EVALUATION OF IRON SLIME AS SOIL AMENDMENT FOR RAISING CABBAGE

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ABSTRACT

Iron ore slime is the waste product of iron and steel industries which has the particle size of below 150mm and is being discarded as waste during the mining and processing stages of iron ore. An experiment was conducted under green house condition to evaluate iron slime as an amendment for growing cabbage during 2012-2013. Low grade iron ore slimes were collected from Tata Steel, Jamshedpur and used as soil amendment in different ratio. Six treatments were replicated four times and all necessary observations were taken. Destructive sampling was followed. Soil and plant samples were tested for both macro and micronutrients. Results revealed that mixing of soil with iron slime in different proportions might be useful in augmenting soil nutrient status as well as improvement of organic carbon content in the amended soil. Amongst the primary nutrients, higher concentration of P was observed in both soil and plant. The total micronutrients content especially Fe, Mn, Cu and Zn were found to be of higher order in cabbage grown in sole iron slime and iron slime treated soil. The total Fe content in cabbage was found directly proportional to the amount of added iron slime. From this investigation, it is clear that iron slime can be utilized for agricultural purpose for raising cabbage but at adequate proportion of iron slime and soil.

Key words: *Iron slime, soil amendment, macro and micronutrients, cabbage, etc.*

Introduction

Iron ore slime is the waste product of iron and steel industries which have the particle size of below 150μm and is being discarded as waste during the mining and processing stages of iron ore and it will be stored at the tailing dam. It is estimated that 15% - 20% of tailing will be generated during the processing of iron ore. The major compositions of iron ore slime are hematite, quartz, alumina, mica and kaolin. The iron ore slime is discarded as was due to its particle size and chemical composition which are not suitable to feed the blast furnace. For the production of one ton of steel, about 200 to 400 kg of by-products is liberated during processing of iron ore mines. Globally, about 400 million tons of these by- products are generated annually. India alone produces about 14 million tons of by-products of which 15-20% is iron slime (www.worldsteel.com). Tata steel is producing iron concentrates from its caption mine at Noamundi and Joda. In the process of producing iron ore concentrates the plants at mine site also produces iron ore slime as wastes. These wastes mainly contain iron oxides and hydroxides (55-57%), alumina (4-6%) and silica (2-3%).

The relevant physical, chemical and physico-chemical properties of the said iron slime are pH 7.2, moisture holding capacity 33.40%, particle density 2.78 g/cc, bulk density 1.45 g/cc, electrical conductivity 0.164 dSm-1, Cation exchange capacity1.86 cmol (P+) kg-1, Organic carbon 0.08%, Total Nitrogen 0.027%, exchangeable NH4 167.93 mg kg-1, soluble nitrate 32.00 mg kg-1, available K2O 60 kg ha-1 and available P 28.40 mg kg-1. Based on the test report, it appears that the iron slime may act as one of the agricultural inputs in soil health and nutrients as well.

In the present study, the utilization of iron ore fines and slimes has been dealt with. Various proportions of iron slime is amended to soil and its changes on chemical, physical and physico-chemical properties of soil and its effect on crop growth have been studied. Experimental findings based on green house experiment with cabbage are discussed in detail. The main objective of the study is to evaluate iron slime as an amendment for growing cabbage under green house condition.

Materials and Methods

Soil was collected from the BCKV main campus and low grade iron ore slime collected from TATA Steel Limited, Jamshedpur. They were used to investigate whether iron slime can be used as an amendment. Before use, the potting materials were air dried and passed through 5 mm sieve. Green house experiment was conducted with 5 kg air dried soil in earthern pot. Cabbage seedlings (Var. NS- 183) were planted in each pot. Recommended dose of nitrogen, phosphorus and potassium [120:80:80 (N: P2O5: K2O) per hectare] were applied in the form of urea, single super phosphate and murate of potash respectively to each pot as basal application along with FYM 10 tons per hectare. Destructive sampling procedure was followed for collection of plant sample on the 60th, 75th and 90th days after planting and the plant samples were analyzed for total N, P, K, Zn, Cu, Fe and Mn. All the treatments were replicated three times. Irrigation was done to each pot as required. The crop was raised with best possible management practices. The treatments adopted for the experiment is given in detail as follows:

Treatments	Details
T1	Soil
T2	Soil + Iron slime (1:1)
T3	Soil + Iron slime (2:1)
T4	Soil + Iron slime (3:1)
T5	Soil + Iron slime (4:1)
T6	Iron Slime

Soil samples were collected from each pot on the 0th, 30th, 45th, 60th and 90th day of the experiment and analysed immediately for exchangeable ammonium, soluble nitrate, available N, organic carbon, available phosphorus, available potassium, DTPA extractable Zn, Cu, Fe and Mn following standard procedure. Data were analyzed statistically for analysis of variance and critical difference was calculated at 5% level of probability to test the significance of means for the treatment difference following standardized package of Genstat Discovery Edition 4.

Results and Discussion

Irrespective of treatments and stages of sampling, the amount of oxidisable organic carbon differed significantly with treatments and stages of crop growth (Table 1). In general, the amount of organic carbon was found to be of higher order in only soil and the least amount was recorded in only iron slime system. Again, in general, higher amount of soil organic carbon was recorded on 60th day of planting. The results further showed that the amount of organic carbon in sole iron slime treatment increased with time and the highest amount (1.56 percent) was observed on 60th day of crop growth. The increase in the amount of organic carbon on 60th day is due to secretion of higher amount of root exudates which are very much rich in carbohydrate and are proteinous materials (Arshad and Frankenberger, 1996). The results find support of earlier investigation carried out by Saha et al., 2002. The decrease in organic carbon after 60th day is due to its utilisation by growing cabbage crop.

Table 1. Changes in the amount of organic carbon (g 100g-1) in soil cropped with cabbage and amended with different proportions of iron slime

Treatments	Days after planting					
	0	30	45	60	90	Mean
Soil + NPK+FYM	0.47	1.17	0.89	2.34	2.09	1.39
Soil + Slime (1:1)+NPK+FYM	0.43	0.66	0.54	0.97	0.90	0.70
Soil + Slime (2:1)+NPK+FYM	0.52	0.92	0.78	1.70	1.70	1.12
Soil + Slime (3:1)+NPK+FYM	0.47	1.01	0.71	1.22	1.63	1.01
Soil + Slime (4:1)+NPK+FYM	0.54	1.01	1.01	1.36	1.27	1.04
Slime + NPK+FYM	0.07	0.41	0.43	1.56	0.67	0.63
Mean	0.42	0.86	0.73	1.52	1.38	

Statistical Analysis

Treatments		Stages of sampling		Treatments x Sampling stages	
SEm(±)	CD (p=0.05)	SEm(±)	CD (p=0.05)	SEm(±)	CD (p=0.05)
0.0011	0.0030	0.0010	0.0027	0.0024	0.0067

The results thus clearly pointed out that soil is the main source of organic carbon in iron slime added systems. Addition of FYM further increased organic carbon content in soil because of the presence of higher amount of organic carbon in organic matter. The incorporation of iron slime to soil along with organic matter also enhanced the biological activities in the system. The results thus revealed that mixing of soil with iron slime in different proportions might be useful in augmenting soil nutrient status as well as improvement of organic carbon content in the amended soil.

Results of changes in the amount of exchangeable NH4+in soil cropped with cabbage and amended with different proportions of iron slime (Table 2) reveal that the amount of exchangeable ammonium in soil increased initially but thereafter, in general, the amount decreased with the period of investigation. Recorded higher amount of exchangeable NH4+ on 45th day after planting is due to the application of N in split dose on 35th day of planting. The decrease in the amount of exchangeable NH4+with time is due to its loss through volatilization and/or denitrification (Freny and Black, 1987; Groffman et al., 1987) and utilisation by the growing cabbage crop. The amount of exchangeable ammonium in sole iron slime treated pots was found to be surprisingly in higher order. This shows that the iron slime has the property to retain nutrients in available forms. Therefore, amending the soil with iron slime may have higher availability of the supplied nutrients particularly nitrogen.

Table 2. Changes in the amount of exchangeable NH4+ (mg kg-1) in soil cropped with cabbage and amended with different proportions of iron slime

Treatments	Days after planting					
	0	30	45	60	90	Mean
Soil + NPK+FYM	62.38	70.51	78.64	49.22	45.57	61.26
Soil + Slime (1:1)+NPK+FYM	88.24	82.84	83.82	48.10	46.12	69.82
Soil + Slime (2:1)+NPK+FYM	79.42	78.64	79.42	49.22	45.42	66.42
Soil + Slime (3:1)+NPK+FYM	83.82	77.20	82.84	44.31	48.10	67.25
Soil + Slime (4:1)+NPK+FYM	83.82	76.70	77.20	45.42	46.12	65.85
Slime + NPK+FYM	84.96	69.72	78.64	43.98	49.22	65.30
Mean	80.44	75.94	80.09	46.71	46.76	

Statistical Analysis					
Treatments		Stages of sampling		Treatments x Sampling stages	
SEm(±)	CD (p=0.05)	SEm(±)	CD (p=0.05)	SEm(±)	CD (p=0.05)
0.980	2.877	0.787	1.991	1.721	4.943

Results of the changes in the amount of soluble NO-3 and available N in soil amended with and without iron slime are presented in Table 3 and 4 respectively. More or less similar trend of results of soluble nitrate was observed as was found for exchangeable NH4+. The amount of soluble nitrate N was found to decrease with the period of crop growth and comparatively higher amount of soluble nitrate was observed in only soil treatment. The recorded higher amount of soluble nitrate on 45th day after planting was due to topdressing of N fertilizer on 35th day. The explanation furnished earlier for exchangeable NH4+is equally applicable for soluble nitrate as well. However, considerable amount of soluble nitrate is accumulated in soil treated with only iron slime system. Therefore, it could be concluded that the iron slime has excellent capacity to supply plant nutrients.

Table 3. Changes in the amount of soluble NO-3-N (mg kg-1) in soil cropped with cabbage and amended with different proportions of iron slime

Treatments	Days after Planting					
	0	30	45	60	90	Mean
Soil + NPK+FYM	92.23	68.98	70.11	48.54	43.98	64.77
Soil + Slime (1:1)+NPK+FYM	83.51	71.23	71.23	44.17	42.78	62.58
Soil + Slime (2:1)+NPK+FYM	66.84	69.04	70.11	46.78	43.98	59.35
Soil + Slime (3:1)+NPK+FYM	70.11	70.11	86.17	45.58	41.09	62.61
Soil + Slime (4:1)+NPK+FYM	84.64	68.98	69.04	46.41	43.10	62.43
Slime +NPK+FYM	75.31	70.11	69.04	43.10	41.09	59.73
Mean	70.11	70.11	86.17	45.58	41.09	

Statistical Analysis					
Treatments		Stages of sampling		Treatments x Sampling stages	
SEm(±)	CD (p=0.05)	SEm(±)	CD (p=0.05)	SEm(±)	CD (p=0.05)
1.091	2.310	0.954	1.823	2.013	4.312

The amount of available N (Table 4) in soil has been found to decrease with the period of investigation. Higher amount of available N was recorded at initial stage there after showed a gradual decrease with growing period of the crop. The recorded higher amount of available N on 45th day of planting is due to the external supplement of N fertilizer as topdressing on 35th day. The progressive decrease in the amount of available N is due to the utilisation of available N by cabbage as well as loss through leaching and denitrification. Data of available N follow similar trend of results as that of exchangeable NH4+and soluble NO-3-N. Higher order of available N was recorded in the treatment where soil: slime was mixed in the ratio of 3:1 along with NPK and FYM. The overall results suggest that the management of iron slime through mixing with soil in the ratio of either 3:1 or 1:1 or 4:1 along with NPK and FYM might be useful in improving soil health vis-à-vis growing crops.

Table 4. Changes in the amount of available N (mg kg-1) in soil cropped with cabbage and amended with different proportions of iron slime

Treatments	Days after Planting					
	0	30	45	60	90	Mean
Soil + NPK+FYM	154.61	139.49	148.75	97.76	89.55	126.03
Soil + Slime (1:1)+NPK+FYM	171.75	154.07	155.05	92.27	88.90	132.41
Soil + Slime (2:1)+NPK+FYM	146.26	147.68	149.53	96.00	89.40	125.77
Soil + Slime (3:1)+NPK+FYM	153.93	147.31	169.01	89.89	89.19	129.87
Soil + Slime (4:1)+NPK+FYM	168.46	145.68	146.24	91.83	89.22	128.29
Slime + NPK+FYM	160.27	139.83	147.68	87.08	90.31	125.03
Mean	150.55	146.05	166.26	92.29	87.85	

Statistical Analysis					
Treatments		Stages of sampling		Treatments x Sampling stages	
SEm(±)	CD (p=0.05)	SEm(±)	CD (p=0.05)	SEm(±)	CD (p=0.05)
2.654	6.431	1.987	5.872	5.438	15.937

Changes in the amount of available P in soil amended with different proportions of iron slime and cropped with cabbage are presented in Figure 1. Perusal of results reveals that irrespective of stages of crop growth, higher amount of available phosphorus is recorded in iron slime treated with FYM along with NPK fertilizers. Thus it is clear from the results that iron slime contains enough amount of phosphorus in available forms. Closer examination of the data reveal that addition of recommended doses of N, P and K fertilizers increased available P content in soils. This trend of results is observed in both the untreated and iron slime added systems. Addition of N, P and K fertilizers increased the activities of phosphate solubilizing organisms in soil which in turn maintains more amount of P in available form. However, results of the available P with respect to treatments and stages of crop growth were found significant.

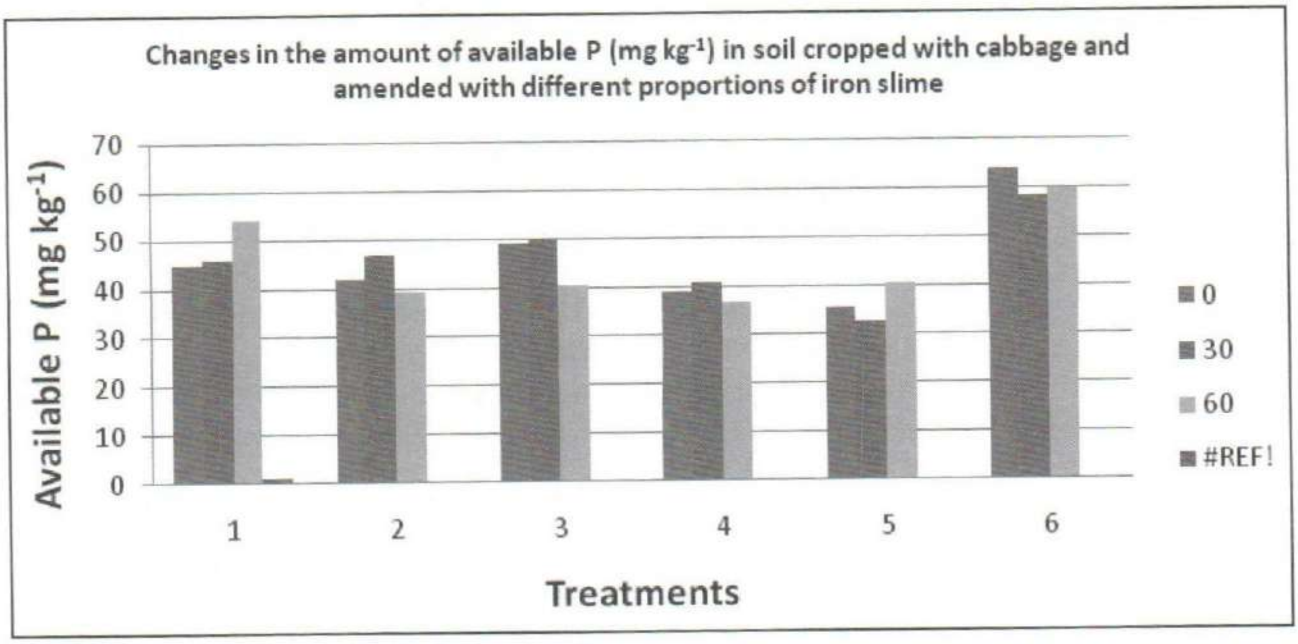

Figure 1. Changes in the amount of available P (mg kg^{-1}) in soil cropped with cabbage and amended with different proportions of iron slime

Irrespective of treatments and stages of sampling, the available potassium content of soil grown with cabbage also varies significantly with treatments and stages of sampling (fig. 2). In general, irrespective of treatments, available potassium of the soil decreased with the stages of sampling. Available K tended to decrease at the last stage of cabbage. Furthermore, lowest amount of available K was recorded at harvesting stage of the experiment. The decrease in the amount of available K with time is due to the continuous uptake of K by the growing cabbage. The decrease in available K at harvest is due to requirement of higher amount of nutrients for formation and development of cabbage head. The explanation furnished for the results of available N and P is equally applicable here as well.

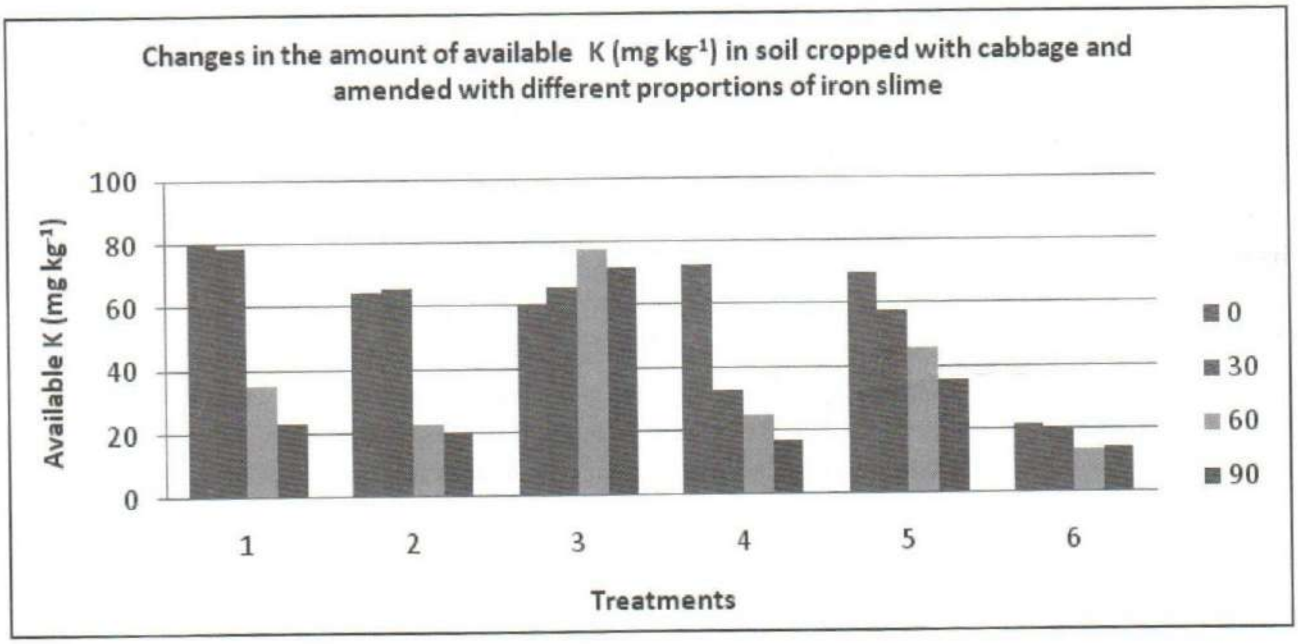

Figure 2. Changes in the amount of available K (mg kg^{-1}) in soil cropped with cabbage and amended with different proportions of iron slime

Soils of West Bengal showed micronutrient deficiencies particularly Zn and Cu. The amendment of iron slime to soil in different proportion influence the availability of Zn, Cu, Fe and Mn content in soils. To get a picture in this regard, DTPA extractable Zn, Cu, Fe and Mn content in soils amended with different proportions of iron slime are monitored, at different growth stages of cabbage and the results are discussed in detail. Results of available Zn showed that irrespective of treatments, the amount of available Zn tended to increase from 30thday to the final stage of the experiment except sole iron slime system. The increase in available Zn is very much prominent both in sole soil or sole iron slime systems. However, only soil treatment showed opposite trend of results as that of only iron slime system. The amount of Zn decreased with the period of experimentation.

Table 5. Changes in the amount of DTPA extractable Zn (mg kg-1) in soil cropped with cabbage and amended with different proportions of iron slime

Treatments	Days after Planting			
	30	60	90	Mean
Soil + NPK+FYM	2.04	3.10	6.47	3.87
Soil + Slime (1:1)+NPK+FYM	1.18	1.86	1.34	1.46
Soil + Slime (2:1)+NPK+FYM	0.95	2.13	3.31	2.13
Soil + Slime (3:1)+NPK+FYM	1.00	1.10	2.09	1.39
Soil + Slime (4:1)+NPK+FYM	1.36	2.26	3.42	2.35
Slime + NPK+FYM	6.45	5.98	5.72	6.05
Mean	2.16	2.74	3.72	

Statistical Analysis

Treatments		Stages of sampling		Treatments x Sampling stages	
SEm(±)	CD (p=0.05)	SEm(±)	CD (p=0.05)	SEm(±)	CD (p=0.05)
0.0527	0.511	0.0372	0.1068	0.0912	0.2616

Data further showed that irrespective of treatments and stages of growth of cabbage, results do not differ significantly. The concentration of available Zn in iron slimel was found to be of higher order under all the treatments and stages of crop growth.

Data of the amount of DTPA extractable Cu in soil grown with cabbage was found non-significant with treatments and stages of sampling (Table 6). In general, the amount of available Cu slightly decreased on 60thday after planting and then increased at the last stage of the experiment. Higher amount of available Cu was observed in iron slime throughout the period of experimentation.

In general, the available Fe content (fig. 3) in only soil as well in soil amended with iron slime is high Data further revealed that the average available iron content was found to be of higher order in iron slime added systems. Addition of iron slime had direct influence on the availability of Fe in soil. Sole iron slime showed highest amount of available Fe and proportionate increase in soil decreased the available Fe in the soil. The available iron in soil increased with the period of experiment and it was of higher order at the last stage of the experiment. The increase in iron content at the last sage of the experiment is due to release of Fe from fixed to available form with time.

Table 6. Changes in the amount of DTPA extractable Cu (mg kg-1) in soil cropped with cabbage and amended with different proportions of iron slime

Treatments	Days after Planting			
	30	60	90	Mean
Soil + NPK+FYM	20.75	13.35	12.35	15.48
Soil + Slime (1:1)+NPK+FYM	1.96	5.15	1.90	3.00
Soil + Slime (2:1)+NPK+FYM	9.75	3.15	17.55	10.15
Soil + Slime (3:1)+NPK+FYM	6.75	2.55	12.75	7.35
Soil + Slime (4:1)+NPK+FYM	5.55	2.75	20.95	9.75
Slime +NPK+FYM	1.57	15.75	50.35	22.56
Mean	7.72	7.12	19.31	

Statistical Analysis

Treatments		Stages of sampling		Treatments x Sampling stages	
SEm(±)	CD (p=0.05)	SEm(±)	CD (p=0.05)	SEm(±)	CD (p=0.05)
0.2227	0.6401	0.1575	0.4526	0.3858	1.1088

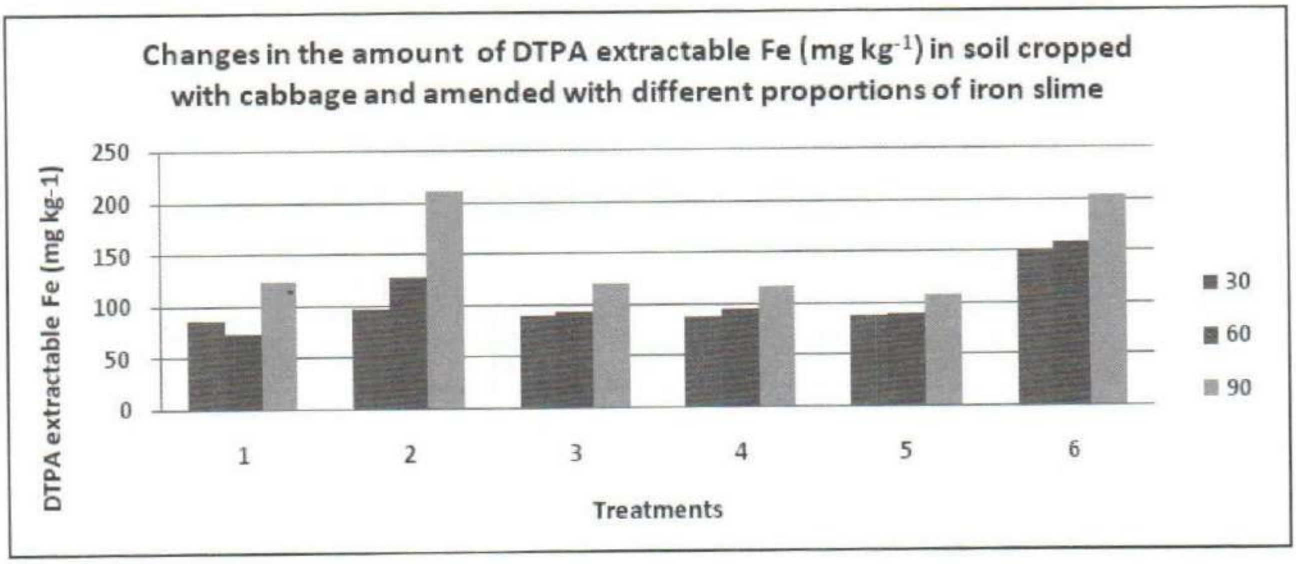

Figure 3. Changes in the amount of DTPA extractable Fe (mg kg-1) in soil cropped with cabbage and amended with different proportions of iron slime

Data of changes in available Mn content (Table-7) in soil amended with different proportion of iron slime and grown with cabbage showed that very appreciable amount of available Mn is present in soil. Results further revealed that higher amount of available Mn were recorded in only soil and sole iron slime system throughout the experimentation period. No definite trend of results was observed except in only iron slime treatment where the amount of available Mn tended to increase with the age of cabbage crop. However, in general, no sharp effect of iron slime was observed on the availability of Mn in soils. Available Mn content remains more or less same throughout growing period of cabbage. Data of the available Mn are found significant with respect to treatments and stages of crop growth.

Table 7. Changes in the amount of DTPA extractable Mn (mg kg-1) in soil cropped with cabbage and amended with different proportions of iron slime

Treatments	Days after Planting			
	30	60	90	Mean
Soil + NPK+FYM	19.10	17.90	23.50	20.17
Soil + Slime (1:1)+NPK+FYM	6.90	6.50	9.50	7.63
Soil + Slime (2:1)+NPK+FYM	14.30	9.90	17.50	13.90
Soil + Slime (3:1)+NPK+FYM	10.10	9.70	13.70	11.17
Soil + Slime (4:1)+NPK+FYM	11.50	11.70	24.30	15.83
Slime + NPK+FYM	8.10	11.30	37.30	18.90
Mean	11.67	11.17	20.97	

Statistical Analysis

Treatments		Stages of sampling		Treatments x Sampling stages	
SEm(±)	CD (p=0.05)	SEm(±)	CD (p=0.05)	SEm(±)	CD (p=0.05)
0.735	1.463	0.618	1.217	1.072	3.872

Irrespective of treatments and stages of sampling, total nitrogen content of cabbage varies significantly with treatments and stages of sampling. The average N content does not show drastic variation with the stages of crop growth and treatments. The N content of the cabbage plant was found to be of higher order at harvesting stage of the crop. In general, the total N content in the aboveground portion of the cabbage plant progressively increased with the stage of crop growth. The higher amount of total N at harvesting stage is due to higher uptake of nutrient by cabbage plants.

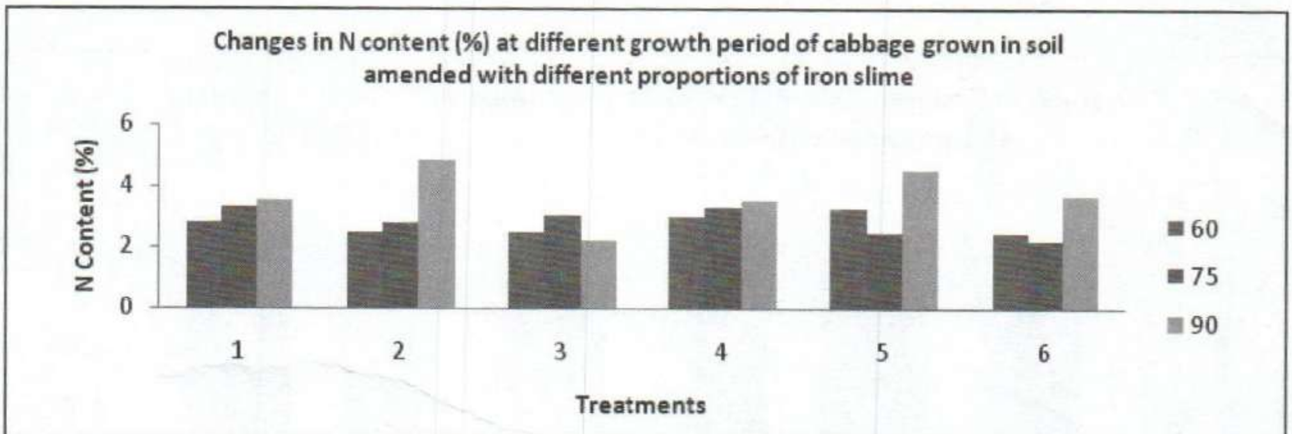

Figure 4. Changes in N content (%) at different growth period of cabbage grown in soil amended with different proportions of iron slime

In general, the total phosphorus content (table-8) of the cabbage plant was found to increase with the stages of sampling. This trend of result is due to higher order of uptake of P by cabbage for formation and development of head. Results further revealed that higher amount of total phosphorus was recorded in cabbage grown in soil amended with iron slime in a proportion of 1:1. The results thus showed that soil has higher capacity to supply P to the crop plants when amended with iron slime. However, the total phosphorus content in the aboveground portion of the cabbage did not vary significantly with the treatments and stages of sampling.

Table 8. Changes in P content (%) at different growth period of cabbage grown in soil amended with different proportions of iron slime

Treatments	Days after Planting			
	60	75	90	Mean
Soil + NPK+FYM	0.299	0.334	0.289	0.307
Soil + Slime (1:1)+NPK+FYM	0.325	0.360	0.392	0.359
Soil + Slime (2:1)+NPK+FYM	0.273	0.345	0.312	0.310
Soil + Slime (3:1)+NPK+FYM	0.341	0.322	0.376	0.346
Soil + Slime (4:1)+NPK+FYM	0.233	0.273	0.285	0.264
Slime + NPK+FYM	0.303	0.239	0.458	0.334
Mean	0.296	0.312	0.352	

Statistical Analysis

Treatments		Stages of sampling		Treatments x Sampling stages	
SEm(±)	CD (p=0.05)	SEm(±)	CD (p=0.05)	SEm(±)	CD (p=0.05)
0.0424	0.1218	0.030	0.0861	0.0734	0.2110

Irrespective of treatments and stages of crop growth, the amount of total potassium in the above ground portion of cabbage varies significantly with the treatments and stages of sampling. In general, the total potassium was found to be of higher order on 60th day and then decreased upto 75th day and again showed an increasing trend upto 90th day after planting. The increase in K content at later stage of growth of cabbage is due to higher uptake of K by the crop for formation and development of head.

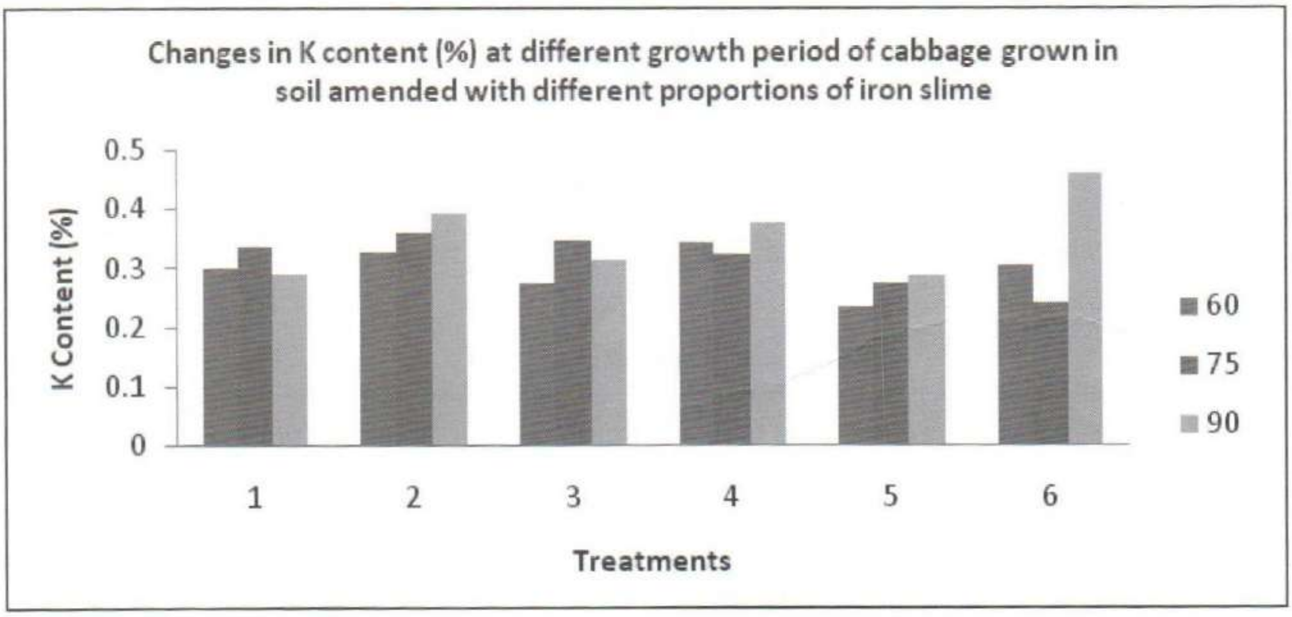

Figure 5. Changes in K content (%) at different growth period of cabbage grown in soil amended with different proportions of iron slime

Data on changes in total Fe content of cabbage at different growth period grown in soil amended with different proportions of iron slime revealed that the total Fe content on aboveground portion of cabbage is directly influenced by the amount of iron slime added to the soil. It was observed that higher the amount of iron slime added, higher is the total iron content in the plant samples. Irrespective of treatments and stages of sampling, the amount of total Fe recovered in the plant samples showed a direct relationship with the proportion of iron slime added to soil. The total iron content decreased at 60 days after transplanting in cabbage and then again increased at the last stage of crop growth. The amount of total Fe in cabbage differed significantly with both treatments and stages of sampling.

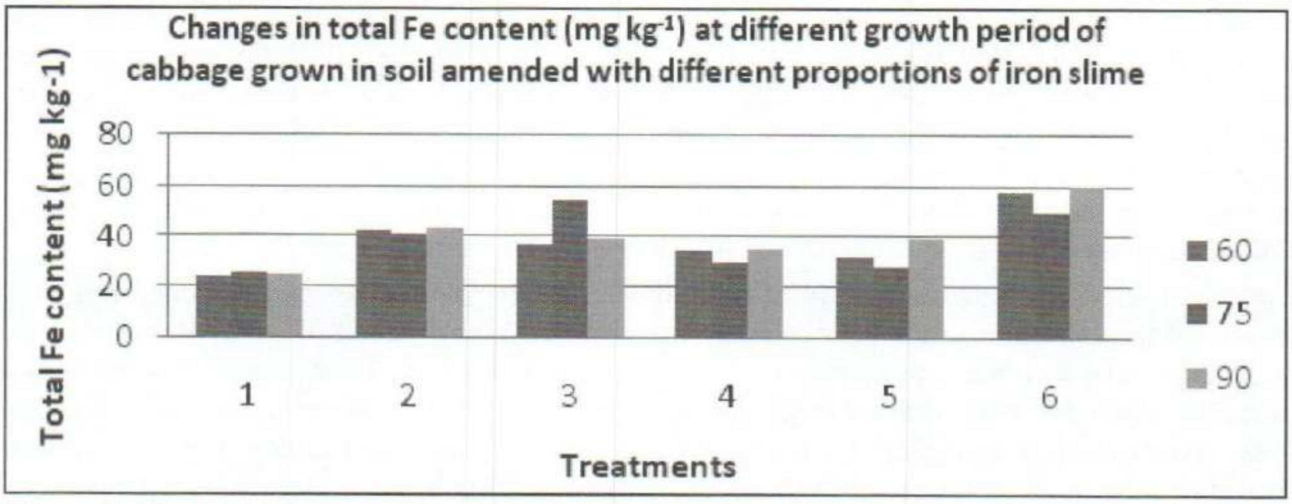

Figure 6. Changes in total Fe content (mg kg-1) at different growth period of cabbage grown in soil amended with different proportions of iron slime

Summary and Conclusion

A completely new venture on evaluation of iron slime as soil amendment for cabbage was taken up to explore its utility. Experiment was conducted to investigate the effect of iron slime on physical, chemical and physico-chemical properties of soil as well as uptake of both macro and micronutrients by cabbage under green house condition. Results obtained in the course of investigation pointed out that iron slime can be utilized for agricultural purpose for raising cabbage but at suitable proportion of iron slime and soil.

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