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Application of Crusher Dust as Mineral Fertilizer for Plant Growth

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Abstract: *Stone crusher units generate a considerable amount of micro-fine and airborne dust particles at the source which causes detrimental effects on people and the environment including flora and fauna. These rock fines contain minor to traces of elements locked in the silicate structures which are insoluble in water. Weathering by carbonation process has been made to use crusher dust as a supplement of fertilizer by conversion of silicate rock fines into clay minerals. In the present study, the weathered crusher dust as a source of mineral fertilizer has been used as a substrate for the growth of plants such as Oryza sativa L. and Zea mays L. Pot experiments have been conducted on control soil with the admixture of crusher dust and weathered crusher dust (mineral fertilizer) in different weight proportion. No visible symptoms of phytotoxicity are observed in any treatments. The findings of this study open up new opportunities for utilization of crusher dust as a source of mineral fertilizer for plant growth.*

Keywords - *Chlorophyll, Crusher Dust, Sustainable utilization*

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I. Introduction

Stone crushing industry is an important industrial sector in the country engaged in producing crushed stone of various sizes depending upon the requirement which acts as raw material for various construction activities such as construction of roads, bridges, buildings, canals etc. In India, there are about 12,000 stone crusher units which produce an annual turnover of Rs. 5000 crore (equivalent to over US$ 1 billion) and is therefore an economically important sector [1]. The number is expected to grow further keeping in view the future plans for the development of infrastructure of roads, canals and buildings that are required for an overall development of the country. The sector is providing direct employment to people and increases the economic growth of the country, but on the other side has resulted in considerable degradation of the environment [2]. Stone dust is primary aerosol and has a detrimental effect on people and the environment including flora and fauna. The dust changed the soil pH and productivity that results in the destruction of habitat and natural resources like valuable vegetations and wild lives, promotion of spreading of many diseases etc. [3, 4]. Effect of cement, petroleum coke dust, fly ash, coal dust, automobile exhaust and other airborne particulates on various morphological and physiological parameters in different plants are well-studied by many workers [5, 6, 7, 8, 9, 10, 11, 12]. Although it contains potentially harmful trace elements, but also contains mineral constituents which can act as a secondary source of fertilizers. Crusher dust, with its abundant availability and remarkable amelioration and nutritive properties, warrants an eco-friendly approach to is te utilization in the reclamation of problem soils. Application of crusher dust amended with soil for growing crops may be tried through the scientific research studies to explore its feasibility. Hence, the present study is undertaken to study the effect of crusher dust, crusher dust fertilizer, soil and their combination on the germination and biochemical behavior of *Oryza sativa* and *Zea mays*.

II. Materials And Methods

Stone crusher dust is collected from Tapanga Industrial Estate, Khurdha, Odisha, India. The crusher dust samples are ground to below 1mm size with the help of a balling mill. The grinded stone crusher dust sample has been used for weathering of minerals present in the process of carbonation [13]. In the natural weathering process, alkaline earth metals (Ca, Mg, Fe) combine with CO_2 to form stable carbonates in atmospheric condition which is an exothermic reaction process occurs in nature. But the present work focused on weathering of crusher dust by addition of low grade sulphate bearing material in the presence of chemical activators [14]. The resultant sulfatised mixture of crusher dust is disposed outside for atmospheric exposure for one month with the addition of water frequently for weathering. After one month there is a change in the colour of the sulfatised mixture has also been observed. The pH of the mixture also changed from 9.8-11.0 to 7.2 to 8.0. This sulfatised weathered crusher dust is used as mineral fertilizer (crusher dust fertilizer, CDF) for plant growth. The experiment is conducted at the experimental site of CSIR-Institute of Minerals and Materials

Laboratory, Bhubaneswar, Odisha, India. Various physical, chemical parameters and concentration of heavy metal of the soil, CD, and CDF samples are analysis. Texture analysis is carried according to the standard protocol of APHA [15]. pH and electrical conductivity (EC) is determined using a portable pH meter (Hanna instrument model 209) in a 1:5 soil–water suspension. Organic carbon (OC) content is determined by rapid dichromate oxidation technique; CEC by 1(N) ammonium acetate extraction method [16, 17]. Heavy metals viz., Pb, Cd, Fe, Ni and Cr are analyzed using Atomic Absorption Spectrophotometer (AA-6300 SHIMADZU) after digestion with the mixture of concentrated HNO_3, H_2SO_4 and H_2O_2 (2:6:6) for 30 minutes. All the reagents and reference standards are of analytical grade from Merks (Darmstandt, Germany). Suprapure sulphuric and nitric acids (Merks, Darmstandt, Germany) are used for sample digestion and preparation of standards. Mineralogy study of the CD, CDF are carried out using X-ray Diffraction and Thermo Gravimetric Analysis study. The physical properties of soil, raw crusher dust and crusher dust fertilizer are given in the Table-1. The heavy metal concentration is carried out as per the standard protocol and found to be under permissible limit.

III. Results And Discussions

The general properties of soil, crusher dust and crusher dust fertilizer samples presented in Table -1 shows that CD has a pH of about 6.9 and EC is 2281µS/cm which might be due the presence of high concentration of oxides of Ca and Mg [18]. CDF has a pH of 7.2 which slightly alkaline in nature which might be due to the sulfatization process. EC of the samples ranges between 218 to 258 µS/cm. Electrical conductivity values decreased with increasing pH values. Organic carbon is very low as compared to soil. From the physical appearance of crusher dust fertilizer it is noticed that the structural transformation by weathering breaks the material into smaller pieces which causes erosion**.** This is very slow process in atmospheric condition. So after 30days of atmospheric exposure characterization of the both the samples (CD &CDF) have been carried out. Mineralogy is the important way to understand the coalescent status of elements. [19]. X-ray power diffraction analysis of both CD and CDF has been carried out and presented in Fig.-1. CDF consists of mostly amorphous glossy phases of SiO_2 and alumino-silicate in the poorly crystalline mullet form. X-ray power diffraction analysis (Fig.- 1) has confirmed the presence of alpha quartz and mullet. Fe is reported mostly in the form of Magnetite having d (A) =2.5. It is observed partially molten and coating the surface of the aluminosilicate cenospheres as evident from scanning electron- micrography revealing spherical shape particles with hardly any crystalline structure of phase separation. However, the SiO_2 rich phase is crystalline having tetrahedron structure. But the amorphous nature of spherical particles commonly leads to disordered crystal structure. Many cations and anions are held in spaces of alumino-silicate network [20]. It is found that the crusher dust contains quartz, plagioclase and sanidine mineral phases, but in case of crusher dust fertilizer there are formation of some new mineral phases resembling to muscovite, and orthoclays along with quartz, plagioclase and sanidine which may be formed by weathering process. Weathering of crusher dust by chemical activation convert primary minerals to secondary minerals (clays and carbonates) which will release plant nutrient elements in soluble forms.

Chemical activation of crusher dust through mineral carbonation reaction is a complex reactive process. During the chemical activation process the moisture content of the mixture varies from 15-20%. To observe the formation of hydrated minerals both the samples have been characterized by TGA given in Fig- 2 a &b. From the TGA study of crusher dust (Fig- 2 a &b) it is found that and an endothermic peak has been found at 600-700^{O}C temperature which shows very less quantity of mass loss. The TGA study of crusher dust fertilizer shows two endothermic peaks; one at 200-300^{0}C and another at 600-800^{0}C temperature. The endothermic peak at 200-300^{0}C and 600-700^{0}C may be due to dehydration of hydrated minerals and decarbonation of carbonated minerals respectively. Temperatures are only indicative because they depend on the extension of the precedent peak and on the matter quantity and also on the carbonate stability and progress of the carbonation process [21]. During the experimental process the reaction initiates by thorough mixing and atmospheric exposure in presence of water. It is a strongly exothermic reaction process and may occurs due to gradual physicochemical weathering of silicates minerals present in crusher dust [22, 23, 24].

In this experimental study both CD and CDF are used as mineral fertilizer (crusher dust fertilizer, CDF) for plant growth. The experiments are conducted at the experimental site of CSIR-Institute of Minerals and Materials Laboratory, Bhubaneswar, Odisha, India. Seeds of Oryza *sativa* L. and *Zea mays* L. are procured from Orissa seeds cooperation Ltd. and germinated during 2014 and 2015 to determine the effect of the crusher dust and crusher dust fertilizer(mineral fertilizer). During this work red lateritic soil is used as the major substrate. The soil samples are collected from agricultural field up to a depth of 20 cm. The soil is steam sterilized keeping in gunny bags in the autoclave at 20 lb pressure for 20 minutes. This autoclaved dry soil with different weight proportion of raw crusher dust and crusher dust fertilizer is used as substrate for plant growth. The mix design is presented in Table -2. Graded seeds are treated with 0.1% mercuric chloride for 5 minutes, followed by 70% alcohol for 1 minute. The sterilized seeds are thoroughly is hed with distilled water. The seeds are soaked for 48 hours before sowing. The pots are kept on the glasshouse bench at 25-27^{0}C. The seeds are sowed into 15 cm diameter pots and are arranged in randomized block design on greenhouse benches to observe the rate of germination. Germination is a prime plant-growth process; the effect of different ratio of crusher dust and crusher dust fertilizer blended with soil on germination of rice and maize is presented in Fig.- 3. Germination of rice occurs after 3 days of sowing in all the treatment and but in case maize germination starts after 5 days, it might be due hard seed coat. Enhanced seed germination of both the plants is observed in CDF substrate (T7) as compared to other treatments. But the rate of germination is high in rice as compared to maize. After a different interval of time, plants are analyzed for various growth and biochemical parameters such as, length of shoot and root; fresh weight and dry weight; photosynthetic pigments. Data is analyzed statistically for significance.

Random samples of the plants are taken from each replicate pot after 15 and 30 days after sowing (DAS) for the analysis of growth parameters and photosynthetic pigments. 5 plants are collected randomly from each set of study, i.e. uprooted carefully with their roots intact. The root and shoot portions are separated and is hed with de-ionized water. Samples are now made moisture free and weight quickly to obtain fresh weight (FW) in grams. After this the plant parts (roots and shoots) are kept in an oven running at 80^{o}C for 24 hours and the dry weights are recorded in grams. Chlorophyll-a, chlorophyll-b, Total chlorophyll, pheophytin and carotenoid content are calculated on (mg/g) of fresh weight tissue basis [25]. Lengths of root and shoot are separately measured. The roots and shoots of plants are separated and oven dried at 80 ^{0}C till constant weight obtained. Fully expanded fresh leaves of plants are sampled randomly from each replicate plot for various biochemical analyses. Pigment contents are extracted from the leaf disc with 80% acetone and quantified according to the methods given by Chance and Maehly, Duxbury and Yentsch [26, 27]. Foliar protein content is analyzed according to the method of Lowry *et al.* using bovine serum albumin as standard [28]. Data are subjected to an analysis of variance, using SPSS 13.0 software and the difference between means are compared by Duncan multiple range test at 5% level of probability.

The trend of growth of plant with respect to shoot length and of maize and rice has been presented in Fig -3 and 4 respectively. In the present study, no visible injury symptoms are observed in any of the treatments during the growth and development. Soil blended with 20 % crusher dust fertilizer shows significant positive effect as compared to other treatments. The retarded plant growth in other treatments may be coupled with undesirable chemical properties of the CD and CDF including low N and P contents. The seedling growth of both the plants is higher as compared to other treatments as shown in Figure 3 & 4. The maximum shoot and root lengths are found to be 8.00 and 7.90 cm, respectively after one month in case of maize in the treatment, T7 which contains 20 % CDF. But in case of rice the elongation of root is maximum at T7 and found to be 14.0cm. The presence of photosynthetic pigments such asChlorophyll-a, chlorophyll-b, Total chlorophyll, pheophytin and carotenoid content are calculated and presented in Fig. -6. The chlorophyll content of leaf of both the seedlings is measured at fifteen day intervals. Observations suggest a marked increase in chlorophyll a, chlorophyll b and total protein content with increase in time and treatment containing CDF (20%): soil (80%). In T7, the impact on chlorophyll synthesis is maximum as compared to other treatments because macronutrients present in the CDF is act as structural and catalytic components of proteins, enzymes and as cofactors for normal development of chlorophyll biosynthesis.

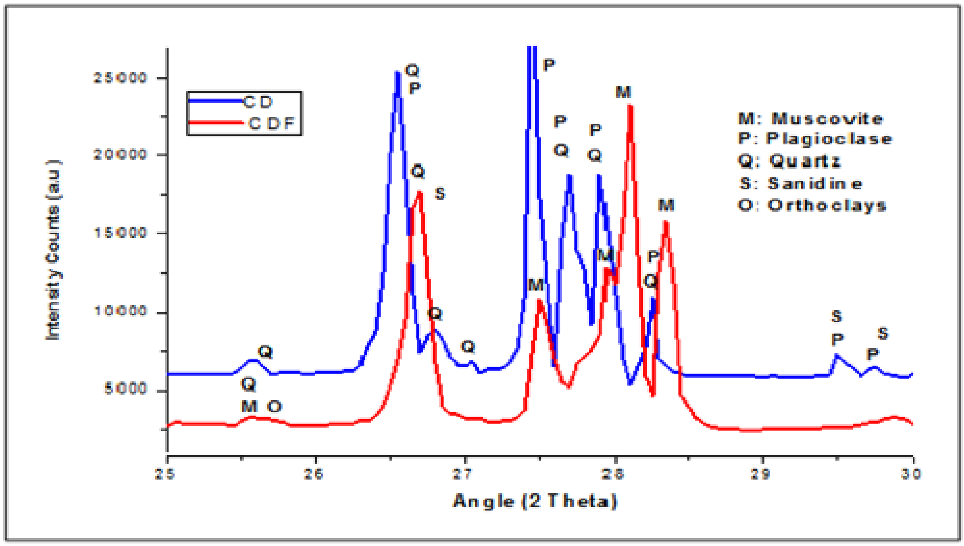

Figure 1: XRD pattern of crusher dust and crusher dust fertilizer

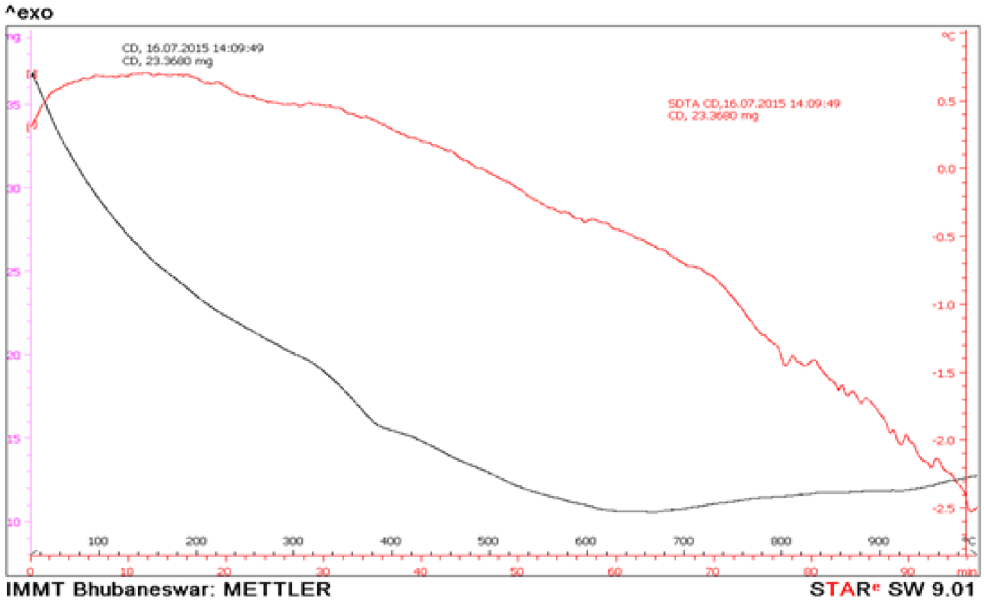

Figure 2(a): Thermo gravimetric analysis of crusher dust

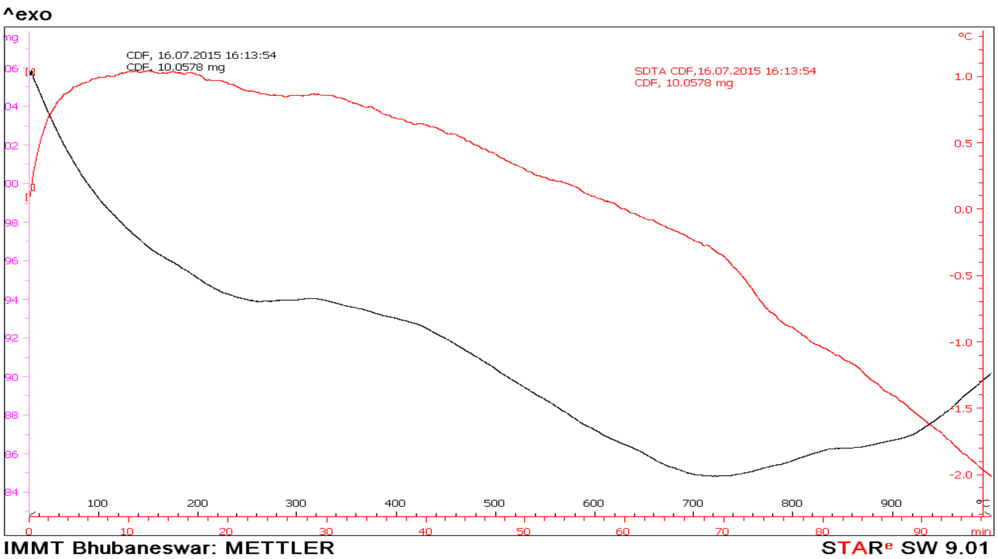

Figure 2 (b): Thermo gravimetric analysis of crusher dust fertilizer

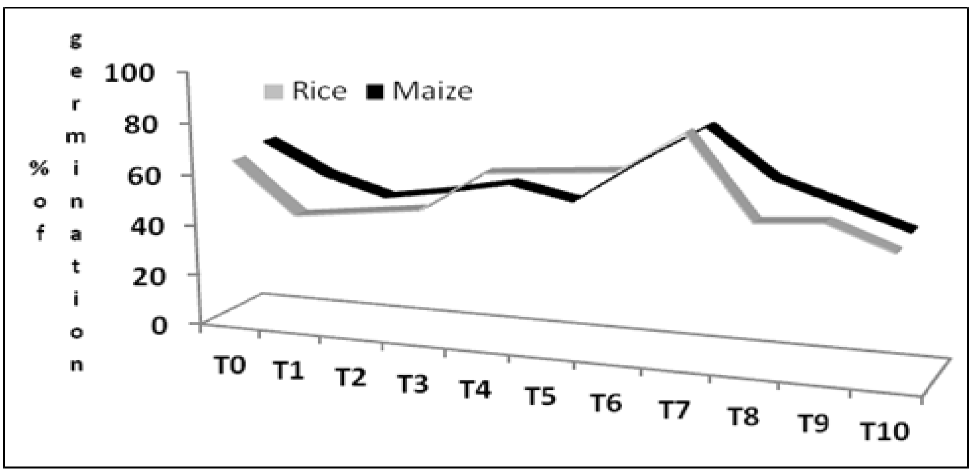

Figure 3: Rate of germination in rice and maize

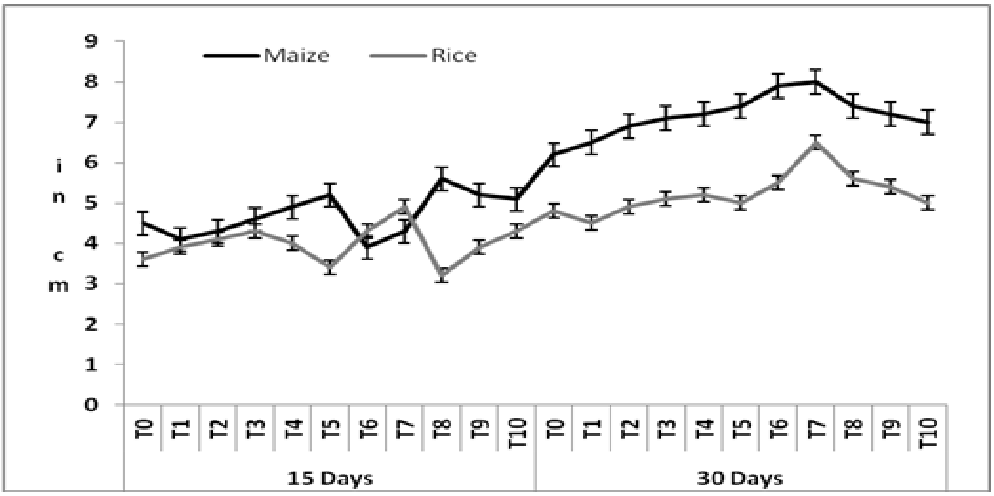

Figure 4: Effect of different treatments on shoot length of maize and rice

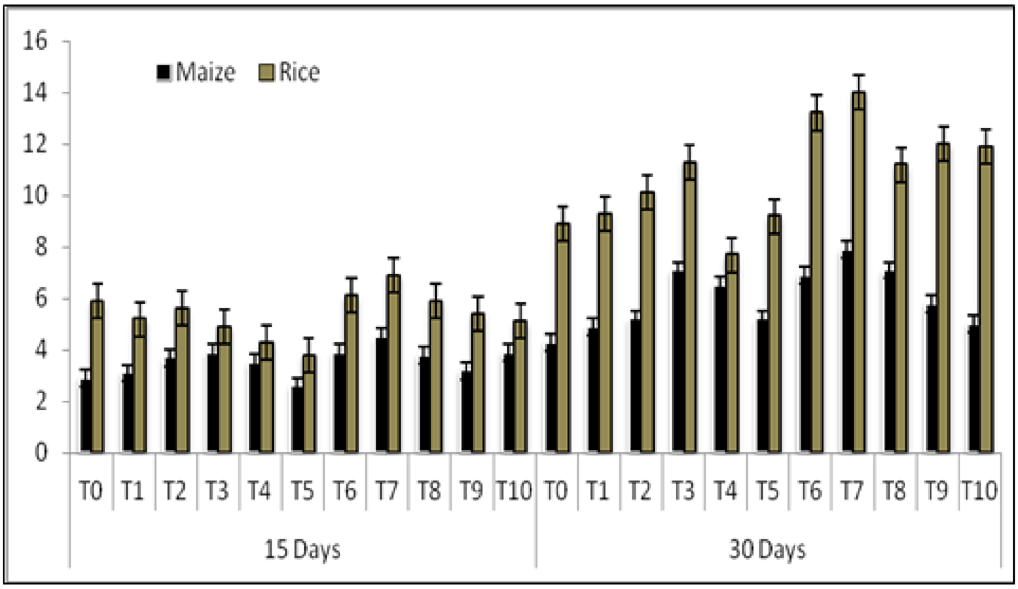

Figure 5: Effect of different treatments on root length of maize and rice

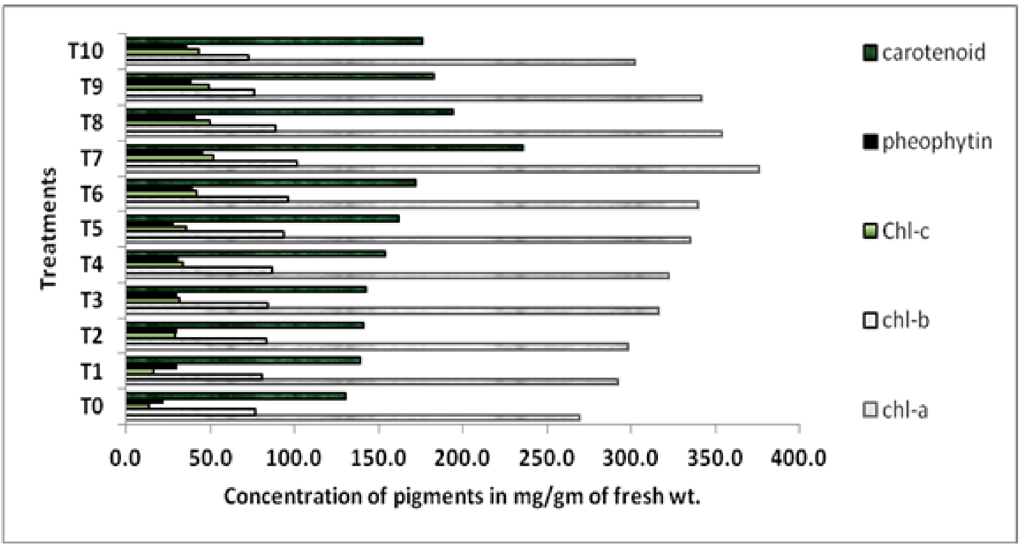

Figure 6: Concentration of photosynthetic pigments under different treatments in rice

Table 1: physical properties of soil, raw crusher dust and crusher dust fertilizer

Sample	pH	EC (μS/cm)	Organic Carbon (%)	Texture			Na	K	Ca	Mg	CEC
				Sand	Silt	Clay	Concentration (mg/kg)				
Soil	6.2	258	4.1	37.31	53.74	8.94	4.04	4.41	1.75	1.25	11.45
Crusher dust	6.9	228	1.2	22.34	76.94	0.02	4.43	2.05	0.75	0	7.23
Crusher dust fertiliser	7.2	218	2.6	27.05	71.35	1.59	8.08	1.97	1.5	4.16	15.71

Table 2: Mix design of substrate

Sample ID	Soil (Wt %)	Crusher dust (Wt %)	Sample ID	Soil (Wt %)	Crusher dust (Wt %)
0	100 (Control)	--	T6	90	10
T1	90	10	T7	80	20
T2	80	20	T8	70	30
T3	70	30	T9	60	40
T4	60	40	T10	50	50
T5	50	50			

IV. Conclusion

The present investigation affirms that crusher dust can be weathered through mineral carbonation in presence of suitable chemical activators. By weathering reaction the structural transformation of minerals occur which liberate the nutrients present in the crusher dust and plants absorb the essential constituents. Crusher dust fertilizer or mineral fertilizer can be used for growth of agricultural crops and hence can sort out the problem of is te disposal and in turn giving us benefit. The study reflects that it acts as an excellent soil modifier, conditioner and a source of essential nutrients for appreciably improving the texture and fertility with significant increase in crop yield over the control at a particular concentration only and is supportive to plant growth. This study show that the available ingredients in crusher dust fertilizer where useful for certain levels for utilization of a particular plant species. Thus utilization of crusher dust in agriculture may provide a feasible alternative for its safe disposal without serious deleterious effects and may save the cost of fertilizers and elevates the economy of farmers if used in proper ratio by blending. Hence, there is an opportunity with crusher dust to be used as an eco-friendly and non-conventional fertilizer at particular concentration.

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