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SHORT COMMUNICATION

Impact of Bagasse and Press Mud on Availability and Fixation Capacity of Phosphorus in an Inceptisol of North India

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Abstract An incubation experiment was carried out at the Indian Agricultural Research Institute, New Delhi, India to explore the possibility of utilizing the organic residue i.e. press mud and bagasse byproducts generated from sugar industries to enhance the availability and reduction in fixation capacity of phosphorus (P). Three levels of organic residue (mixing press mud, bagasse and chopped rice straw in the ratio of 1:1:1) was applied at 0, 2.5 and 5 g/kg of soil with two levels of phosphorus i.e. 0 and 10 mg P_2O_5/kg of soil. Incorporation of organic residue enhanced the availability of P by 68 % over the control. Maximum P availability was observed after 11th month in maximum organic residue treatment. Phosphorus fixation capacity also decreased from 43 % (control) to 32 % (5 g/kg of soil). But the P fixation capacity increased with increasing level of P, due to easy availability of P for fixation. Use of the bagasse and press mud can be a good source of P mineralization in the already P fixed soil. It also reduced the storage problem in sugarcane industries across the India.

Keywords Bagasse · Press mud · Organic residue · Available P · Phosphorus fixation capacity

Sugarcane industries are one of the most important agricultural industries across the globe (Chand et al. 2013). In last five decades, Indian sugar production share has gone up from 5 to >15 % in global sugar production. India is the second largest producer of sugar in the world and its global level share is >20 % in cane sugar production. Sugar consumption in India is growing more as compared to global average. More disposable income, better lifestyle and growth in gross domestic product support more consumption in India. All over the country more than 527 sugar mills operate in 2011–2012. Most of the mills located in the rural heartland, directly contributes to rural economic development and employment. But it produces a huge amount of byproducts like bagasse and press mud and leads to storage problem. It is now realized to produce many value added products by diversification and utilizing the by-products of the sugar industry (Chand et al. 2011), instead depending on just one product i.e. sugar (Godshall 2004). Sugar cane is a versatile crop being a rich source of food (sucrose, jaggery and syrups), fiber (cellulose), fodder (green leaves and tops of cane plant), fuel and chemicals (bagasse, molasses and alcohol). In a typical Indian sugar factory processing of 100 tonnes of cane produces about 30 tonnes of bagasse and 3 tonnes of press mud (Verma et al. 2012). The annual availability of major sugarcane by-products in India is more than 45–55 million tonnes bagasse and 8–10 million tonnes press mud. Generally it contains, 2.5–5 % in bagasse and 5–15 % sugar in press mud with appreciable amount Si, Ca, P_2O_5, MgO, Fe and Mn, etc. (Yadav and Solomon 2006). Both byproducts dominated by the microflora, Bacili and Actinomycetes increases the plant nutrient in soil as well as the stability of soil aggregates. Decomposition of bagasse and pres mud by microbial action enhanced the organic acids into the soil. These organic acids compete for the phosphorus (P) binding sites for fixation. Phosphorus is the one of the important plant nutrient, with 15–20 % use efficiency. More than

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80 % applied P fertilizer during crop production is fixed into plant unavailable form in the soil. Use of sugarcane industries byproduct bagasse and press mud enhanced the P concentration in soil solution. It increased the phosphorus use efficiency in crops. Use of the bagasse and press mud reduced the P fixation capacity and enhanced the P uptake in wheat crop (Dotaniya et al. 2012). This is eco-friendly and economically viable technologies to mobilize residual P compounds (reaction products) which is highly desirable. The current investigation was thus planned with an objective to study the effect of the incorporation of sugar cane industry byproducts with rice straw on the phosphorus fixation capacity behavior and soil solution P.

A laboratory incubation experiment was conducted for one year to study the effect of organic residue on availability and fixation capacity of P in soil. For this purpose, a bulk soil samples were collected from a research farm of the Indian Agricultural Research Institute (IARI), New Delhi, India. A series of 80 g processed soil was taken into 100 ml plastic beaker. Experimental soil was silt loam in texture and belongs to Holambi series, *Typic Haplustepts*. Initial pH, organic carbon, available nitrogen, available phosphorus and available potassium content were 8.2, 0.31 %, 180 kg/ha, 19.2 kg/ha and 302 kg/ha, respectively. Organic residue was prepared by mixing of press mud, bagasse and chopped rice straw in the ratio of 1:1:1 (by weight). It contained 1.1 % N, 0.2 % P and 0.3 % K and was incorporated for 1 year. It was applied as three doses viz. 0, 2.5 and 5 g/kg of soil. Two doses of phosphorus were also applied as 0 and 10 mg P_2O_5/kg of soil. The moisture content at field capacity (1/3 bar) level and temperature was maintained at 25 °C. Intermittently soil sampling was done at an interval of 1 month time interval, air dried under shed and ground with a wooden roller and then passed through a 2 mm sieve and stored in labeled polythene bags in dry place. These samples were subsequently used for chemical analysis. Available phosphorus in the soil was extracted by 0.5 M $NaHCO_3$ adjusted to pH 8.5 as per the method of Olsen et al. (1954) and P in the aliquot was determined by developing blue color by the ascorbic acid method. Determination of the P fixation capacity of soil was done by Waugh and Fitts (1966). In this procedure, the soil samples were treated with graded doses of P and incubated for 72 h to allow maximum fixation. The soil was then extracted with Olsen reagent and P determined. The recovery of P was subtracted from the added P and the retained or fixed P was calculated. The amount of fixed P from different doses of P was plotted against applying P and the curve was fitted to a trend line and the equations and R^2 value were obtained. The slope of the line was multiplied by 100 to get fixation capacity. The experiment was carried out in Completely Randomized Design with three replications. Analysis of variance was followed to elucidate the effect of organic residue, phosphorus levels, and time interval on availability and fixation capacity of P (Snedecor and Cochran 1967). MSTAT-C package used for analysis with a 1 % level of significance.

There was a significant increase in available P due to the addition of organic residue as well as phosphorus. Increasing residue levels from control to higher levels, P availability increased 14.2 % (in 2.5 mg P/kg) and 68 % (in 5 mg P/kg). However, the interaction effect of added phosphorus and residue was significant (average over all the time periods) (Table 1). Yadvinder-Singh et al. (1988) reported a progressive increase in P availability only after 30 days of incorporation of both rice straw and wheat straw. Availability of P from organic residue depends on C: N ratio of the applied material, if it is in lower side it enhanced the P concentration in soil solution. In bagasse and press mud contains sugar enhanced the microbial decomposition and thus P release in soil (Eghball et al. 1996). The available P was measured 25.7 mg/kg when applied at 10 mg P_2O_5/kg of soil, where as in control it was only 23 mg/kg. Addition of inorganic phosphorus enhanced the P concentration in the soil solution (Dotaniya et al. 2013). Increasing the time interval available P initially decreased but after 5th month onward increased significantly from an initial value of 19 mg P/kg with time attained a maximum value 24.3 mg/kg at 11 months (Fig. 1). The organic residue addition enhanced the microbial activity in soil, which resulted as P immobilization. But after a period microbial decomposition rate greater than immobilization, enhanced the available P in soil. The P availability in soil enhanced by the effects of residue and hence carboxylates can be grouped into direct and indirect effects. The direct effects generally result in an immediate P release. They refer to the blocking of P adsorption sites (ligand exchange), oxide dissolution by complexing Al or Fe held in minerals or mobilization of P held in metal–humic substances (Staunton and Leprince 1996).

Incorporation of organic residue decreased the phosphorus fixation capacity (average over all the time periods) 43 % (control) to 32 % (5 g/kg of soil) by the application of organic residue (Fig. 2). Addition of organic residue in the soil; it decomposed by soil microflora, and produced organic acids, which fix on the P binding sites of clay and reduced P fixation capacity. During incubation the phosphorus fixation capacity increased with P application viz. 0–10 mg P_2O_5/kg i.e. from 39 to 44 % (Fig. 3). The fixation of 39 % in control was due to the fixation of native P. Application of inorganic fertilizer enhanced the amount of P in soil solution for the easily fixation. Immobilization of soil P due to a wider C:P ratio of residue could be efficiently managed by inorganic fertilizers. The effect of fertilizer application increase P availability is so pronounced that P accumulation caused by the continual application of fertilizers has become a concern in certain geographical regions (Gburek et al. 2000). The interaction

Table 1 Effect of phosphorus and organic residue levels on available phosphorus (mg/kg) in soil

Phosphorus level (mg P_2O_5/kg of soil)	Organic residue (g/kg of soil)			Mean
	0	2.5	5	
0	16.0	23.1	29.9	23.0
10	22.3	20.5	34.3	25.7
Mean	19.1	21.8	32.1	
LSD ($P < 0.01$)	Phosphorus = 2.4			
	Organic residue = 2.5			
	P × Organic residue = 5.4			

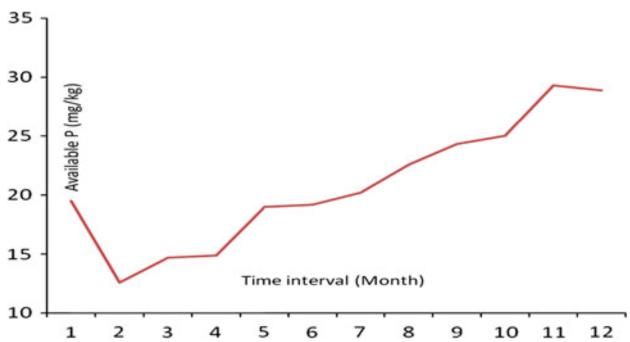

Fig. 1 Effect of time intervals on available phosphorus (mg/kg) in soil

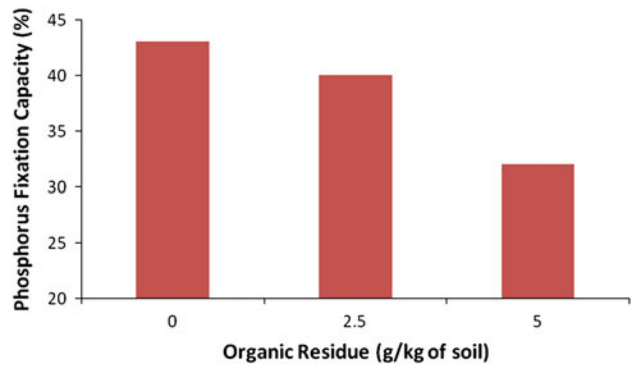

Fig. 2 Effect of organic residue on phosphorus fixation capacity in soil

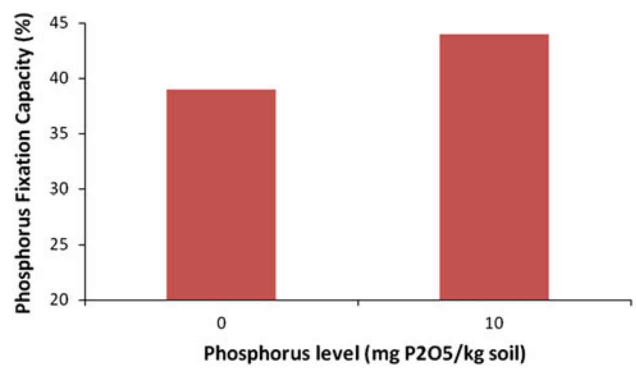

Fig. 3 Effect of phosphorus levels on phosphorus fixation capacity in soil

between time of application and the residue amount was found to be significant and it's initial P fixation but after 5 month availability was more in 10 mg P_2O_5/kg. The integrated use of inorganic fertilizers and on farms available natural resources such as crop residues and organic manures may be effective to improve the bio-availability of residual soil P (Salas et al. 2003). Addition of organic residue enhanced the soil organic carbon in soil and accelerated the microbial activities in soil. Soil microbial diversity as well as microbial population enhanced due to easily available carbon as a food material (Singh et al. 2009). During the organic matter decomposition by soil microbes, it secreted a range of organic acids, which play a crucial role to convert immobile phosphorus into plant available phosphorus. Addition of organic residues reduced phosphorus fixation capacity of soil because secreted organic acid molecules compete for the P fixation sites in soil particle surface (Dotaniya 2012).

Sugarcane industries producing huge amount of bagasse and press mud annually. It's creating storage problem mostly in major industries. It contains plant nutrient as well as sugar, which could be a source of P mineralization from in situ immobilized P in crop fields. Use of both the byproducts enhanced available P as well as decreased phosphorus fixation capacity. Addition of bagasse and press mud enhanced P availability by 68 % over the control in soil solution and reduced P fixation capacity from 43 % (control) to 32 % (5 g/kg of soil). Use of these byproducts one way solved the storage problem and in another way reduces the fertilizer application during crop production.

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