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Influence by physical properties of coal combustion residues (CCRs) on dry root productivity of *Withania somnifera* grown in black cotton soil

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In India, presently ~40% Coal Combustion Residues (CCRs) generated by burning of pulverized coal at Thermal Power Station is being used for cement, bricks, land reclamation etc. Now a day it has also been considered for agriculture applications. This study, an attempt was made to use of CCRs as soil modifier and micro fertilizer for cultivation of *Withania somnifera* under two cropping. Results revealed that production of dry root yields of *Withania somnifera* was found higher in T5 treatment (35.545g and 39.002g per plant) as compared to control treatment (T1). It is showed significant ($p<0.001\%$) from all the treatments in both the years. The essential elements like Cu, Zn, Fe and Mn were found increasing trends in dry root of *Withania somnifera* with increase the concentration of CCRs application. This study is found the bulk utilization of CCRs for cultivation of *Withania somnifera* improved their root yield and chemical quality.

Keyword: Coal Combustion Residues, *Withania somnifera*, Cultivation, Root Yield, Chemical Quality.

1. Introduction

In India, coal based Thermal Power Plants are generating 170 million tonnes of Coal combustion residues (CCRs) by the year 2012. The annual quantity of CCRs generation by power plants, is expected to be about 225 million tonnes by 2017, this will lead to major environmental problems[1,2, 3, 4]. Presently in India ~40% of CCRs is being used in several applications such as cement, road/embankment, building construction materials, bricks, lightweight aggregate, door shutters, blocks, tiles, as partial replacement of fine aggregate in concrete, land reclamation, wasteland development for agriculture and as a adsorbent in waste water treatment[5,6] .

According to several researchers the CCRs application in agriculture revealed that CCRs has some beneficial as well as undesirable effect on the soil fertility and crop yield[7]. CCRs is alkaline in nature and contains many essential elements like Si, Fe, Ca, Mg, Na, K, S, B, Cu, Zn, Mn and P[8]. Addition of CCRs neutralized the soil acidity to suitable for agricultural crops[9]. It is reported that many physical and chemical properties of CCRs can contribute to improve agronomic properties of soil[10]. CCRs application increased the plants growth and crop yield of tomato, potato, cabbage, pea, wheat, mustard, oats and sunflower[11]. The impact of CCRs on soil fertility and crop yield depends on various factors such as pH, conductivity, reactivity of CCRs, ion exchange capacity, moisture content, particle size and finally percentage addition of CCRs. Studies based on Indian CCRs indicate that it can be utilized as soil modifier and micro fertilizer and to increase the agricultural productivity with any additional treatment[12,13]. It is evident from the analysis of Indian CCRs that the presence of heavy/toxic elements and radionuclides are at levels that may not lead to serious concern[14].

Withania somnifera (L.) Dunal (Ashwagandha) is an Ayurvedic medicinal plant which is belong to solaneace family and popular as a home remedy for several diseases and human requirements. It is in use for a very long time for all age groups and sexes and even during pregnancy without any side effects[15]. *Withania somnifera* roots are obtained mostly from Manasa, Neemuch and Javed Tehsil of Mandsaur district, Madhya Pradesh and adjoining area of Rajasthan, India in about 4000 ha[16,17]. According to one of the estimate the annual requirement of the roots is ~7000 tonnes in India. The cultivation is confined to annual production ~1350 tonnes, which is too low to meet the ever increasing demand[18]. Still no work has been reported on use of CCRs for cultivation of *Withania somnifera* and improve it root yield and quality. The present paper deals with the influence of physical properties of CCRs on production of dry root yield of *Withania somnifera* and their chemical quality.

2. Material and Methods

The lab scale experiments were carried out in randomized block design (RBD) at Advanced Materials and Processes Research Institute (CSIR), Bhopal, Madhya Pradesh, India. Plot size was 8 x 6.5mts and sub plot size was 1x1mts. CCRs were transported from ash dyke of Sapura Thermal Power Station, Sarni, Dist. Betul, and Madhya Pradesh, India to experimental site in dry state at about 4 to 6 percent moisture. CCRs were mixed with soil manually on the basis of soil bulk density. *Withania somnifera* a valuable medicinal plant was considered for this study. The experiments were designed with five treatments viz.-T1 (Control no CCRs), T2 (5% CCRs), T3 (10% CCRs), T4 (15% CCRs) and T5 (20% CCRs) with four replications.

2.1 Sampling of soil and CCRs

Equal volume of soil from each plot of same depth was collected. Samples were prepared by adopting conventional quartering and coning method. Collected samples were air dried and sieved through 2 mm size sieve and were used for of physical characterization.

2.2 Physical properties of soil and CCRs

Bulk Density (BD) was measured[19] following method. Porosity was calculated empirically using particle density and bulk density following[20] method. Water holding capacity (WHC) was measured using saturated soil past and was verified with Keen Box Method[21]. The electrical conductivity (EC) was measured using Colones Conductivity Meter in 1:2 soil water suspensions and pH was determined calorimetrically using pH meter[22].

2.3 Chemical properties of plant materials

The content of chemical constituents such as Cu, Zn, Fe, Mn, Pb, Cd, As, Cr, Ni and Co was analyzed. For elemental analysis, powdered samples were digested in microwave digester (QLAB 6000 Microwave Digestion System, Canada) and digested samples were filtered using whatman filter paper 44 and analyzed[22] by Atomic Absorption Spectrophotometer (AAS), Z-5000, Hitachi, Japan. The content of nitrogen and sulphur were determined by CHNS Analyzer, (Elementar Vario-EL) Germany.

2.4 Dry Root Yield

The plants were harvest 15-20cm above the ground level and fresh root was washed and oven dried at 80^0C till reach to constant weight and used for determining dry root yield production.

2.5 Statistical Analysis

All the data were analyzed statistically by using the computer programme of SIGMA plot/ MICROSTAT and from the formulae in the book[23]. The values were classified in different possible ways and were analyzed for analysis of variance by ANOVA.

3. Results and Discussion

3.1 Physico chemical properties of initial soil and CCRs

The result showed that textural class of initial soil and CCRs was clayey and loamy sand respectively (Table 1). The sand content in CCRs was maximum (85.50%) as compared to initial soil (21.25%) but silt (30.65%) and clay (48.10%) content was found higher in soil as compared to CCRs. The texture of CCRs is loamy sand and facilitates good drainage and aeration[24]. The results obtained were showed that, the pH of the CCRs and initial soil varies from 7.85-8.23, which is slightly alkaline in nature. However, there is not much variation between the pH of initial soil and CCRs. pH plays an important role in improving the soil fertility[25]. The Electrical conductivity (EC) of CCRs was 0.416dS/m and that of soil was 0.185dS/m. The bulk density of soil was 1.32g/cc, CCRs exhibits relatively low bulk density (1.02g/cc). The CCRs has higher porosity (48.22%) as compared to soil (42.18%). Porosity of CCRs was found higher that is beneficial for low porosity of clay soil. For ideal condition of aeration, permeability and water retention, a soil should have an equal amount of macro and micro-pores[24]. The water holding capacity of soil and CCRs was observed as 58.30% and 66.70% respectively. The silty nature of CCRs has comparatively, increased the water holding capacity by 12.62% than the initial soil.

3.2 Physico chemical properties of admixed soil collected after harvesting of first and second cropping

Table 2 shows the results on the physical properties of admixed soil of *Withania somnifera* plot at after harvesting of first (2006-07) and second (2007-08) cropping. Results revealed that clay content was maximum (46.12% and 44.88%) in T1 treatment at after harvesting of *Withania somnifera* in both years. The sand (32.26%), silt (39.28%) and clay (28.47%) content in soil at first year was almost same and during second year, sand (32.66%), silt (40.24%) and clay (27.10%) content was found higher/lower in T5 treatment.

Table 1: Physico chemical property of initial soil and CCRs

S. No.	Parameters	Initial Soil	CCRs*
1.	Sand (%)	21.25	85.50
2.	Silt (%)	30.65	13.60
3.	Clay (%)	48.10	0.90
4.	Texture	Clay	Loamy sand
5.	pH	8.23	7.85
6.	Electrical conductivity (dS/m)	0.416	0.185
7.	Bulk density (g/cc)	1.32	1.02
8.	Porosity (%)	42.18	48.22
9.	Water holding capacity (%)	58.36	66.79

*CCRs was applied only at the start of the experiments

The maximum pH was noticed in T1 treatment at after harvesting first and second cropping (Table 2). Not much variation was found in other treatments of the both cropping. The plant absorbs most of the nutrient within the pH range of 6.5 to 7.5 of soil. The soil, pH may influence nutrient absorption and plant growth through a direct effect on the hydrogen ions, indirectly through its influence on nutrient availability and presence of trace and heavy elements[26]. Alkaline nature of CCRs also contributes to enhance mineralization of organic matter and promotes nutrient supply to the plants[27]. During the cultivation of *Withania somnifera* in the CCRs admixed soil, increased the availability of free ions along with an increase in electrical conductivity from control plot to maximum CCRs applied plot in the first cropping (Table 2). The second year cropping results revealed that maximum electrical conductivity was in maximum CCRs treated plot. But increasing trend was noticed in T2, T3 and T4 treatments as compared to T1. CCRs addition to soil lowered the bulk density. Porosity in all treatments was observed in increasing trends after harvesting of both the cropping. The addition of CCRs also improved physical properties of soil and enhanced plants growth which was supported by the work done[28].

Table 2: Physico chemical properties of admixed soil collected after harvesting of first and second cropping

S. No.	Parameters	Treatments									
		T1		T2		T3		T4		T5	
		1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
1.	Sand (%)	21.52	22.68	24.86	28.14	25.26	30.94	31.46	31.72	32.26	32.66
2.	Silt (%)	32.36	32.44	35.78	36.48	36.34	35.52	36.34	37.46	39.28	40.24
3.	Clay (%)	46.12	44.88	39.36	35.38	38.40	34.54	32.20	30.82	28.46	27.10
4.	pH	8.15	8.12	8.12	8.10	8.12	8.10	8.10	8.00	8.10	8.00
5.	Conductivity (dS/cm)	0.228	0.248	0.236	0.254	0.243	0.258	0.254	0.264	0.262	0.274
6.	Bulk Density (g/cc)	1.31	1.30	1.29	1.23	1.28	1.24	1.27	1.23	1.25	1.21
7.	Porosity (%)	44.65	45.62	45.75	46.85	46.56	46.88	47.65	48.58	48.11	48.56
8.	WHC (%)	57.36	57.66	57.42	57.76	57.45	57.88	57.82	48.12	58.21	58.54

3.3 Dry root yield of *Withania somnifera* cultivation under two cropping

Table 3 shows the average dry root yield of the *Withania somnifera* in the first and second cropping. The result revealed that the dry root yield of *Withania somnifera* was increased due to fly ash (5-20 percent) application. The maximum dry root yield was obtained in T5 i.e. 35.545 g per plant in first year and 39.002 g per plant in second year where 20 percent of fly ash was applied as compared to the control i.e. 31.480 g per plant in first year and 35.413 g per plant in second year at harvesting stage (Table 3). Increase in dry root yield of *Withania somnifera* in the first year at harvesting stage was in the following order T5> T4>T3>T2>T1. The increasing trend in dry root yield of *Withania somnifera* during the second year was showed almost similar results to that of first year, but maximum dry root yield was founded in the second year (Fig 1).

The analysis of ANOVA of variance statistically indicates that the dry root yield of *Withania somnifera* showed significant ($p<0.001\%$) from all the treatments in both the years (Table 4 and Table 5). It was visible from the results that addition of CCRs was more effective to get optimum benefit. The slow release of nutrients from the CCRs could be noticed in the second year, which might have resulted in the improvement of the productivity.

Table 3: Dry root yield of *Withania somnifera* cultivation under two cropping

Treatments	Nos.	First cropping			Second cropping		
		Root yield (Mean)	Std Dev	SEM	Root yield (Mean)	Std Dev	SEM
T1	4	31.480	1.481	0.741	35.413	0.912	0.456
T2	4	32.623	0.670	0.335	36.325	0.174	0.0870
T3	4	33.918	0.580	0.290	37.400	0.387	0.194
T4	4	34.918	0.586	0.293	38.335	0.718	0.359
T5	4	35.545	0.674	0.337	39.002	0.169	0.0847

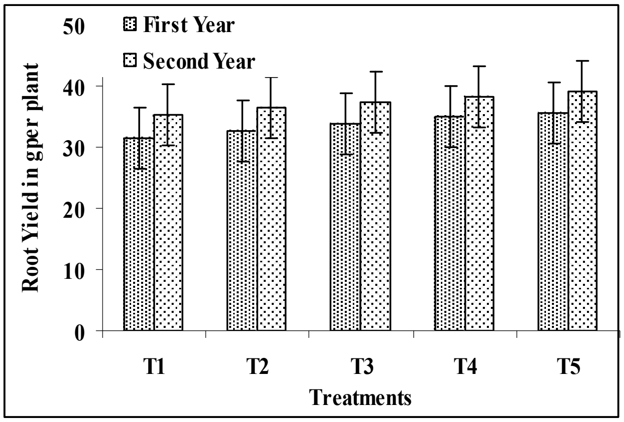

Fig 1: Dry root yield of *Withania somnifera* cultivation under first and second years

The biomass residues generated from the first year cropping might have also contributed toward improvement in the fertility of soil. The application of CCRs might have increased the roots productivity of *Withania somnifera*[29]. Data recorded on root yield and its attribute showed that maximum root length and number of secondary roots and contributed significantly towards dry root yield. Addition of CCRs increased root yield of various plant species[30]. The root yield of *Withania somnifera* increased (~8%) by CCRs application[31].

Table 4: ANOVA analysis of variance of dry root yield of *Withania somnifera* in first cropping

Source of Variation	DF	SS	MS	F	P
Between Groups	4	44.092	11.023	14.594	<0.001
Residual	15	11.330	0.755		
Total	19	55.422			

Table 5: ANOVA analysis of variance of dry root yield of *Withania somnifera* in second cropping

Source of Variation	DF	SS	MS	F	P
Between Groups	4	33.972	8.493	27.274	<0.001
Residual	15	4.671	0.311		
Total	19	38.643			

3.4 Chemical properties of dry root of *Withania somnifera* cultivation under two cropping

Table 6 shows the chemical properties of dry root of *Withania somnifera* cultivated in different concentration of fly ash treated plot at after harvesting of both cropping. Result revealed that the maximum nitrogen content was in T5 (1.74% and 1.74%) treatment as compared to T1 (1.45% and 1.46%) in both the years. The maximum phosphorous (0.322% and 0.320%) was found in T5 (20%) treatment root as compared to control plot (0.296% and 0.296%) after harvesting of both cropping. Not much variation was found in phosphorous concentration between first year and second year in the all treatments. The maximum content of potassium and sulphur was found in T5 treatment (0.018%, 0.019% and 0.226%, 0.305%) as compared to other fly ash treatment roots at after completion of first and second cropping. The micronutrients, trace and heavy metals content in root of *Withania somnifera* is shown in table 6 results revealed that Cu, Zn, Fe and Mn were showed in increasing trend in all treatments amended with different concentration of CCRs at the harvesting of both the years. But the maximum content of these micronutrients found in root T5 treatments as compared to control plot in both the years. It was reported that the total accumulation of toxic metals particularly, Ni and Pb, were recorded many times higher in the plants grown on CCRs amended soil[32]. It was possible that high accumulation of Mn and Zn, particularly in the root tissues could be due to the complexes of metals with the sulphydryl groups, which resulted in less translocation of metals in to upper parts of the plant. The heavy metals such as Co, and Pb were found within the permissible limit and Ni, As Cr and Cd were found of below detectable limit in dry roots of all treatments at after harvesting of both cropping. It seemed that no toxicity effect was shown in the dry root of *Withania somnifera* grown under different concentration of CCRs. This is reported that high accumulation of essential metals like Fe, Mn, Zn and Cu was found in different parts of the plants namely *Cassia siamea* (Lamk.) and *Sesbania* *cannabina* (L.)[32,33]. Several reports indicated that the metal accumulation in the plants depended on the concentration of available metals in the soils, solubility sequences and the plant species grown on these CCRs treated soils[33,34]. During this study, accumulation of metals such as Zn, Fe and Mn were recorded more in root of maximum CCRs treated plot plant as compared to control plot. This result has supported by finding[34] that the translocation of metals was more from roots to shoots in the plants grown under CCRs treated plots.

Table 6: Chemical properties of dry root of *Withania somnifera* cultivation first and second cropping

S. No.	Parameters	Treatments									
		T1		T2		T3		T4		T5	
		1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
1.	N (%)	1.45	1.46	1.51	1.52	1.57	1.56	1.63	1.65	1.74	1.74
2.	P (%)	0.296	0.296	0.289	0.291	0.298	0.296	0.312	0.313	0.322	0.320
3.	K (%)	0.012	0.013	0.014	0.014	0.016	0.015	0.016	0.016	0.018	0.019
4.	S (%)	0.517	0.526	0.365	0.413	0.236	0.368	0.230	0.312	0.226	0.305
5.	Cu (ppm)	12.36	14.26	15.84	16.38	16.25	17.75	16.28	17.85	18.56	17.96
6.	Zn (ppm)	32.26	36.25	34.26	38.64	36.38	41.23	42.56	45.68	54.26	48.65
7.	Mn (ppm)	14.26	18.56	15.24	21.49	15.26	22.37	15.36	22.55	16.38	23.68
8.	Fe (ppm)	256.34	265.56	388.34	372.61	396.28	386.41	416.34	412.8	485.26	421.35
9.	Co (ppm)	1.56	1.45	1.42	1.38	1.32	1.35	1.28	1.31	1.16	1.26
10.	Pb (ppm)	5.63	4.26	5.64	4.12	5.26	4.25	5.42	4.11	4.98	4.10

*As, Ni, Cr and Cd observed in Below Detectable Limit

4. Conclusion

From the above results it is concluded that the maximum dry root yield was founded in maximum CCRs applied plot and better chemical composition was founded in dry root of *Withania somnifera* grown under maximum CCRs treated plot as compared to control in both cropping. The quality of root yield of *Withania somnifera* grown under different concentration of CCRs is comparable to the control and meets the quality standard. The outcome of the study revealed that CCRs can be effectively utilized as a soil modifier and micro fertilizer to increase the dry root yields of *Withania somnifera* without affective any toxicity and followed by protect the environmental pollution and solve the dumping problem of CCRs.

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