14	414
	TVCD2	VC @ 4O	7	1	4	456	8	1122
	TVCD3	VC @ 6O	7	1	5	322	10	654
	Mean		7	0	5	348	11	730
	TFYMD1	FYM @ 2O	7	0	6	100	8	343
	TFYMD2	FYM @ 4O	7	0	6	224	8	587
	TFYMD3	FYM @ 6O	7	0	5	328	1	750
	Mean		7	0	6	217	6	560
	TPMD1	PM @ 2O	7	1	18	1400	1	1537
	TPMD2	PM @ 4O	8	1	19	1573	1	988
	TPMD3	PM @ 6O	7	1	18	1034	9	139
	Mean		7	1	18	1335	4	888
Acacia nilotica	TFYMA1	FYM @ 20kg	7	1	6	572	1	729
	TVCA3	FYM @ 60kg	7	0	13	180	0	440
	Mean		7	0	10	376	1	584
	TPMA1	PM @ 20kg	7	0	5	305	7	196
	TPMA2	PM@ 40kg	7	0	6	257	1	547
	TPMA3	PM @ 60kg	7	1	6	100	7	784
	Mean		7	0	6	221	5	509
G.arborea	TVCG1	VC @ 4O	7	0	10	277	8	871
	TFYMG1	FYM @ 2O	7	0	12	166	13	392
	TFYMG2	FYM @ 4O	7	0	12	252	2	454
	Mean		7	0	12	209	7	423
	TPM1	PM @ 2O	7	0	3	587	8	491
	TPM2	PM @ 4O	7	0	10	411	3	768
	TPM3	PM @ 6O	7	1	4	537	8	1034
	Mean		7	0	6	512	6	764

Table 3. Germination percent of different tree species in organic manure treated soil

Treatment code	Particulars	Germination (%)		
		Dalbergia sissoo	*Gmelina arborea*	*Acacia nilotica*
T00	Control	40.6	28.4	5.2
TVC1	T1: Vermicompost @ 20 kg/ 1.13 m^2	15	5	6
TVC2	Vermicompost @ 40 kg/ 1.13 m2	4	7	5
TVC3	T1: Vermicompost @ 60 kg/ 1.13 m2	8	5	1
	Mean	9	6	4
TFYM1	T1: FYM @ 20 kg /1.13 m^2	21	9	4
TFYM2	T1: FYM @ 40 kg /1.13 m2	22	10	7
TFYM3	T1: FYM @ 60 kg /1.13 m2	21	11	6
	Mean	22	10	6
TPM1	Poultry manure @ 20 kg/ 1.13 m^2	16	18	4
TPM2	Poultry manure @ 40 kg/ 1.13 m2	16	34	5
TPM3	Poultry manure @ 60 kg/ 1.13 m2	17	40	7
	Mean	16	31	6

was in control (Table 3) which may due to seeds were sown before beginning of reclamation process.

CONCLUSION

Addition of organic amendments in coal mine soil not only increased pH towards neutral from acidic conditions, but also enhanced available nutrients content to plants. Among amendments, poultry manure had quicker response in reducing soil acidity in coal mine soil. Seed germination percent varies with type of species and amendments. Among three tested species, *D. sissoo* was performed well in amended coal mine. Addition of organic amendments in coal mine help to reduce physiological nutrient stress by ameliorating physicochemical properties of soil and enhance re-vegetation capacity of coal mine soil. However, more detailed studies are required for development of site-specific reclamation methods.

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