International Journal of Agriculture Sciences
ISSN: 0975-3710 & E-ISSN: 0975-9107, Volume 11, Issue 23, 2019, pp.-9270-9273.
Available online at https://www.bioinfopublication.org/jouarchive.php?opt=&jouid=BPJ0000217

Research Article

EFFECT OF ORGANIC AND INORGANIC FERTILIZER TREATMENTS ON MICRONUTRIENTS AND HEAVY METALS OF MINE AFFECTED AREA SOIL

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Received: December 01, 2019; Revised: December 12, 2019; Accepted: December 13, 2019; Published: December 15, 2019

Abstract: The resent study was carried out to evaluate the effect of different organic and inorganic fertilizer treatment combinations on amendment in mine area soil of Olidih watershed in Jharkhand state of India. Soil samples were collected from study area and analyzed for Available Micronutrients (Cu, Zn, Fe, Mn) and heavy metals (Ni, Cr, Pb). Initially, the soil in study area was found moderately acidic and deficient in organic carbon, macronutrients and micronutrients. Pot experiment was conducted to analyze the effect of different inorganic and organic fertilizer treatments on soil chemical properties in a Maize-cowpea-paddy cropping system. A randomized complete block design was employed with seven treatments and four replicates per treatment. Results of the experiment showed that organic and inorganic fertilizers are effective in restoring the productivity of degraded soils.

Keywords: *Organic and Inorganic Fertilizer, Micronutrient, Soil Science*

Citation: Shinde V.T., *et al*., (2019) Effect of Organic and Inorganic Fertilizer Treatments on Micronutrients and Heavy Metals of Mine Affected Area Soil. International Journal of Agriculture Sciences, ISSN: 0975-3710 & E-ISSN: 0975-9107, Volume 11, Issue 23, pp.- 9270-9273.

Academic Editor / Reviewer: Er Alok Gora, Girja Shanker Tewari, Dr Harpal V Solanki, El-sherbeny Ghada Abd Allah

Introduction

Industrialization plays crucial role in development of any region. Along with the development, it has negative impacts on definite natural resources such as air, water and soil. Coal mining not only visibly disrupts the aesthetic aspect landscapes but also disrupts soil components such as soil structure, soil microbial biomass and nutrient cycles which are crucial for a healthy ecosystem [1,2]. It has been reported that every million tonnes of coal extracted from surface mining methods damages surface area of about 4ha in India [3]. Mine sites contain materials of high Fe-oxyhydroxides, sulphates and potentially leachable contents of heavy metals (mainly Pb, Cu and Zn) due to extreme acidic conditions. Therefore, these soils have very low vegetation due to poor soil fertility. Removal of metals from the mining area is difficult, the transformation of metals into simpler forms or their removal in a suitable recycled mineral form such as carbonates using amendments is a possible solution for the remediation of a mining area [4]. Reclamation is the process which restores the ecological integrity of disturbed mine land areas. Organic amendments are environment friendly, cheap and easily available which can be applied to contaminated mine soils for natural establishment of vegetation. Though there is a general unanimity that effectiveness of soil remediation also depends on the presence and activity of microorganisms. However, the long-term ecological significances of inorganic and organic improvements for these features have received diminutive attention [5]. Sustainable development in agriculture and yield improvement of crops can be achieved by restoration and scientific management of land productivity. The objective of this work was the assessment of the effectiveness of the remediation of contaminated mine soils by means of different inorganic and organic amendments using soil properties as indicators.

Materials and methods

Study area

Jharia coalfield (JCF) is one of the most important coalfields in India, located in Dhanbad district of Jharkhand state, between Latitude 23° 39' to 23° 48' N and Longitude 86° 11' to 86° 27' E. It lies in the heart of Damodar valley along the north of Damodar river. The coal basin extends for about 38 km in an East-West direction and a maximum of 18 km in North-South direction, and covers an area of about 450 sq. km. This is the most exploited coalfields because of available metallurgical grade coal reserves. Olidih watershed of Jharia coalfield was choosen as study area to carry out this analysis. Joriya river flowing through this area, is severely affected by adjacent mining activities. Watershed covers an area of 5512 ha and has annual average rainfall of 1100mm. In this region paddy is the major grown crop followed by maize. Mostly mine affected land at upland is kept barren whereas crops are taken at lowland areas. Therefore, to for vegetation growth in mine affected areas, proper soil amendment measures are very important and essential. The location of study area is shown in [Fig-1]. About 20% area of Olidih watershed is affected by open cast mining.

Experimental details

20 soil samples were collected from different mine and unmine locations in study area. The basic physiochemical properties of the soil samples were determined and samples of mine and unmine area were compared to evaluate the effect of mine activities on soil properties. The results of initial soil analysis are presented in [Table-1]. Mine affected locations in study area were chosen to carry out further analysis. Surface soil (0-25 cm) was collected from the mine affected arable land of study area by following standard procedures. The soil was cleaned for foreign materials and then air dried. The collected soil is then analyzed for Available micronutrients (Cu, Zn, Fe, Mn) and heavy metals (Ni, Cr, Pb) in the soil chemical analysis laboratory.

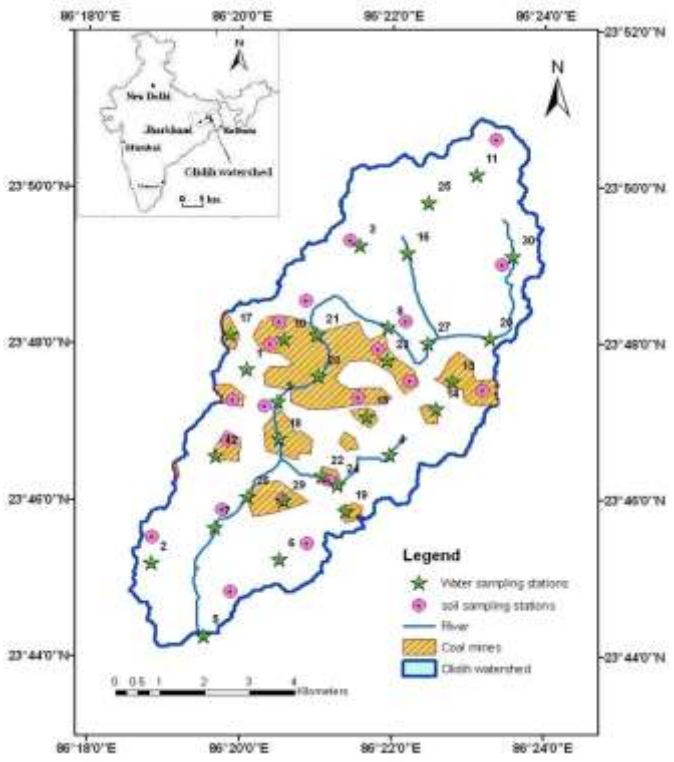

Fig-1 Location of Olidih Watershed

Table-1 *Statistics of physico-chemical parameters in soil samples*

SN	Parameter	Standard range	Unmine area soil			Mine area soil		
			Min	Max	Mean	Min	Max	Mean
1	pH	6.5-8.5	6.3	8.4	7.1	5.8	7.2	6.6
2	EC	-	0.134	0.53	0.39	0.153	0.61	0.407
3	N	125-250	85.2	356	194	33.5	291	85.7
4	P	4.5-11	2.6	24.6	9.4	0.5	7.19	3.4
5	K	50-125	12.5	142	38.4	24.5	303	80.3
6	OC	> 0.75	0.1	4.6	1.68	0.13	3.5	0.56
7	Fe	> 4.5	13.2	76.3	21.5	9.2	26.1	12
8	Mn	>2	4.7	56.6	17.2	5.5	16.1	9.6
9	Zn	> 1	0.6	4.96	1.83	0.31	3.02	1.48
10	Cu	>0.2	0.16	5.72	1.06	0.34	4.32	0.84
11	Ni	8.1*	0.56	2.13	1.12	0.73	1.82	1.04
12	Cr	8.0*	0.17	2.48	1.09	0.47	2.36	1.33
13	Pb	13.0*	1.35	5.31	1.57	0.42	6.84	2.07

*EC is in dS/m; OC is in %; N, P, K, Fe, Mn, Zn, Cu, Ni, Cr, Pb is in mg/kg; *permissible limits*

Pot experiment was conducted to analyze the effect of different treatments on soil available micronutrients (Cu, Zn, Fe, Mn) and heavy metals (Ni, Cr, Pb) in maize-cowpea-paddy cropping system. A randomized complete block design was employed with seven treatments with four replicates per treatment. Each experimental unit was a ten litres pot (10 L) filled with 10 Kg top soil. Maize and cowpea crops are moistened to the required soil moisture content (15-20% FC) determined gravimetrically and maintained at field capacity (15-20% moisture) by periodic addition of water as required. In case of paddy, soil was kept under saturated condition. The 3 crops selected for experiment are:

1) Maize (Sweet corn)- Duration: December 2011-April 2012.
2) Cowpea- Duration: May-June 2012 and
3) Paddy- Duration: July-October 2012.

The 7 treatments selected are given below.

T1: Control (Without fertilizer)
T2: Lime (0.5 T/ha)
T3: Chemical fertilizer (CF) at 100% recommended dose of N, P and K (CF_{100}) (Maize- 120:60:60 kg/ha and Paddy- 80:40:20 kg/ha)
T4: Organic matter (OM) at 100% recommended dose of N, P and K (OM_{100})
T5: Liming + CF_{100} (LCF_{100})
T6: Liming + OM_{100} (LOM_{100})
T7: Liming + CF_{50} + OM_{50} ($LCF_{50}OM_{50}$)

The recommended doses of CF N: P: K as 120:60:60, 25:75:60 and 80:40:20 kg ha^{-1} for maize, cowpea and paddy respectively were used. The nutrients N, P and K were supplied through urea, Single Super Phosphate (SSP) and Mutate of Potash (MOP) respectively. Soil organic matter is a key contributor to soil due to its capacity to affect plant growth indirectly and directly [6]. For OM_{100} treatment, the dose of organic manure 10 t ha^{-1} for maize, cowpea and paddy were used and the quantity of manure was calculated considering 1.5% N, 1.1% P and 0.8% K in the organic manure. In case of combined treatment LCF50OM50 half dose of chemical fertilizer and organic manure was applied. For lime treatment, the quantity of lime requirement was calculated using Shoemaker method [7]. For estimation of lime requirement three doses via, 0.5 t ha^{-1}, 1 t ha^{-1} and 1.5 t ha^{-1} of lime were tested against mine soil and 0.5 t ha^{-1} dose of lime was applied to soil during experiment. Various doses of lime, organic matter and fertilizers were mixed with the pot soils. The seeds of maize & cowpea were sown in pots manually and seedlings of paddy were transplanted in pots. The duration of maize, cowpea and paddy was 110, 60 and 120 days respectively. In the control pot fertilizer and chemicals were not added; however, the soil preparation was done in the same manner as those of other soil treatments. Weeding was done manually to keep the pot weed free. No plant protection measures were taken as there was no incidence of major pest and diseases.

Soil fertility and soil analysis

Nitrogen, phosphorous and potassium are the three major macronutrients which generally found deficient in mine soils [8,9]. Mine soil requires significant fertilizer applications for effective crop production. Organic carbon is positively correlated with available N & K and negatively correlated with Fe, Mn, Cu and Zn [10]. Some of the important micronutrients that are essential for plant growth are Fe, Mn, Cu and Zn. These micronutrients are more soluble in acidic solution, they dissolve and form toxic concentrations that may actually hinder plant growth [11-14]. Physico-chemical properties of soil samples from the pots were analyzed to estimate the effect of different fertilizer treatment combinations in amendment of soil in mine area. The standard procedure followed for estimation of various soil properties are given in the [Table-2]. The soils in pots were analyzed at regular interval i.e., 60 days after sowing of maize, 110 days (at harvesting of maize), after harvesting of cowpea (60 days after sowing), 60 days after transplanting of paady seedlings and at the harvesting time of paddy (120 days).

Table-2 *Methods for estimating chemical properties of Soil*

Chemical properties	Method
Available Fe, ppm	DTPA extraction (Lindsay and Norvell, 1978)
Available Mn, ppm	DTPA extraction (Lindsay and Norvell, 1978)
Available Zn, ppm	DTPA extraction (Lindsay and Norvell, 1978)
Available Cu, ppm	DTPA extraction (Lindsay and Norvell, 1978)
Ni, ppm	AB-DTPA extraction (Soltanpour and Schwab, 1977)
Cu, ppm	AB-DTPA extraction (Soltanpour and Schwab, 1977)
Pb, ppm	AB-DTPA extraction (Soltanpour and Schwab, 1977)

Statistical analysis

Analysis of variance (ANOVA) was performed using randomized completely block design (RCBD), with four replicates per treatment. The differences between means of the different treatments were compared by the Least Significant Difference (LSD) at 5 % level of significance.

Results and Discussion

Soil chemical properties / Micronutrients (Fe, Mn, Zn, Cu)

The results of soil analysis for iron (Fe) are shown in [Fig-2]. Iron is necessary for the synthesis of chlorophyll. Treatment LOM_{100} showed significantly superior amount of Fe than other treatments. In all the treatments, except Lime, the Fe content was highest at the harvest of the cowpea and lowest during paddy harvest. Variation of Manganese (Mn) for different treatments and for various crop growth periods is shown in [Fig-3]. For all the treatments Mn in soil showed similar trend and raise Mn value above the critical limit required for crop production. Contrary to Fe, Mn was found higher during the paddy crop period *i.e.*, after the harvest of cowea, this may be due to the fact that Mn functions with the enzyme systems which involves breakdown of carbohydrates and nitrogen metabolism.

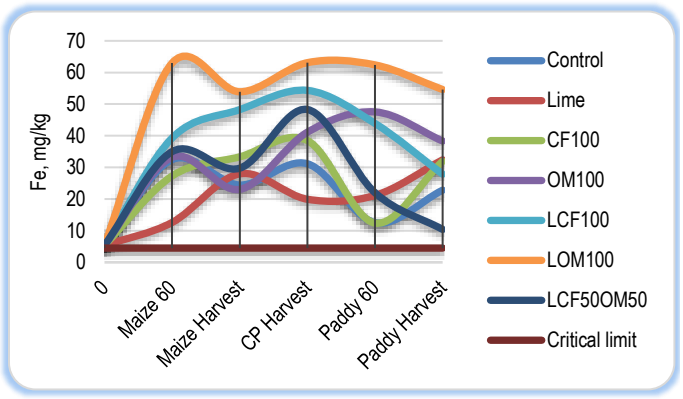

Fig-2 Effect of various treatments on the iron content of soil

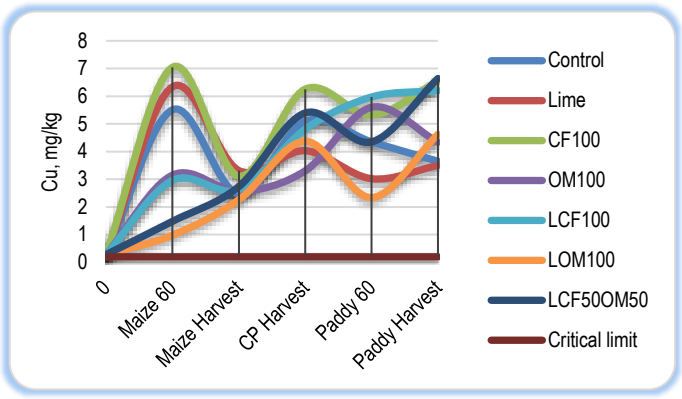

Fig-5 Effect of various treatments on the Cu content of soil

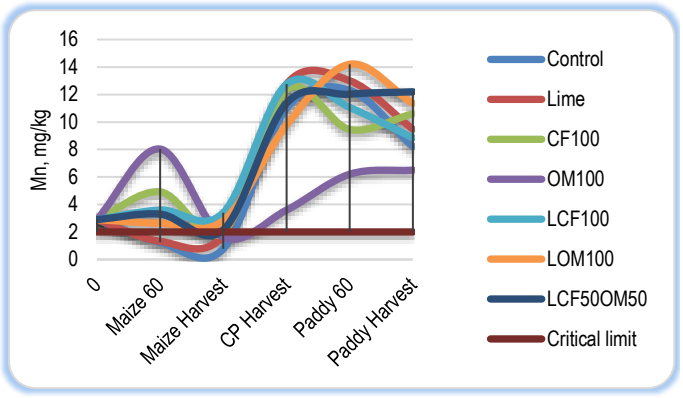

Fig-3 Effect of various treatments on the Mn content of soil

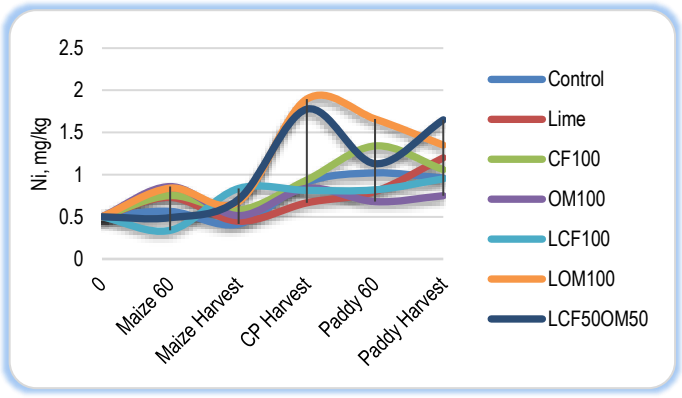

Fig-6 Effect of various treatments on the Ni content of soil

Thus, it is important micronutrient for crop production. There was no significant difference between various treatments for Mn in soil except OM_{100}.

Results of soil analysis for zinc (Zn) are shown in the [Fig-4]. Zn is essential for the transformation of carbohydrates during crop growth. For all treatment it was found that the Zn content in the soil was always higher than the critical limit required for crop production. In most of the treatments, the Zn content gets reduced during the harvest of the maize and increased after the cowpea harvest. The increase in amount of Zn could be beneficial for the crops. It is essential for transformation of carbohydrates in crops and also an important part of enzyme system which regulates the growth. Zn content in soil is found higher with treatment CF_{100}.

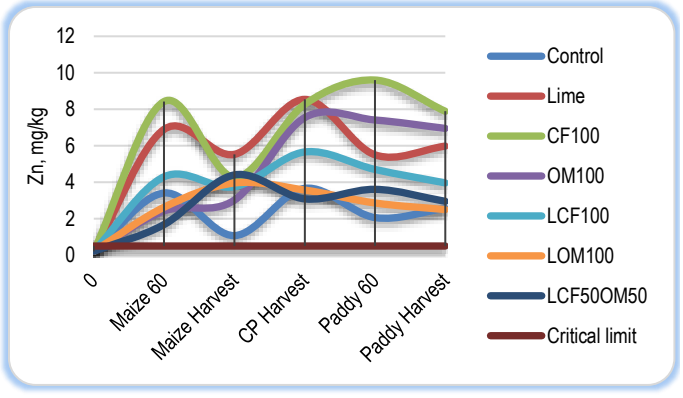

Fig-4 Effect of various treatments on the Zn content of soil

Variation of Copper (Cu) for different treatments and for various crop growth period is shown in [Fig-5]. It is an important constituent of plastocyanin (copper containing protein) and important for panicle development of paddy crop. The trend of Cu for all treatment showed the similar trend by and large. The amount of Cu in the soil for various treatments was found always greater than critical limit during experiment period. For the treatment CF_{100} the amount of Cu was found highest during growth stages of all crops. Cu is very important micronutrient for reproductive growth and also aids in root metabolism.

Heavy metals (Ni, Pb, Cr)

Results of soil analysis for Nickel (Ni) are shown in [Fig-6]. The increasing trend of Ni in the soil was observed. During and after harvest of cowpea, the highest amount of Ni in soil was observed. It was found least with treatment OM_{100} and highest in Lime treatment.

Variation of Lead (Pb), which is the toxic metal, in the soil during growth stages of three different crops is shown in the [Fig-7]. At the time of paddy harvest the reduction of Pb in the soil was observed. Almost in all treatments the decreasing trend in the Pb of soil was observed at the time of paddy harvest. The reduction in toxic element like Pb would be beneficial for crop growth.

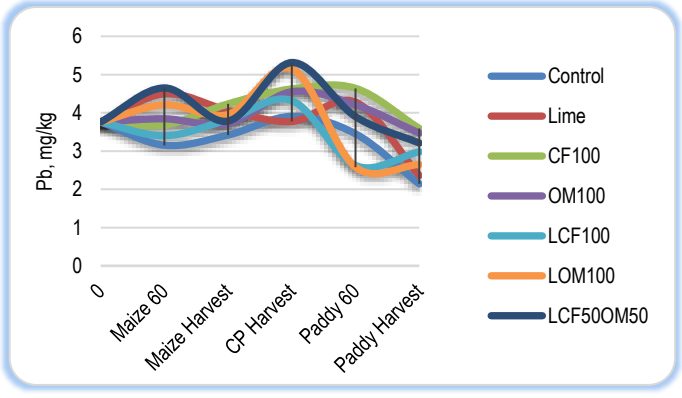

Fig-7 Effect of various treatments on the Pb content of soil

The variation of Cr in soil during the growth period of all crops is shown in the [Fig-8]. For the treatment LOM_{100} the amount of Cr remained higher throughout the growth period of all three crops. During the cowpea harvest the Cr in the soil was maximum for the LOM_{100} whereas it was minimum for the Lime treatment. After harvesting of cowpea Cr increased rapidly for Lime and it showed decreasing trend for the LOM_{100} treatment. Decrease in the Cr is favorable for crop production as high amount of Cr may lead to health hazards if the crop is consumed as a food.

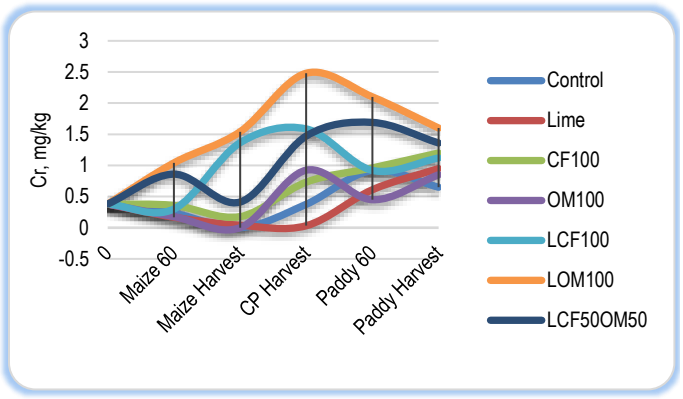

Fig-8 Effect of various treatments on the Cr content of soil

Conclusion

Reclamation of abandoned coal mine land is a very complex process. Once the reclamation plan is complete and vegetation has established, some assessment should be made to determine how closely the reclaimed site functions as an ecosystem compared to similar undisturbed sites. In this study an attempt was made to evaluate the effect of different fertilizer treatment combinations on amendment in soil and to study the response for crop production in mine affected watershed of Jharkhand state in India. Results of the experiments showed that organic and inorganic fertilizers are effective in restoring the productivity of degraded soils in open cast mine area.

Application of research: This study is useful to ascertain the effect of various organic and inorganic fertilizer treatments on micronutrients (Cu, Zn, Fe, Mn) and heavy metals (Ni, Cr, Pb) in mine area soil.

Research Category: Fertilizer treatments on micronutrients

Acknowledgement / Funding: Authors are thankful to College of Agriculture, Waghai, 394730, Navsari Agricultural University, Navsari, 396 450, Gujarat, India

***Principal Investigator or Chairperson of research: Dr V.T. Shinde**
University: Navsari Agricultural University, Navsari, 396 450, Gujarat, India
Research project name or number: Research station trials

Author Contributions: All authors equally contributed

Author statement: All authors read, reviewed, agreed and approved the final manuscript. Note-All authors agreed that- Written informed consent was obtained from all participants prior to publish / enrolment

Study area / Sample Collection: Olidih watershed of Jharia coalfield, Jharkhand

Cultivar / Variety / Breed name: Nil

Conflict of Interest: None declared

Ethical approval: This article does not contain any studies with human participants or animals performed by any of the authors.
Ethical Committee Approval Number: Nil

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