

Original Research Article

<https://doi.org/10.20546/ijcmas.2018.702.276>

Effect of Basic Slag on Yield, Nutrient Status and Uptake by Paddy in Acid Soils of Karnataka, India

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ABSTRACT

Keywords

Basic slag, Lime, Paddy, Yield, Nutrient status, Nutrient uptake

Article Info

Accepted:

20 January 2018

Available Online:

10 February 2018

Soil acidity is an important agricultural problem while evaluating the production potential of most of the crops. A field experiment was carried out at Alasulige village of Sakleshpur taluk, Hassan district, Karnataka to utilize the basic slag as a soil amendment and source of nutrients in acid soil in comparison with lime. Liming materials viz., basic slag and lime were tried along with farmer's practice and RDF with RCBD design. The results of the experiment revealed that significantly higher grain (50.32 qha^{-1}) and straw (65.93 qha^{-1}) yield of paddy was recorded in treatment T_9 (100% RDF + basic slag @ 2 tha^{-1}) followed by T_{10} (100% RDF + lime @ 2 tha^{-1}). Similarly, higher nutrient uptake was recorded in treatment T_9 as compared to other treatments. Soil pH, available P_2O_5 , exchangeable Ca and Mg contents of the soil were increased and the levels of DTPA extractable Fe and Mn in soil were decreased in treatments receiving basic slag and lime as compared to farmer's practice. The study clearly indicated that in acidic soils, application of basic slag or lime @ 2 t ha^{-1} along with RDF is more beneficial in enhancing the crop yield as well as available nutrient status of soil.

Introduction

Rice (*Oryza sativa* L.) is an important cereal crop grown in India, contributing about 45 per cent to the total food grain production and staple food for more than 60 per cent of world population (Singh *et al.*, 2013). Among rice growing countries, India has the largest area (44.11 m ha) with a production and productivity of 105.48 m t and 2.39 t ha^{-1} respectively. In Karnataka, rice is grown in an area of 1.33 m ha with an annual production of 3.54 m t having average yield of 2.67 t ha^{-1} (MoA, 2016). Rice crop has got wide physical

adaptability. Hence, it is grown on diverse soil, climatic and hydrological conditions. Demand for rice is growing every year. To sustain present self-sufficiency of food and to meet future food requirements, India has to increase rice yield per unit area. Many abiotic and biotic factors such as such as drought, soil acidity, salinity, pests, and disease, are responsible for lower yield of crops. Soil acidity is an important yield limiting abiotic factors for crop production. In India acid soils occupy about 49 m ha area, of which 26 m ha has pH below 5.5 and 23 m ha has pH between 5.6 and 6.5 (Panda, 1979). In

Karnataka, nearly 9.6 m ha of area is acidic in nature (Ananthanarayana, 1969). Rice grown in acidic soils (pH <4.0) commonly encounter with several relatively severe mineral stresses. The H⁺ associated with soil acidity has indirect effects on mineral elements in low pH soils so that deficiencies of P, Ca, Mg, K, and Zn and toxicities of Al and Mn commonly appear (Clark *et al.*, 1999). In this context, use of appropriate management practices include management of soil pH, water management, supplying essential nutrients through proper inorganic and organic nutrient sources in adequate rates, at appropriate time has become an essential component in rice production. Liming is one of the well-known soil management practices used for amelioration of acid soils. Ground lime or agricultural lime, in the form of CaCO₃ or CaCO₃ + MgCO₃, has been the traditional material used for liming in acid soils. Now a day some industrial byproducts such as slag's from iron and steel industries, lime sludge from paper mills, cement kiln wastes *etc.* are also being used as liming agents. Basic slag is one such alkaline byproduct obtained from steel industry contains CaO, MgO, SiO₂ and micronutrients, such as copper, zinc, manganese and iron. Calcium and magnesium compounds, because of their basicity, improve soil pH and also serve as plant nutrients. According to Dent (1986) application of basic slag of steel industry is potential and cost effective in reducing soil acidity. The present investigation was carried out to study the amelioration capacity of basic slag and agricultural lime in acid soil and its influence on yield and nutrient uptake by paddy crop.

Materials and Methods

Site description

A field experiment was conducted during *Khari*, 2014 at Alasulige village which comes under hilly zone of Karnataka (Sakleshpura

taluk) to study the effect of basic slag and agricultural lime on soil properties, yield and nutrient uptake by paddy (*Oryza sativa* L.). The basic slag was obtained from Horsco Company, Hyderabad. Basic slag was alkaline in nature (pH 9.2) and contained about 24.8 per cent Ca, 10.08 per cent Mg, 0.62 per cent phosphorus and 8.2 percent silicon. Physico-chemical properties of the experimental site are presented in Table 1.

Experimental details

The experiment was laid out in a randomized complete block design with ten treatments replicated thrice. The treatment combination include, T₁ : Farmer's practice (FP-Only DAP), T₂ : FP + basic slag @ 2 t ha⁻¹, T₃ : FP + lime @ 2 t ha⁻¹, T₄ : Recommended doses of NPK (RDF), T₅ : 50 % RDF + basic slag @ 2 t ha⁻¹, T₆ : 50 % RDF + lime @ 2 t ha⁻¹, T₇ : 75 % RDF + basic slag @ 2 t ha⁻¹, T₈ : 75 % RDF + lime @ 2 t ha⁻¹, T₉ : 100 % RDF + basic slag @ 2 t ha⁻¹, T₁₀ : 100 % RDF + lime @ 2 t ha⁻¹. Farmer's practice comprises of application of 250 kg DAP ha⁻¹. The recommended dose of NPK for paddy is 100:50:50 kg NPK ha⁻¹. Basic slag and lime were applied to the soil fifteen days in prior to transplanting paddy seedlings and mixed thoroughly. At the time of planting, 50 per cent of nitrogen, and 100 per cent of phosphorus and potassium were applied and mixed well with the soil and remaining nitrogen was top dressed after first weeding (30DAP).

Soil and plant analysis

Grain and straw samples collected at the time of harvest were dried at 65°C in a hot air oven, ground and digested in di-acid mixture (HNO₃: HClO₄ in 10:4) by volume and the extract was analysed for P and K contents. Phosphorus was analyzed by vanado molybdate coloured method (Piper, 1966). N estimation was done using micro-kjeldahl N

distillation apparatus and K through flame photometer. The uptake of these nutrients by paddy crop was computed by using the following formula.

$$\text{Nutrient Uptake (kg ha}^{-1}\text{)} = \text{Nutrient concentration (\%)} \times \text{Biomass (kg ha}^{-1}\text{)} / 100$$

The post-harvest soil samples were analyzed for pH (Jackson, 1973), organic carbon (Walkley and Black, 1934), available N (Subbiah and Asija, 1956), phosphorus, potassium, exchangeable Ca and Mg (Jackson, 1973) and DTPA extractable Fe, Mn, Cu and Zn (Lindsay and Norwell, 1978) by using standard procedures. Fisher's method of analysis of variances was adopted for statistical analysis and interpretation of the data.

Results and Discussion

Effect on grain and straw yield

Data presented in table 2 indicated that application of basic slag and lime had significant effect on grain and straw yield of paddy. The higher grain (50.32 q ha⁻¹) and straw yield (65.93 q ha⁻¹) was recorded in treatment T₉ (100% RDF + basic slag @ 2 t ha⁻¹) followed by T₁₀ (100% RDF + lime @ 2 t ha⁻¹) and significantly differed with other treatments. These results demonstrated that a balanced fertilization of N, P and K coupled with liming are essential to obtain higher paddy yield in acidic soils. The yield benefits from the application of basic slag and lime can be ascribed to the lime induced changes in soil environment, especially increase in soil pH along with the associated improvement in nutrient availability, reduced Al toxicity and many other attributes of soil fertility (Manoj Kumar *et al.*, 2012). Vacharotayan *et al.*, (1984) reported that liming with N and P fertilizers resulted in the 37% additional increase of paddy yield compared to liming

alone. Bhat *et al.*, (2010) reported that liming with basic slag and calcite application improved availability of plant nutrients and yield attributing parameters of mustard, but increase was more with basic slag than with calcite.

Effect on nutrient uptake

Higher total uptake of nitrogen (101.90 kg ha⁻¹), phosphorus (20.20 kg ha⁻¹) and potassium (107.46 kg ha⁻¹) by paddy crop were recorded in treatment (T₉) receiving 100 % RDF + basic slag @ 2 t ha⁻¹ compared to all other treatments (Table 3). The lowest level of N, P and K uptake was found in case of T₁ (farmer's practice). Nutrient uptake is usually governed by the nutrient concentrations and dry matter yield. The absorption of nutrients depends on their ionic forms in the rhizosphere, which is influenced by soil acidity and the overall concentrations of nutrients in the soil (Masud *et al.*, 2014). The reduction in soil acidity might have increased the pH and availability of N and ultimately its uptake by the crop (Kihanda *et al.*, 1988). Liming increased root proliferation by reducing toxic effects of Al (Tang *et al.*, 2003) and thus enhanced the uptake of P and K (Chang and Sung, 2004), which attributed in increase in the yield of paddy.

Effect on soil pH and available nutrient status

Application of basic slag and lime @ 2 t ha⁻¹ has effectively increased pH (Fig. 1). However, the effect of lime on pH was slightly higher than basic slag. Increase in pH indicates that usefulness of basic slag as liming material for amelioration of acid soil. Further, the basic slag and lime treatments significantly increased available P, exchangeable Ca and Mg contents of soil. The available N and K contents did not show any significant difference between treatments (Table 4).

Table.1 Physico-chemical properties of experimental site

Soil properties	
Textural class	Loamy sand
B.D (g cc ⁻¹)	1.43
P.D (g cc ⁻¹)	2.42
pH (1:2.5)	4.92
EC (dSm ⁻¹)(1:2.5)	0.09
CEC [cmol(p ⁺)kg ⁻¹]	12.0
O.C (%)	0.50
Available N (kg ha ⁻¹)	298
Available P ₂ O ₅ (kg ha ⁻¹)	28.5
Available K ₂ O (kg ha ⁻¹)	182
Exchangeable Ca [cmol(p ⁺)kg ⁻¹]	1.40
Exchangeable Mg [cmol(p ⁺)kg ⁻¹]	0.6 0
DTPA extractable Fe (ppm)	125
DTPA extractable Mn (ppm)	9.40
DTPA extractable Zn (ppm)	3.10
DTPA extractable Cu (ppm)	0.84

Table.2 Influence of basic slag and lime treatments on grain and straw yield of paddy

Treatments	Grain yield (qha ⁻¹)	Straw yield (qha ⁻¹)
T ₁ : FP (Only DAP)	39.48	46.94
T ₂ : FP + basic slag @ 2 t ha ⁻¹	40.00	48.32
T ₃ : FP + lime @ 2 t ha ⁻¹	40.02	50.55
T ₄ : Recommended doses of NPK (RDF)	44.84	52.40
T ₅ : 50 % RDF+ basic slag @ 2 t ha ⁻¹	40.81	56.25
T ₆ : 50 % RDF+ lime @ 2t ha ⁻¹	40.70	55.72
T ₇ : 75 % RDF+ basic slag @ 2 t ha ⁻¹	44.19	60.58
T ₈ : 75 % RDF+ lime @ 2 t ha ⁻¹	44.70	60.78
T ₉ : 100 % RDF+ basic slag @ 2 t ha ⁻¹	50.32	65.93
T ₁₀ : 100 % RDF+ lime @ 2 t ha ⁻¹	49.96	62.01
SE.m±	1.7	3.4
CD @ 5%	5.0	10.0

Table.3 Effect of basic slag and lime treatments on nutrient uptake by paddy crop

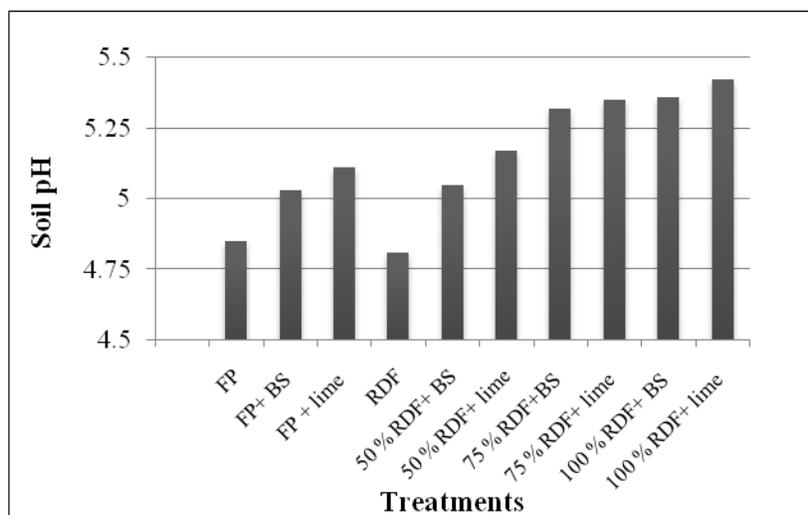
Treatments	Nitrogen			Phosphorus			Potassium		
	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total
	(kg ha ⁻¹)								
T ₁ : FP(Only DAP)	31.92	27.57	59.49	6.51	4.56	11.08	10.48	59.55	70.03
T ₂ : FP + basic slag @ 2 t ha ⁻¹	33.33	30.12	63.45	6.27	5.10	11.37	10.16	63.10	73.26
T ₃ : FP + lime @ 2 t ha ⁻¹	38.92	30.82	69.74	7.04	5.20	12.20	11.72	65.45	77.17
T ₄ : Recommended dose of NPK (RDF)	48.98	34.66	83.64	10.31	6.22	16.52	13.84	72.74	86.59
T ₅ : 50 % RDF+ basic slag @ 2 t ha ⁻¹	39.17	34.79	73.96	7.04	6.47	13.52	11.92	73.22	85.14
T ₆ : 50 % RDF+ lime @ 2t ha ⁻¹	39.46	35.12	74.59	7.74	5.48	13.22	11.36	74.38	85.75
T ₇ : 75 % RDF+ basic slag @ 2 t ha ⁻¹	49.03	39.53	88.57	10.37	7.31	17.69	13.17	82.57	95.75
T ₈ : 75 % RDF+ lime @ 2 t ha ⁻¹	45.09	38.77	83.86	9.28	6.89	16.18	11.37	82.97	94.34
T ₉ : 100 % RDF+ basic slag @ 2 t ha ⁻¹	56.38	45.52	101.90	11.61	8.59	20.20	15.79	91.66	107.46
T ₁₀ : 100 % RDF+ lime @ 2t ha ⁻¹	55.62	41.86	97.48	10.82	6.86	17.68	13.26	84.98	98.24
SE.m±	2.80	1.73	3.90	0.45	0.22	0.81	0.54	3.89	6.16
CD @ 5%	8.32	5.13	11.6	1.34	0.65	2.41	1.61	11.55	18.32

Table.4 Effect of basic slag and lime treatments on available nutrient status of soil after harvest of paddy crop

Treatments	Avail. N	Avail. P ₂ O ₅	Avail. K ₂ O	Exch. Ca	Exch. Mg	Fe	Mn	Cu	Zn
	(kg ha ⁻¹)			(cmol[p ⁺]kg ⁻¹)		(mg kg ⁻¹)			
	T ₁ : FP (Only DAP)	219.2	27.4	151.2	1.50	0.7	127.3	11.2	3.32
T ₂ : FP + basic slag @ 2 t ha ⁻¹	224.7	29.9	123.2	1.67	1.0	115.6	10.9	3.52	0.94
T ₃ : FP + lime @ 2 t ha ⁻¹	219.5	26.7	132.0	2.00	1.0	110.1	8.9	3.28	0.90
T ₄ : Recommended doses of NPK (RDF)	229.2	30.0	138.7	1.53	0.6	137.3	15.7	3.45	0.92
T ₅ : 50 % RDF+ basic slag @ 2 t ha ⁻¹	238.8	27.6	138.4	1.97	1.1	118.3	10.5	3.52	0.95
T ₆ : 50 % RDF+ lime @ 2t ha ⁻¹	228.3	29.7	140.0	1.83	1.0	117.4	9.2	3.26	1.00
T ₇ : 75 % RDF+ basic slag @ 2 t ha ⁻¹	227.7	31.0	147.2	2.63	1.1	119.8	10.4	3.53	0.97
T ₈ : 75 % RDF+ lime @ 2 t ha ⁻¹	237.9	29.9	140.0	2.47	1.0	114.1	9.0	3.36	0.93
T ₉ : 100 % RDF+ basic slag @ 2 t ha ⁻¹	228.3	33.8	132.0	2.33	1.2	109.5	10.4	3.31	1.02
T ₁₀ : 100 % RDF+ lime @ 2t ha ⁻¹	217.4	30.5	132.8	2.17	1.1	104.3	9.4	3.28	0.97
SE.m±	9.5	1.1	5.8	0.11	0.07	4.6	0.7	0.2	0.04
CD @ 5%	NS*	3.2	NS*	0.32	0.22	13.6	2.0	NS*	NS*

*NS-Non significant

Fig.1 Effect of basic slag and lime treatments on soil pH



*FP- Farmer's practice; RDF- Recommended Dose of NPK; BS- Basic slag; BS& lime applied @ 2tha⁻¹

Higher available status of phosphorus (33.8 kg ha⁻¹) after harvest was recorded in T₉ (100 % RDF+ basic slag @ 2 t ha⁻¹). This treatment was significantly differed from rest of the treatments except T₇ (75 % RDF+ basic slag @ 2 t ha⁻¹). The highest exchangeable Ca (2.63 cmol [p⁺] kg⁻¹) and exchangeable Mg (1.2 cmol [p⁺] kg⁻¹) contents were found in treatment T₇ and T₉, respectively compared to all other treatments. The increase in available P content of the soil might be due to increased soil pH upon liming. The basic slag and lime upon dissolution released a large amount of Ca and Mg which neutralized soil acidity by displacing the aluminum, hydrogen and iron ions, which are prevalent in acid soils thus increasing soil pH and consequent increase in P, Ca and Mg in soil. Since basic slag contains appreciable amounts of P that could contribute to the increasing trend in available P in basic slag treatments over lime treatments. Takahashi *et al.*, (1990) reported the silicate ion can replace and release the phosphate ion fixed in the soil, thus increasing the amount of phosphate available to the plant. This is in agreement with the result of Ali and Shahram (2007) who reported that converter slag proportionately enhances the P availability in acid soil.

Application of basic slag and lime significantly decreased the levels of DTPA extractable Fe and Mn contents whereas, DTPA extractable Cu and Zn contents of the soil differed non-significantly.

Similar effect of liming materials in reducing levels Fe and Mn content in soil has reported by Takac *et al.*, 2009 and Tang *et al.*, 2003.

Results of the study indicated a promising potential for basic slag to be used as an alternative to lime for amelioration of acid soils. Results also showed that the combined application of basic slag or lime @ 2 t ha⁻¹ along with RDF (NPK) was more beneficial in improving available nutrient of status of acid soil and thus enhancing crop yield and uptake of nutrient by paddy plants.

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How to cite this article:

Mamatha, D., R.C. Gowda and Shivakumara, M.N. 2018. Effect of Basic Slag on Yield, Nutrient Status and Uptake by Paddy in Acid Soils of Karnataka, India. *Int.J.Curr.Microbiol.App.Sci.* 7(02): 2286-2292. doi: <https://doi.org/10.20546/ijcmas.2018.702.276>