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Various impact of different sources of liming materials on growth, yield and productivity of the maize crop grown in acid soil of Odisha

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Abstract
A comprehensive field experiment was conducted to study the "Various Impact of different sources of Liming materials on Growth, Yield and Productivity of the Maize crop Grown in Acid soil of Odisha " in the village Bajpur, Haladia, Andharua, Mendhasal in khorda district of Odisha during *Kharif,* 2013.The soil was ameliorated with three different source sof liming materials (paper mill sludge @ 0.1LR, Stromatolyte @ 0.1 & 0.2 LR and Calcium Silicate @ 0.2 LR)added with soil test based dose with or without FYM. The FYM integrated treatments maintained higher chlorophyll content (SPAD values) than FYM untreated one. However use of liming materials did not influence the recorded chlorophyll content (SPAD values) much in the crop. The calcium silicate source applied @ 0.2 LR and the ST @ 0.2 LR when applied mixed with FYM recorded highest average growth rate of 3.9 cm day^{-1}. Liming of soil and their combined application with FYM resulted in increasing root length, cob length, diameter and seed weight cob^{-1} respectively. Inorganic (Lime) amelioration of acid soil resulted in 32 per cent higher yield compared to the yield of 22 qha^{-1} due to inorganic nutrition only. Combining organic amelioration (FYM) with inorganic amelioration measure and inorganic nutrition yielded 26 per cent higher grain yield in maize crop. Irrespective of the sources, the stromatolyte @ 0.2LR mixed with FYM produced higher grain (39.3 q/ha) and stover (31.3 q/ha) yields with higher relative agronomic efficiency (234).

Keywords: Acid soil, Paper mill sludge, Stromatolyte, Calcium Silicate, growth rate and yield

Introduction
Soil acidity is a major yield limiting factor for crop production worldwide. Land area affected by acidity is estimated at 4 billion hectares, representing approximately 30% of the total ice-free land area of the world (Sumner and Noble, 2003) [9]. Acid infertility factors limit crop growth and yield as well as soil productivity in highly weathered soils of humid and sub-humid regions of the world due to deficiency of essential nutrient elements (Akinrinade *et al.*, 2006) [1]. Soil acidity affects nearly 50 percent of the world's potentially arable land, particularly inhumid tropics (von Uexkull and Mutert 1995) [10]. InIndia, approximately one-third of the cultivated landis affected by soil acidity (Mandal 1997) [11]. Majority of these soils are concentrated in north-easternregion of India, with nearly 65% of its area being under extreme forms of soil acidity (pH below 5.5) (Sharma and Singh 2002) [12]. Crop productivity onsuch soils is mostly constrained by aluminium (Al)and iron (Fe) toxicity, phosphorus (P) deficiency, low base saturation, impaired biological activity and other acidity-induced soil fertility and plantnutritional problems (Patiram 1991; Manoj-Kumar *et al.* 2012) [13-18, 14]. According to Kisinyo *et al.* (2005) [15], continuous cropping has led to development of soil acidity which is a major constraint to maize production on tropical soils due to toxic levels of aluminium (Al) and the concomitant phosphorus (P) deficiency that hinder plant growth.The levels of soil acidity along withits associated impacts on soil fertility and cropproductivity are expected to further intensify in achanging climate (Oh and Richter 2004) [16]. Soil acidity management andcrop productivity improvement on such soils istherefore important for enhancing food securityglobally and regionally. Lime application along with integratednutrient management is often recommended toincrease the phytoavailability of essential nutrientsand ameliorate the other acidity-induced fertilityconstraints on such soils (Haynes 1984; Patiram 1991; Manoj-Kumar *et al.* 2012) [17, 13-18, 14]. It is thereforeimperative to ascertain the yield benefits ofindividual as well as combined application of lime, chemical fertilisers and organic manure in aparticular edapho-climatic condition. We evaluatedthe same in a field experiment (with maize as a testcrop) on an acid Alfisol of odisha, India. The main objective of this work, therefore, was to determine the combined effect of lime and manure on soil acidity for improvement maize growth, yield and productivity.

Materials and Methods

Three different types of liming materials were used in the experiment. These were Paper Mill Sludge (PMS), Stromatolyte (ST) and Calcium Silicate (CS). Liming materials were applied mixed with and without FYM in the field. Absolute control treatment was included without any addition of external source of nutrients. The test crop Maize (Hishell-hybrid) received 10 treatments. Each treatment was replicated three times and imposed over statistically laidout field with Radomised Block Design (RBD) in the field. The chlorophyll content was measured by the use of Spadometeri.e called as SPAD value. The reading was taken in every 7 days or a week. The plant height was measured by the measuring long scale. The height was measured within 7 days interval or in a week. From this plant height the growth rate also measured. The Maize root, Cob and plant samples were collected at the harvesting stage. The root length, weight, diameter, density and Cob length, diameter & seed/cob was measured. The grain, rachis, and spathewas separated. The all the samples (grain, rachis, spathe, root and plant samples) were oven dried separately and the dry weight was taken separately. The grain and stover yield was evaluated by the use of dry weight of grain and plant samples of Maize. The total biomass was calculated by mixing the dry weights of all the samples. The percent yield response was calculated from the grain yield by using this formula:-

$$\text{Per cent yield response} = \frac{\text{Yield in treatment} - \text{yield in control}}{\text{Yield in treatment}} \times 100$$

The Relative Agronomic Efficiency (RAE) was calculated from the total biomass by using this formula:-

(Total Biomass production in treatment – Total Biomass production in Absolute Control/ Totlal Biomass production in STD - Total Biomass production in Absolute Control) x 100

Results and Discussion

(a) Growth parameters of maize under the influence of liming materials during crop growth period

- **Chlorophyll content**

The photosynthetic activity (chlorophyll content) of maize crop under the influence of application of different liming materials have been presented in Fig-1.The photosynthetic activity was measured by SPAD cholorophyll meter. The values recorded at six growth stages starting from 28th DAS till 77th DAS. At 28th DAS stage the SPAD values in the leaf varied between 31.13 and 49.50, which increased and maintained between 33.48 and 49.19 at 42nd DAS, there after decreased invariably in all the treatments and maintained between 28.8 and 48.54, further decreased by 56th DAS where it was maintained between 26.72 and 43.86, there after increased to the level varying between 32.85 and 49.55 at 70th DAS, there after either increased or maintained in the most of the treatments between 37.87 and 49.93 at 77th DAS (Fig-1).

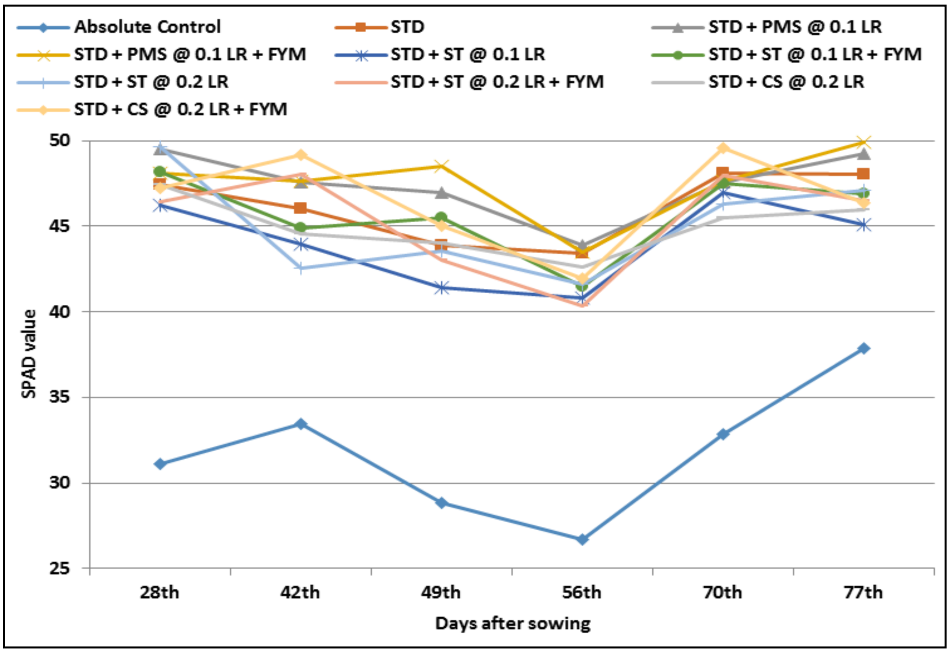
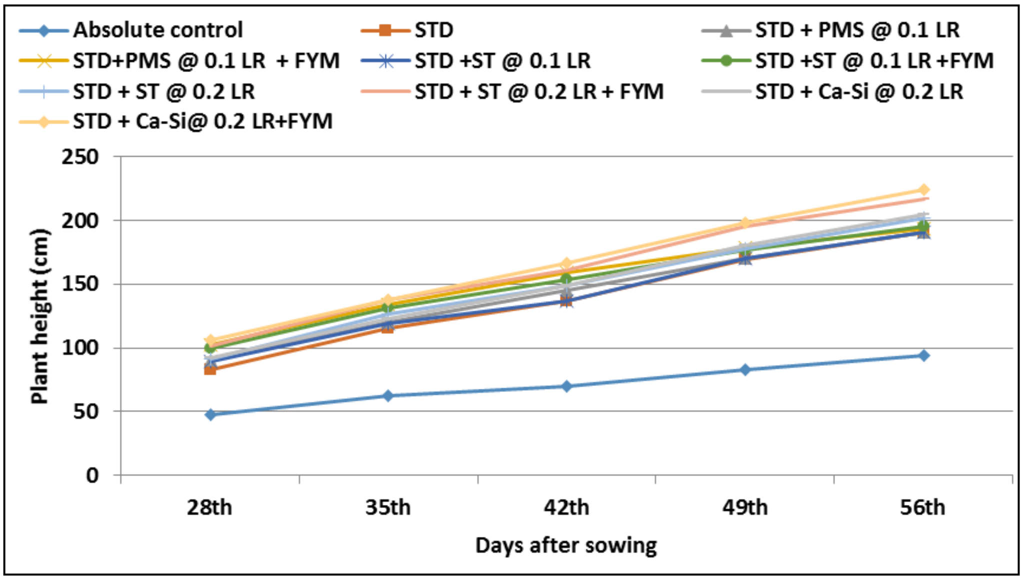


Fig 1: Crorophyll content (SPAD value) at different growth stage

The average recorded SPAD value in different treatments varied between 31.8 and 47.56. At all stages the absolute control treatment recorded lowest SPAD values. The FYM integrated treatments maintained higher SPAD values than FYM untreated one. However use of liming materials did not influence the recorded SPAD values much in the crop.

- **Plant height under the influence of different liming materials**

The maize crop heights recorded at different growth stages have been presented in Fig-2. The height of the crop continued to grow at differential rates under different treatments. The height ranged from 48.1 to 106.5 cm, from 62.1 to 137.7 cm, from 70.4 to 166.7 cm, from 83.2 to 198.2 cm and from 93.73 to 223.9 cm at 28th, 35th, 42nd, 49th and 59th DAS, respectively. The average crop height varied between 71.5 and 66.6 cm and the growth rate between 1.28 cmday^{-1} and 2.98 cmday^{-1}, lowest with control and highest with STD + CaSi @ 0.2 LR + FYM. Integrating PMS @0.1 LR, ST



@ 0.1 LR, ST @ 0.1 LR and CS @ 0.2 LR with STD resulted in 3.0, 2.0, 7.3 and 8.0 per cent increase in plant height compared to the average heightdue to STD of 139.1 cm. Further integration of FYM with STD and lime sources increased the plant height by 7.3, 9.2, 9.1 and 11.2 per cent compared to the height due to respective lime sources.

Fig 2: Plant height at different growth stage

The growth rate of the crop differed from treatment to treatment and from day to day. Growth rate of the crop was 1.77 cmday^{-1} at 28th DAS in absolute control treatment which increased to 2.98 cmday^{-1} with STD. Still higher with liming materials when used either alone or more with FYM ranging from 3.19 to 3.8cmday^{-1}. The growth rate increased irrespective of the treatments up to 49th DAS except in control and decreased there after to a range of 1.67 to 4.0 cmday^{-1} in 56th DAS (Table-1). All along the growing period integrated use of inputs had recorded positive influences.

Table 1: Plant growth rate (cmday^{-1}) at different growth stage of maize

Treatments	28th	35th	42th	49th	56th	Mean
Absolute control	1.77	1.77	1.68	1.7	1.67	1.28
STD	2.98	3.30	3.30	3.45	3.4	2.48
STD + PMS @ 0.1 LR	3.21	3.44	3.45	3.47	3.40	2.55
STD+PMS @ 0.1 LR + FYM	3.67	3.83	3.8	3.65	3.46	2.74
STD +ST @ 0.1 LR	3.19	3.41	3.42	3.47	3.4	2.52
STD +ST @ 0.1 LR +FYM	3.57	3.74	3.76	3.6	3.48	2.75
STD + ST @ 0.2 LR	3.25	3.62	3.62	3.63	3.60	2.66
STD + ST @ 0.2 LR + FYM	3.62	3.94	3.9	3.98	3.87	2.70
STD + Ca-Si @ 0.2 LR	3.29	3.52	3.54	3.69	3.65	2.68
STD + Ca-Si@ 0.2 LR+FYM	3.8	3.93	3.97	4.05	4.0	2.98

(b) Root characteristics of maize crop under the influence of application of liming materials

At harvest, the root length, their weight, volume, and calculated density have been presented in Table-2.The root length of the maize crop under the influence of different liming materials varied significantly between 15 and 62 cms, lowest with no nutrient control and highest with the integration of STD + ST @ 0.2 LR + FYM (Table-2).Application of liming materials with STD resulted in 27, 15.2, 10.4 and 19 per cent increase compared to the root length of 26 cm due to STD alone. Integrating FYM application with liming materials further influenced the root growth which as 36, 13.3, 17.0 and 22.6 per cent higher compared to the root length due to respective liming materials.

Table 2: Root charecteristics of Maize crop as influenced by different liming materials

Treatments	Root length (cm)	Root dry wt (g)	Root volume (cc)	Root density (g/cc)
Absolute Control	15	0.83	10	0.08
STD	26	4.76	30	0.14
STD + PMS @ 0.1 LR	33	7.45	50	0.15
STD + PMS @ 0.1 LR + FYM	45	16.56	100	0.17
STD + ST @ 0.1 LR	30	9.80	50	0.19
STD + ST @ 0.1 LR + FYM	34	11.99	60	0.20
STD + ST @ 0.2 LR	53	8.29	40	0.20
STD + ST @ 0.2 LR + FYM	62	10.99	50	0.22
STD + CS @ 0.2 LR	31	6.07	35	0.18
STD + CS @ 0.2 LR + FYM	38	7.83	40	0.20
CD (P=0.05)	2.8	1.8	3.8	0.098

Root weight: The root weight of maize crop under the influence of different lime integrated treatments varied significantly between 0.83 and 16.5 g plant^{-1}.

Root volume: The volume of roots under individual treatments ranged from 10 cc (lowest in control) to 100 cc (STD + PMS @ 0.1 LR + FYM). There was significant influence of application of liming materials and their combined use with FYM and STD on root volume.

Root density: As a result of variation in root weight (mass) and volume of maize crop due to the application of liming materials either alone or with FYM, their density varied between 0.08 and 0.22 g/cc.

Not only the root length, but also root weight, their volume and density were influenced by soil amelioration measure with lime sources and more positively by combined use of FYM. Similar results of positive impact of liming on root grown were also reported by Onwuka *et al* (2009) [5], Fageria *et al* (2007) [3].

(c) Maize cob characteristics under the influence of soil amelioration with liming materials

The characteristics of the economic part of maize crop i.e, cob, its length, diameter, seeds weight cob^{-1} have been presented in Table-3. Application of different liming materials for amelioration of acid soils when added with or without FYM influenced the cob charecteristics in terms of its length, its diameter and seed weight cob^{-1} which varied between 11.0 and 17.6 cm, 10.2 and 13.9 cm, 22.8 g and 75.4 gcob^{-1} respectively. Lowest values were recorded with the cobs produced form absolute control treatment and highest values with STD + PMS @ 0.1 LR + FYM (Table-3). On an average liming of soil and their mixing with FYM resulted in 4 to 11 per cent increase in cob length, 4.8 to 12.1 per cent in their diameter and 10.4 to 38 per cent increase in seed weight cob^{-1} compared to the length, diameter and seed weight cob^{-1} of 15.2, 12.4 and 54.8 gcob^{-1} due to STD respectively. Combined use of FYM with individual liming materials recorded positive influence.

The proper inorganic nutrition of crop coupled with acid soil amelioration measures with lime sources and further with organic source FYM, not only produced bigger sized cobs which could accommodate more grains compared to no fertilization and no amelioration measure was indicative of better growing environment for higher production with INM practice. The results corroborate the findings of Dierolf *et al* (1997) [2], Pattanayak and Mishra, (2002) [6].

Table 3: Maize cob charecteristics as influenced by different liming materials

Treatments	Cob length (cm)	Cob diameter (cm)	Seeds/Cob (g/Cob)
Absolute Control	11.0	10.2	22.8
STD	15.2	12.4	54.7
STD + PMS @ 0.1 LR	17.1	13.6	66.0
STD + PMS @ 0.1 LR + FYM	17.6	13.9	75.4
STD + ST @ 0.1 LR	16.2	13.5	60.4
STD + ST @ 0.1 LR + FYM	16.6	13.6	66.0
STD + ST @ 0.2 LR	16.5	13.6	68.7
STD + ST @ 0.2 LR + FYM	16.9	13.9	74.9
STD + CS @ 0.2 LR	15.8	13.0	68.0
STD + CS @ 0.2 LR + FYM	16.4	13.8	74.0

(d) Maize productivity under the influence of integrated use of lime and FYM fertilizers

- **Grain yield**

The grain yield of maize crop varied significantly between 11.3 and 39.3 qha^{-1} (Table-4), lowest due to control and highest due to STD + ST @ 0.2 LR + FYM. There was 49 per cent yield loss in maize grain yield when grown without addition of external source of nutrients (-STD). Soil ameliorating with PMS @ 0.1 LR resulted in 23 per cent yield increase (27 qha^{-1}) with ST @ 0.1 LR by 21.4 per cent (26.7 qha^{-1}), with ST @ 0.2 LR by 44 per cent (31.7 qha^{-1}) and with CS @ 0.2 LR by 37.7 per cent (30.3 qha^{-1}) compared to 22 qha^{-1} due to STD alone. Combined use of FYM @ 5 tha^{-1} with PMS increased the grain yield by 40 per cent (37.7 qha^{-1}) over PMS alone (27.0 qha^{-1}). Similarly mixing FYM with ST @ 0.1 LR by 20 per cent (32.0 qha^{-1}), ST @ 0.2 LR with FYM by 24 per cent (39.3 qha^{-1}) and CS @ 0.2 LR with FYM by 22 per cent (37.0 qha^{-1}) over ST @0.1 LR,ST @ 0.2 LR and CS @ 0.2 LR. Combined use of FYM with liming materials increased the usefullness of the liming materials (Table-4).These results indicate that combined use of inorganic and organic ameliorants are essential for better yield. These results are in aggrement with the results reported by Mishra and Pattanayak (2002) [6], Mishra, 2004 [4], Sharma and Sarkar (2005) [8], Sarkar (2013).

Table 4: Maize productivity under the influence of integrated use of lime sources and FYM

Treatments	Grain	Stover	Rachis	Spathe	Root	Total Biomass
	(q/ha)					
Absolute Control	11.3	9.4	2.7	2.9	0.1	26.4
STD	22.0	18.2	6.5	5.0	0.5	52.2
STD + PMS @ 0.1 LR	27.0	22.9	6.4	8.6	0.8	65.7
STD + PMS @ 0.1 LR + FYM	37.7	31.0	7.6	7.4	1.7	85.4
STD + ST @ 0.1 LR	26.7	21.7	5.5	4.8	1.1	59.8
STD + ST @ 0.1 LR + FYM	32.0	25.4	5.8	6.6	1.2	71.0
STD + ST @ 0.2 LR	31.7	26.4	6.1	6.8	1.1	72.1
STD + ST @ 0.2 LR + FYM	39.3	31.3	6.7	8.1	1.4	86.8
STD + CS @ 0.2 LR	30.3	24.4	6.0	6.4	1.2	68.3
STD + CS @ 0.2 LR + FYM	37.7	29.1	7.1	8.2	1.6	83.0
CD (P=0.05)	3.97	5.13	1.19	1.03	---	9.02
CV (%)	7.9	11.8	11.5	11.8	---	7.9

- **Stover yield**

The stover production of maize under different ameliorated treatments were less than the grain yield which varied between 9.4 and 31.3 qha^{-1} and followed similar trend as that of grain yield (Table-4). The grain to stover ratio in maize crop indicated that, the FYM integrated treatments maintained higher ratios than the FYM unintegrated treatments (Table-5). The rachis of maize cob (after grain separating) under different treatments varied between 2.7 and 7.6 qha^{-1}. The spathe (covering the cob) content also varied between 2.9 and 8.6 qha^{-1}. The root mass of the crop also exhibited differences under the influence of lime and FYM treatment, which varied between 0.1 and 1.7 qha^{-1}. All the INM treatments under study recorded higher HI than unintegrated one (Table-5).The total biomass production of maize crop significantly varied between 26.4 and 86.8 qha^{-1} under the influence of lime, FYM and fertilizers applications. Individual input had significant influence on biomass production (Table-4).

Table 5: Grain: Straw ratio, Harvesting Index (HI) and Relative Agronomic Efficiency (RAE) of Maizecrop as influenced by different liming materials.

Treatments	Grain: Straw	Harvesting Index (HI)	Relative Agronomic Efficiency (RAE)
Absolute Control	1.21	0.42	----
STD	1.20	0.42	100
STD + PMS @ 0.1 LR	1.18	0.43	152
STD + PMS @ 0.1 LR + FYM	1.22	0.45	228
STD + ST @ 0.1 LR	1.23	0.45	129
STD + ST @ 0.1 LR + FYM	1.26	0.45	173
STD + ST @ 0.2 LR	1.20	0.45	177
STD + ST @ 0.2 LR + FYM	1.26	0.46	234
STD + CS @ 0.2 LR	1.24	0.45	162
STD + CS @ 0.2 LR + FYM	1.27	0.45	219

Considering the efficiency of STD in biomass production taken as 100, the performance of other integrated treatments varied between 129 and 234 (Table-5). The performance of different treatments can be arranged as follows:
STD (100) < STD + ST @ 0.1 LR (129) < STD + PMS @ 0.1 LR (152) < STD + CS @ 0.2 LR (162) < STD + ST @ 0.1 LR + FYM (173) < STD + ST @ 0.2 LR (177) < STD + CS @ 0.2 LR + FYM (219) < STD + PMS @ 0.1 LR + FYM(228) < STD + ST @ 0.2 LR + FYM (234).

Conclusion

The FYM integrated treatments maintained higher clorophyll content (SPAD values) than FYM untreated one. However use of liming materials did not influence the recorded clorophyll content (SPAD values) much in the crop. The calcium silicate source applied @ 0.2 LR and the ST @ 0.2 LR when applied mixed with FYM recorded highest average growth rate of 3.9 cm day^{-1}. Liming of soil and their combined application with FYM resulted in increasing root length, cob length, diameter and seed weight cob^{-1} respectively. Inorganic (Lime) amelioration of acid soil resulted in 32 per cent higher yield compared to the yield of 22 qha^{-1} due to inorganic nutrition only. Combining organic amelioration (FYM) with inorganic amelioration measure and inorganic nutrition yielded 26 per cent higher grain yield in maize crop. Irrespective of the sources, the stromatolyte @ 0.2LR mixed with FYM produced higher grain and stover yields with higher relative agronomic efficiency.

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