Chromium, Lead and Cadmium accumulation in crops through lime materials used as ameliorating material in maize-greengram cropping system grown in acid *Alfisols*.

RAHUL DEV BEHERA[1], S. K. PATTANAYAK[2], KUSHAL SACHAN[3], DRISHTY KATIYAR[4], TUSHAR SINHA[5]
[1]Subject Matter Specialist (Soil Sc. & Ag. Chem.), Krishi Vigyan Kendra, Bolangir, Odisha Pin-767002, Ph-7077961051. INDIA
[2]Eminerate Professor in Dept. of Soil Sc. & Ag. Chemistry, OUAT, Bhubaneswar, Odisha Pin 751003. INDIA
[3]Ph.D. Research Scholar (Soil Sc. & Ag. Chem.), Chandra Shekar Azad University of Agriculture and Technology, Kanpur (U.P.) Pin-208002, INDIA
[4]Ph.D. Research Scholar (Soil Sc. & Ag. Chem.), Chandra Shekar Azad University of Agriculture and Technology, Kanpur (U.P.) Pin-208002, INDIA
[5]Project SRF, Plant Genetic Resources and Crop Improvement, CSIR- National Botanical Research Institute, Rana Pratap Marg, Lucknow, Uttar Pradesh, INDIA

Abstract: In Odisha more than 70 % soils are acidic in nature which requires amelioration measures through liming but some amount of heavy metals are present in liming materials. So in the present investigation the evaluation of heavy metals was done which accumulate through liming in the crop. The field experiment was conducted consecutively for two years (2017-2018) by taking the two crops Maize followed by greengram to study the "Chromium-Cr, Lead-Pb and Cadmium-Cd accumulation in crops through lime materials used as ameliorating material in maize-greengram cropping system grown in acid *Alfisols".* Out of two test crops, maize crop accumulated both Cr and Pd where as greengram crop accumulated only Cd. In maize crop, the concentration of Cr was more in root than grain and its stover, but the uptake was more through the stover than grain and the roots. The concentration of Pb was more in the stover than root and grain. Its uptake was more through stover, grain followed by roots. The concentration and uptake of Cd were more in stover than the greengram seed. The lowest concentration and uptake of Cr and Cd were observed in the control practice without soil ameliorants. The calcium silicate having 290 mg/kg Cr and paper mill sludge having 7.0 mg/kg Cd toxic to crops and health hazard to human being also. The stromatolyte source contains very less amount of heavy metals viz. cadmium and chromium but little amount of lead which is very suitable because the concentration an uptake of heavy metals in crops is very less. Among the liming materials the concentration and uptake of chromium followed the order : CS>PMS>ST, the cadmium : PMS>ST>CS and the Lead : ST>PMS>CS. Out of three liming sources the application of Stromatolyte source with Nutrient Expert package gives better results which will be helpful for the extension workers of acid soil areas.

Keywords: Calcium silicate, Nutrient expert package, paper mill sludge, soil test dose and stromatolyte etc.
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1. Introduction

Soil acidity is a serious constraint for crop production in many regions of the world including India (Mandal, 1997). The acid soil can be managed through amelioration measure by application of liming materials (Mishra, 2004 and Pattanayak, 2016). Lime is applied to increase the soil pH by neutralising protons and subsequently to decrease the heavy metal uptake by plants with respect to soil charecteristics and behavior of individual elements in soil (Ciecko *et al*., 2004). A range of liming materials available include, limestone

($CaCO_3$), burnt lime (CaO), slaked lime [$Ca(OH)_2$], dolomite [$CaMg(CO_3)_2$], calcium silicate ($CaSiO_3$) and paper mill sludge varying in acid-neutralizing capacity ranging from 60 to 118 per cent (Bolan and Duraisamy, 2003, Pattanayak, 2016). Some times liming materials contain heavy metals like chromium (10-290 $mgkg^{-1}$), cadmium (3.0-7.0 $mgkg^{-1}$, Pattnayak 1992) and lead (9-13 $mgkg^{-1}$).

Cadmium is a non-essential heavy metal pollutant element for the environment, resulting from various agricultural, mining and industrial activities it also come from the exhaust gases of automobiles (Foy *et al*., 1978). It has been considered as an extremely pollutant element due to its high toxicity and greater solubility in water which determine wide distributions in aquatic ecosystems (Lockwood, 1976). It is naturally present in the soil and sediments at concentrations which are generally more than 1 $mgkg^{-1}$ (Peterson and Allowy, 1979). Jarvis *et al.*, (1976) observed that roots of lettuce released much more of the absorbed Cd for translocation to the shoots compared to other crops. John *et al*. (1972) observed that soil pH influenced significantly with sludge-borne soil Cd content to affect corn leaf Cd concentrations. The highest grain Cd concentrations occurred at a soil pH of 6.0. Uptake of Cd by corn was less from the most acid soil that also had the highest organic matter content (Street *et al*., 1977). The Cd concentrations were reported to be higher in roots than in shoots (Rauser, 1986). Solubility and availability of Cd increases with decreasing soil pH (Williams and David, 1976). Low clay content and low CEC of soil produce the high concentration of the Cd as compared to the high clay and CEC of supplied from same source of Cd (Gunnareson, 1983). Soil with 3 ppm Cd may be considered as polluted where as 10 ppm is usually toxic to plants depending upon availability (Gunnareson, 1983).

Chromium present in nature in the form of chromites ($FeCr_2O_4$) in ultramafic and serpentine rocks or combined with other metals in the forms like crocoite ($PbCrO_4$), bentorite Ca_6 (Cr, Al)^2 $(SO_4)^3$ and tarapacaite (K_2CrO_4), vauquelinite ($CuPb_2CrO_4P$ O_4OH), (Behera *et al.*, 2018). The growth of root and shoot, dry matter were adversely affected by heavy metals (Humanaz *et.al*, 2015). Seed germination is the first physiological process of plant to be effected. So the level of tolerance to Cr is measured when the seeds germinate in a medium containing Cr (Prasad *et al*., 2001). They reported that the order of metal toxicity to new root primordial in *Salix viminalis* is Cd>Cr>Pb, whereas root length was more affected by Cr than other heavy metals studied. Barcelo *et al.*, (1986) described the inhibition of P, K, Zn, Cu and Fe translocation within the plants parts when bean plants were exposed to Cr in nutrient solutions. In soil Cr concentration range from 1 to 1000 $mgkg^{-1}$ with an average concentration ranging from 14 to bout 70 $mgkg^{-1}$, but in water the concentration of Cr range from 0.4 to 8 $\mu glit^{-1}$ (Health assessment document for chromium, 1984).

In Worldwide mean total lead content of uncontaminated soils range from 10 to 84 ppm, but more commonly below 50 ppm. It's toxicity causes abnormal growth of the child during pregnancy, reduces the fertility level of man, weakness the fingers. The high blood pressure and abnormal nervous systems are observed in adults. According to Kabata-Pendias (2011) and Murthy (2008), Pb in world soils ranged from 1.5-176 $mgkg^{-1}$, but in polluted soils in India from 1.1 to 1833 $mgkg^{-1}$ (Panwar *et al.*2011).

In the present investigation the main objective of the study was to evaluate the heavy metal like cadmium, chromium and lead accumulation in crops through liming materials used as ameliorating material in maize-greengram cropping system grown in acid *Alfisols*.

2. Materials Methods

The experiment was conducted for two consecutive years in the same field (2017 and 2018) by growing the two crops i.e. kharif maize (Var. Hishell) and greengram (Var. Chetak) in the village MV-3 of Malkangiri district of Odisha. The test crops were grown for two years in *kharif* and *rabi* seasons which received 12 treatments. Each treatment was replicated three times and imposed over statistically laid out field with Radomised Block Design (RBD) in the field. Three different types of lime materials were used in the experiment as ameliorating material. These were Paper Mill Sludge (PMS)-industrial waste, Stromatolyte (ST)-natural deposit and Calcium Silicate (CS)-industrial waste having neutralizing values 60, 80 and 80 per cent respectively . Liming materials were applied @ 0.1 LR with soil test dose and nutrient expert package of practice for maize because as per recommendation liming materials should applied @ 0.1 LR for monocot crops. The greengram crop was the residual crop received only seed inoculation with *Rhizobium* except in control practice. Absolute control treatment was included among 12 treatment to study the influences without addition of any external source of nutrients and lime in both the crops (Table-1). The different plant parts like leaf, shoot, cob, grain and roots were collected, washed, labeled properly and dried in hot air oven till a constant weight was recorded. Each sample was grinded separately (morter and pastle) and was used for analysis of Cr, Pb and Cr by diacid digestion followed by Atomic Absorption Spectrophotometer method **(**Page *et al*., 1982). The samples were digested in diacid mixure [HNO_3: $HClO_4$ (3:2)] and analysed in Atomic Absorption Spectrophotometer (AAS). The Cr, Pb and Cd in liming materials were analysed is placed in Table-2.

***Nutrient Expert :** It is a computer-based decision support tool that uses the principles of site-specific nutrient management for developing fertilizer recommendations tailored to a specific field or growing environment.

The amount of Chromium 600 gha^{-1} through Calcium Silicate, 25 gha^{-1} through Paper mill sludge and 12 gha^{-1} through Stromatolyte were added to the soil over the two years of cropping. The amount of Cadmium 4.0 gha^{-1} through Calcium Silicate, 11 gha^{-1} through Paper mill sludge and 6 gha^{-1} through Stromatolyte were added to the soil over the two years of cropping. The amount of Lead 10 gha^{-1} through Calcium Silicate, 18 gha^{-1} through Paper mill sludge and 15 gha^{-1} through Stromatolyte were added to the soil over the two years of cropping. The highest amount of Chromium through Calcium silicate and Cadmium & Lead through Paper mill slug were added to soil over the two years of cropping.

3. Results & discussion

Experimental soil

The soil of experimental site was loamy sand in texture (silt-14 % and clay-10 %) with pH_w (1:2.5) 4.15, EC 0.09 dSm^{-1}, organic carbon content 2.9 gkg^{-1} soil. The available N, K, B were limiting nutrients in the soil. The P, S, Ca, Mg, Fe, Mn, Cu, Zn were adequate in the experimental soil. The soil was strongly acidic in reaction, it was dominated with aluminium acidity (0.68 cmol(p+)kg^{-1} soil) in addition to acidity due to H^+ (0.40 cmol(p+)kg^{-1} soil). The lime requirement to raise the pH to 6.5 was 4.5 t $CaCO_3ha^{-1}$. The Pb and Cd content in the experimental soil were 0.86 and 0.004 $mgkg^{-1}$ soil. The Cr was in non detectable level. The Pb was more in ST than PMS and CS (Table-2). The extent of application ranged from 10 to 18 gha^{-1}, lowest with Cs and highest with PMS (Table-3).

Concentration and uptake of chromium (Cr) in different plant parts of maize

The concentration and uptake of Cr in different plant parts of maize under the influence of liming materials during two years of cropping is presented in table-4.

The concentration of Cr was more in maize root than grain and the stover, which varied between 33 and 45 $mgkg^{-1}$, 8 and 31 $mgkg^{-1}$, 7 and 23 $mgkg^{-1}$ respectively. The lowest concentration of Cr was recorded in control practice i.e. 8 $mgkg^{-1}$ in grain, 7 $mgkg^{-1}$ in stover and 33 $mgkg^{-1}$ in the root but application of calcium silicate source of lime with nutrient expert package showed the highest concentration of it i.e. 31 $mgkg^{-1}$ in grain, 23 $mgkg^{-1}$ in stover and 45 $mgkg^{-1}$ in root. With the application of organic manure, Cr concentration increased slightly compared to control practice. Whereas the application of fertilizers as per nutrient expert package increased the concentration of Cr more compared to the use of soil test based recommended dose of fertilizers. The application of liming materials such as PMS, CS and ST with nutrient expert package also increased the concentration of Cr more compared to the application of these liming materials with soil test dose (STD). Among the three liming material sources, the CS contributed higher concentration of Cr.

The Cr content in calcium silicate was highest (290 $mgkg^{-1}$) followed by 16.3 $mgkg^{-1}$ in PMS and 10.3 $mgkg^{-1}$ in ST (Table-2). With the application of lime @ 0.1 LR to maize crop, Cr of 300, 25 and 12 gha^{-1} have been applied in respective treatments in two years.

The Cd content of PMS was more than ST and CS (Table-2). Its extent of application to maize crop varied between 4.0 and 11 gha^{-1}, lowest with Cs and highest with PMS.

The uptake of Cr through stover was more than grain and the root, which varied between 20 and 200 gha^{-1} through grain, 30 and 250 gha^{-1} through stover, 10 and 80 gha^{-1} through root based on biomass production. The total uptake of Cr varied between 60 and 530 gha^{-1}. The lowest uptake of Cr was recorded with control practice i.e. 20 gha^{-1} through grain, 30 gha^{-1} through stover and 10 gha^{-1} through root, with a total uptake of 60 gha^{-1}. Soil amelioration with Cs source adopting nutrient expert package showed the highest uptake of Cr of 200 gha^{-1} through grain, 250 gha^{-1} through stover and 80 gha^{-1} through root. The total uptake was 530 gha^{-1} The application of organic manure slightly increased the uptake of Cr compared to control practice, where as the application of fertilizers as per nutrient expert package increased the uptake of Cr more compare to the soil test based recommended dose of fertilizers. The application of liming materials such as PMS, CS and ST with nutrient expert package also increased the uptake of Cr more compared to the application of liming materials with soil test dose of fertilizers. Among the three liming materials, the use of CS resulted in significantly higher uptake of Cr.

4. Concentration and uptake of Lead (Pb) in different plant parts of maize

The concentration and uptake of Pb in different plant parts of maize under the influence of liming materials during two years of cropping have been presented in table-5.

The concentration of Pb was more in stover than root and the grain, which varied between 20 and 42 $mgkg^{-1}$ in stover, 8 and 38 $mgkg^{-1}$ in root, 4 and 26 $mgkg^{-1}$ in grain. The lowest concentration of Pb was recorded in control practice i.e. 4 $mgkg^{-1}$ in grain, 20 $mgkg^{-1}$ in stover and 8 $mgkg^{-1}$ in the root but application of stromatolyte with nutrient expert package showed the highest concentration of Pb i.e. 26, 42 and 38 $mgkg^{-1}$ in grain, stover and root respectively. Application of organic manure slightly increased the concentration of Pb compared over control practice, where as the application of fertilizers as per nutrient expert package increased the concentration of Pb more compared to the use of soil test based recommended dose of fertilizers. The application of liming materials such as paper mill sludge (PMS), calcium silicate (CS) and stromatolyte (ST) with nutrient expert package also increased the concentration of Pb more compared to the application of liming materials with soil test dose (STD). Among the three liming materials, the stromatoyte contributed higher concentration of Pb.

The uptake of Pb through stover was more than grain and the root which varied between 10 and 160 gha^{-1} through grain, 110 and 350 gha^{-1} through stover, 10 and 50 gha^{-1} through root. The total uptake of Pb varied between 130 and 560 gha^{-1}. The lowest uptake of Pb was recorded with control practice i.e. 10 gha^{-1} through grain, 110 gha^{-1} through stover and 10 gha^{-1} through root, with a total uptake of 130 gha^{-1}. Soil amelioration with stromatolyte adopting nutrient expert package showed the highest uptake of Pb of 160 gha^{-1} through grain, 350 gha^{-1} through stover and 50 gha^{-1} through root. The total uptake was 560 gha^{-1} The application of organic manure slightly increased the uptake of Pb as compared to control practice, where as the application of fertilizers as per nutrient expert package increased the uptake of Pb more compared to the soil test based recommended dose of fertilizers. The application of liming materials such as PMS, CS and ST with nutrient expert also increased the uptake of Pb more compared to the application with soil test dose of fertilizers. Among the three liming materials, the use of stromatolyte resulted in significantly higher uptake of Pb (Table-5).

5. Concentration and uptake of Cadmium (Cd) in different plant parts of greengram

The concentrations and uptake of Cd through different plant parts of greengram crop under the influence of liming materials during two years of cropping have been presented in the table-6.

The concentration of Cd was more in greengram stover (ranging from 1.46 to 2.55 $mgkg^{-1}$) than the seed (ranging from 0.86 to 1.36 $mgkg^{-1}$). The lowest concentration of Cd was recorded in control practice i.e. 0.86 $mgkg^{-1}$in seed and 1.46 $mgkg^{-1}$in stover. Application of PMS with nutrient expert package of practice showed the highest concentration of Cd i.e. 1.36 $mgkg^{-1}$in seed and 2.55 $mgkg^{-1}$in stover. The integration of the package of practice of organic manure application slightly increased the concentration of Cd compared to control, where as with the application of fertilizers as per nutrient expert practice increased the concentration of Cd compared to the soil test based recommended doses. The application of liming materials like PMS, CS and ST with nutrient expert package also increased the concentration of Cd compared to the application of liming materials with soil test dose. Among the three liming materials, the PMS integrated practice recorded higher concentration of Cd .

The uptake of Cd was more through greengram stover (ranging from 12.9 to 36.15 gha^{-1}) than through seed (ranging from 1.58 to 9.38 gha^{-1}). The total uptake of Cd varied between 14.49 and 44.95 gha^{-1}. The lowest uptake of Cd was recorded with control practice i.e. 1.58 gha^{-1}in seed and 12.91 gha^{-1}in stover but the highest uptake was through the seed i.e. 9.38 gha^{-1}through application of ST lime stone with nutrient expert package and in stover i.e. 36.15 $gha^{-1}$with the application of PMS with nutrient expert practice. Integrating application of the organic manure slightly increased the uptake of Cd compared to control practice without organics, where as the use of fertilizers as per nutrient expert increased the uptake of Cd more compare to the practice of soil test based recommended dose of fertilizers. The application of liming materials with nutrient expert package also increasesd the uptake of ‘Cd’ compare to the application with soil test dose. Among the three lime sources, the PMS recorded the highest uptake of Cd .

6. Economic yield of cropping system :

The data related to the economic yields (maize equivalent) of the cropping system have been presented in Table-7.

The economic yield of maize, maize equivalent yield of greengram crop and maize equivalent yield of the cropping system during both the experimental years indicated that there was significant influence of POPs on crop production. The grain yield of maize during 1st year of cropping varied between 2.1 and 6.6 t/ha and during 2nd year between 2.0 and 6.6 t/ha (Table-7). The greengram seed yields varied between 0.33 and 1.21 t/ha during 1st year and between 0.31 and 1.25 t/ha during 2nd year. Their maize equivalent yields of greengram ranged from 1.32 to 4.84 and from 1.24 to 5.01 t/ha respectively. The maize equivalent yield of the cropping system during 1st year varied between 3.4 and 11.34 t/ha. During 2nd year it varied between 3.24 and 11.61 t/ha. The pooled average of maize equivalent yield of the cropping system ranged from 3.33 and 11.48 t/ha, lowest due to control package and highest due to NE+ST+F package of practice. Use of FYM as organic source influenced the economic yields by 15 per cent. Use of fertilizers based on soil test had significant effect on the economic yields compared over control as well as FYM alone. Organic integration with STD influenced the yield by 18 per cent. On the other hand with omittion of organics there was 15 per cent economic yield loss. Combining the practice of ameliorating acid soil with soil test based fertilizers schedule, there was 35.6 per cent yield increase. Without integration, of liming practice there was 26.3 per cent yield loss. Fertilizer recommendation based on NE had positive but significant impact on economic yields (3.0 % over STD). Integrating FYM use with NE package had 17.2 per cent yield advantage. Omittion of FYM use resulted in 14.7 per cent economic yield loss. Adoption of combining liming practice of acid soil to NE + FYM package had significant impact on economic yields, with an yield advantage of 33.2 per cent over no lime integration. Omitting acid soil liming practice had yielded 25 per cent less yield compared to all integrated practices. Irrespective of the practices of fertilizers recommendation, PMS as lime source had less impact on economic yields compared to other sources. The CS source was 8.5 per cent better performer than PMS, so also the ST source by 10 per cent. Considering the performance of STD + F package for maize-greengram as 100, the relative agronomic efficiency of different POPs can be arranged as:NE+ST+F(173)>NE+CS+F(172)>STD+ST+F(169)>STD+CS+F(165)>NE+PMS+F(154)>STD+PMS+F(145)>NE+F(107)>STD+F(100)>NE(81)>STD(74)>F(10) (Fig-1).

7. Conclusion

Out of two test crops, maize crop accumulated both Cr and Pd where as greengram crop accumulated only Cd. The calcium silicate having 290 mg/kg Cr and paper mill sludge having 7.0 mg/kg Cd toxic to crops and health hazard to human being also. The stromatolyte source contains very less amount of heavy metals viz. cadmium and chromium but little amount of lead which is very suitable because the concentration an uptake of heavy metals in crops is very less. Among the liming materials the concentration and uptake of chromium followed the order : CS>PMS>ST, the cadmium : PMS>ST>CS and the Lead : ST>PMS>CS. Out of three liming sources the application of Stromatolyte source with Nutrient Expert package gives better results which will be helpful for the extension workers of acid soil areas.

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Table-1 : Treatment details

SL. No.	Treatments
1	Absolute Control (AC)
2	Farm Yard Manure (FYM)
3	Soil Test Based Dose (STD)
4	*Nutrient Expert (NE)
5	Soil Test Based Dose STD + FYM
6	Nutrient Expert NE + FYM
7	STD + Paper Mill Sludge (PMS) + FYM
8	NE + Paper Mill Sludge (PMS) + FYM
9	STD + Calcium Silicate (CS) + FYM
10	NE + Calcium Silicate (CS) + FYM
11	STD + Stromatolyte (ST) + FYM

12	NE + Stromatolyte (ST) + FYM

Table-2 : Chromium, Cadmium and Lead content (mkg^{-1}) in different liming materials

Liming material	Chromium	Cadmium	Lead
Calcium Silicate	290	3.2	9.2
Paper mill sludge	16.3	7.0	12.1
Stromatolyte	10.3	5.0	13.2

Table-3 : Amount of heavy metals added to soil in two years (gha^{-1}) through liming materials

Liming material	Chromium	Cadmium	Lead
Calcium Silicate	600	4.0	10
Paper mill sludge	25	11	18
Stromatolyte	12	6	15

Table-4: Concentration of Cr and its uptake through different plant parts of maize under the influence of amelioration measure with lime sources

Treatments	Concentration ($mgkg^{-1}$)			Uptake (gha^{-1})			
	Grain	Stover	Root	Grain	Stover	Root	Total
Absolute Control	8	7	33	20	30	10	60
FYM	10	9	38	20	50	20	90
STD	11	7	39	50	60	30	140
Nutrient Expert	14	10	41	70	70	40	180
STD + FYM	11	9	38	100	140	40	280
NE + FYM	25	19	43	100	150	40	290
STD + PMS + FYM	17	8	43	100	90	60	250
NE + PMS + FYM	23	12	44	140	140	60	340
STD + CS + FYM	26	14	40	170	180	60	410
NE + CS + FYM	31	23	45	200	250	80	530
STD + ST + FYM	14	11	33	90	150	50	290
NE + ST + FYM	16	14	35	100	150	60	310
SE(m)	0.12	0.07	0.31	11.2	8.9	8.4	10.3

LSD(0.05)	**11.0**	**8.31**	**10.17**	**12.6**	**7.8**	**4.1**	**5.7**

Table-5 : Concentration of Pb and its uptake through different plant parts of maize under the influence of amelioration measure with lime sources

Treatments	Concentration ($mgkg^{-1}$)			Uptake (gha^{-1})			
	Grain	Stover	Root	Grain	Stover	Root	Total
Absolute Control	4	20	8	10	110	10	130
FYM	14	28	23	30	260	10	300
STD	21	37	18	100	300	10	410
Nutrient Expert	25	42	21	130	310	20	460
STD + FYM	16	33	31	90	320	20	430
NE + FYM	23	36	42	130	330	30	490
STD + PMS + FYM	10	22	11	60	260	20	330
NE + PMS + FYM	14	26	16	90	310	20	420
STD + CS + FYM	6	21	9	40	220	10	270
NE + CS + FYM	11	24	10	70	320	10	400
STD + ST + FYM	15	26	16	90	300	30	420
NE + ST + FYM	26	42	38	160	350	50	560
SE(m)	0.15	0.26	0.19	6.3	5.7	3.2	7.1
LSD(0.05)	2.3	4.7	1.5	7.4	9.3	3.5	4.2

Table-6 : Concentration of Cd and its uptake through different plant parts of greengram under the influence of amelioration measure with lime sources

Treatments	Concentration ($mgkg^{-1}$)		Uptake (gha^{-1})		
	Seed	Stover	Seed	Stover	Total
Absolute Control	0.86	1.46	1.58	12.91	14.49
FYM	0.92	1.50	1.86	13.90	15.76
STD	1.03	1.55	3.28	17.55	20.82
Nutrient Expert	1.07	1.62	3.56	18.82	22.38
STD + FYM	1.08	1.64	4.04	19.39	23.42
NE + FYM	1.10	1.69	4.56	20.69	25.25
STD + PMS + FYM	1.32	2.17	8.40	32.68	41.08
NE + PMS + FYM	1.36	2.55	8.80	36.15	44.95
STD + CS + FYM	1.19	1.76	8.23	28.19	36.41
NE + CS + FYM	1.23	1.84	8.68	29.79	38.47
STD + ST + FYM	1.25	1.91	9.04	31.17	40.20
NE + ST + FYM	1.29	2.00	9.38	32.74	42.12
SE(m)	0.05	0.07	2.5	6.4	9.1

LSD(0.05)	1.08	1.69	8.1	7.1	8.2

Table-7 : Maize Equivalent Yield (t/ha) under the influence of liming practices

Treatments	1st year			2nd year			Pooled Average MEY
	Maize	MEY (GG)	MEY	Maize	MEY (GG)	MEY	(Two Year)
Control	2.1	1.32	3.40	2.0	1.24	3.24	3.33
F	2.4	1.40	3.80	2.4	1.44	3.84	3.82
STD	4.7	2.20	6.90	4.7	2.28	6.68	6.79
NE	4.8	2.32	7.12	4.8	2.36	7.16	7.14
STD + F	5.4	2.56	7.96	5.4	2.64	8.04	8.00
NE + F	5.5	2.72	8.22	5.6	2.92	8.52	8.37
STD + PMS + F	5.8	4.20	10.00	5.9	4.41	10.31	10.16
NE + PMS + F	6.1	4.33	10.42	6.2	4.53	10.73	10.58
STD + CS + F	6.4	4.57	10.97	6.5	4.73	11.23	11.10
NE + CS + F	6.6	4.69	11.29	6.6	4.85	11.45	11.40
STD + ST + F	6.4	4.73	11.13	6.5	4.97	11.45	11.29
NE + ST + F	6.5	4.85	11.34	6.6	5.01	11.61	11.48
LSD (0.05)	**0.44**	**0.32**	**0.53**	**0.40**	**0.30**	**0.52**	**0.45**

Fig-1 : Relative agronomic efficiency of package of practices in maize-greengram cropping system