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Short communication

Dry matter production of rice as influenced by soil amelioration in acid soils

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Abstract

In Kerala, except for a small area of black soil in Chitoor, the entire soil is acidic. Liming is a dominant and effective practice to overcome constraints and improve crop production on such soils. A field experiment was conducted during January to May, 2013 at College of Horticulture, Vellanikkara to study the effects of soil ameliorants on rice crop. Calcium oxide (CaO) @ 377 kg ha^{-1} together with FYM and NPK, and 'Mangala setright' @ 774 kg ha^{-1} enhanced the soil pH from an initial 5.3 and maintained it above 6.0, which is considered good for rice. The treatments also resulted in significantly higher root weight, root spread and leaf chlorophyll content. The treatment which received the recommended package of practices for rice cultivation resulted in a significantly higher rice dry matter production at all the growth stages. Ameliorants other than dolomite created a favourable soil environment with an optimum pH and nutrient content which resulted in greater nutrient uptake by crop and consequent development of chlorophyll, enhanced photosynthesis and ultimately higher dry matter production.

Keywords: Soil ameliorants, Acid soil, Toxicity, Soil pH, Rice dry matter production, Rice chlorophyll content

Substantial portion of rice growing areas in India is comprised of acid soils. Soil acidity and associated low fertility and mineral toxicities are major constraints to agricultural production. On acid soils, iron toxicity is one of the most important constraints to rice production, together with Zn deficiency, which is the most commonly observed micronutrient disorder in wetland rice (Neue et al., 1998). Being in the humid tropics and lateritic belt, more than 68% of Kerala soil is acidic except for a small area of black soil of Chitoor in Palakkad district. Highly acidic *Kari* soils with pH as low as 2.6 is found at Kallara in Kerala (Marykutty and Aiyer, 1987). In acid soils, phosphorus becomes immobile and unavailable to plants due to low pH and dominance of active forms of Al and Fe (Dixit, 2006). Rice produces very low yield in highly acidic soils due to the inhibiting influences produced by specific elements. High leaf content of any nutrient either in the soil or in the plant is not an index of high yield (Bridgit, 1999). Management for yield improvement should involve the diagnosis of the inhibiting factors and adoption of measures to ameliorate soil environment**.** The addition of lime, basic slag, or manganese dioxide (MnO_2) exert significant influences so as to decrease the S content, increase the soil solution pH, and optimize elemental concentrations in the plants and soil solutions (Khan et al., 1994). Calcium is referred to as 'liming element' because it is added to amend soil pH and plays a greater role in neutralizing the acid forming effects of H^+. Several natural materials, industrial by-products and commercial products are available for use as soil ameliorants. In this context the relative efficiency of various natural soil ameliorants such as lime and dolomite, and a commercial product

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Table 1. Effect of soil ameliorants on soil pH and root characteristics of rice

Treatments		Soil pH 25 DAT	Root weight (g hill^{-1})	Root spread (cm)
T_1	CaO 377 kg ha^{-1} + NPK	6.22^{ab*}	7.63^{ab}	30.50^{a}
T_2	Dolomite 676 kg ha^{-1} + NPK	5.84^{bcd}	6.27^{abc}	28.93^{ab}
T_3	'Mangala setright' 774 kg ha^{-1} + NPK	6.03^{bcd}	7.57^{ab}	29.17^{ab}
T_4	CaO 377 kg ha^{-1}	5.99^{bcd}	4.53^{cd}	23.33^{cd}
T_5	Dolomite 676 kg ha^{-1}	5.73^{bcd}	2.77^{d}	21.37^{d}
T_6	'Mangala setright' 774 kg ha^{-1}	5.99^{bcd}	4.87^{cd}	23.90^{cd}
T_7	NPK only	5.51^{cd}	3.10^{d}	24.40^{cd}
T_8	5t FYM + CaO 377 kg ha^{-1} + NPK**	6.55^{a}	8.30^{a}	31.23^{a}
T_9	Absolute control	5.58^{d}	2.5^{d}	23.50^{cd}

* The values followed by same superscript do not differ significantly
**POP recommendation for rice in Kerala

'Mangala setright' in modifying the soil pH, and consequent improvement in rice productivity was studied.

A field experiment was conducted in the rice field of Department of Agronomy, College of Horticulture, Vellanikkara during January to May 2013. The initial pH was 5.31. The soil had 0.98 % organic carbon and available forms of 299 kg N, 34.66 kg P_2O_5, 105.06 kg K_2O ha^{-1} and 599 mg kg^{-1} Ca, 23.00 mg kg^{-1} Mg, 7.08 mg kg^{-1} S, 1413.00 mg kg^{-1} Fe, and 75.40 mg kg^{-1} Mn. Jyothi, a red kernelled, short duration variety was used for the experiment. The experiment was laid out in randomized block design with 3 replications. Transplanted rice was grown at 15 cm x 10 cm in 5.0 m x 4.0 m plots. There were 9 treatments which are detailed in the tables. For treatments T_1 to T_6 and T_8 the quantity of ameliorants were fixed as the equivalent to 600 kg ha^{-1} of $CaCO_3$, which is the recommendation for liming acid soils in Kerala (KAU, 2011). The $CaCO_3$ equivalences of CaO, dolomite, 'Mangala setright' are 159%, 88.5%, 77.5%, respectively. 'Mangala setright' is a commercial ameliorant produced by Mangalore Chemicals and Fertilizers Ltd. which contains 20% Ca, 6.8% Mg and 6.4% S. Ameliorants were applied in two doses: 2/3rd as basal and 1/3rd before the first top dressing of fertilizers. Supply of nutrients was based on the existing package of practices (POP) recommendations for rice i.e., 90:45:45 kg N, P_2O_5, and K_2O ha^{-1}. Urea, rajphos and muriate of potash were used as the sources of nutrients. Nitrogen and potassium were applied in three equal split doses, first as basal dressing, second at tillering stage and the third at panicle initiation stage. The full dose of phosphorus was applied as basal dressing. T_8 is the entire Package of Practices (PoP) recommendation for rice nutrition. T_9 is the absolute control where no ameliorants, organic manure or fertilizer is applied. Statistical analysis of data was done by using statistical package MSTATC.

The initial soil pH of 5.31 is normally considered unsuitable for optimum rice growth. pH values at 25 DAT showed noticeable improvement in all treatments, even in the control (Table 1). This increase noticed in all treatments may be attributed to the fact that continuous submergence of soil, as is practiced in rice cultivation, may bring the soil pH towards neutrality. After soil water logging, the pH tends to coverage to neutrality irrespective of initial pH, whether acidic or alkaline (Ponnamperuma, 1972). CaO @ 377 kg ha^{-1} + NPK (T_1) or with FYM (T_8), and 'Mangala setright' at 774 kg ha^{-1} (T_3) maintained a pH of more than 6, which is considered good for rice grown in acidic lowlands. The root weight and root spread (Table 1) were significantly lower in the treatments where the soil was not ameliorated. Fertilizer application without amelioration also resulted in reduced root weight and root spread. The PoP recommendations for rice resulted in significantly higher root weight and root spread, however the amelioration

Table 2. Effect of soil ameliorants on chlorophyll content and dry matter production

Treatments		Chlorophyll content (60 DAT) (mg kg^{-1})		Dry matter production (Mg ha^{-1})		
		Chl a	Chl b	30 DAT	60 DAT	Harvest
T_1	CaO 377 kg ha^{-1} + NPK	2.36^{ab*}	0.58^{a}	0.98^{c}	8.22^{a}	12.26^{a}
T_2	Dolomite 676 kg ha^{-1} + NPK	1.95^{abcd}	0.47^{a}	1.25^{ab}	7.71^{abc}	11.94^{b}
T_3	'Mangala setright' 774 kg ha^{-1} + NPK	2.31^{ab}	0.53^{a}	1.03^{bc}	8.48^{a}	13.71^{a}
T_4	CaO 377 kg ha^{-1}	1.99^{abcd}	0.45^{a}	0.93^{c}	8.19^{a}	10.09^{bc}
T_5	Dolomite 676 kg ha^{-1}	1.36^{d}	0.48^{a}	0.89^{c}	6.51^{bc}	9.47^{c}
T_6	'Mangala setright' 774 kg ha^{-1}	1.75^{bcd}	0.54^{a}	0.88^{c}	7.79^{abc}	9.70^{bc}
T_7	NPK only	1.50^{cd}	0.41^{a}	1.24^{ab}	7.53^{abc}	12.06^{b}
T_8	5t FYM + CaO 377 kg ha^{-1} + NPK**	2.62^{a}	0.68^{a}	1.31^{a}	8.75^{a}	13.18^{a}
T_9	Absolute control	1.37^{d}	0.37^{a}	0.84^{c}	6.24^{c}	8.27^{c}

* The values followed by same superscript do not differ significantly

**PoP recommendation for rice in Kerala

treatments together with fertilizer application were at par. Restricted root formation in unameliorated treatment may be due to the high deposition of Fe and Mn on root surface. These elements occur in toxic concentrations in acid soils. According to John et al. (2001), toxicities of Fe, Al, and Mn limit crop production in laterites and these nutrient imbalances are to be rectified for sustaining crop production.

Leaf chlorophyll content is considered as a good indicator of plant growth. The variations in chlorophyll contents and dry matter production with the treatments are presented in Table 2. Present POP for rice nutrition (T_8) resulted in significantly high chlorophyll 'a' and highest chlorophyll 'b', closely followed by the treatments receiving CaO @ 377 kg ha^{-1} (T_1) and 'Mangala setright' @ 774 kg ha^{-1} applied with fertilizers (T_3). Soil amelioration with dolomite was on par with the non - application of ameliorants in the acidic rice soil, however amelioration with CaO and 'Mangala setright' improved the chlorophyll 'a' content. Though chlorophyll 'a' is the precursor for production of chlorophyll 'b', significant differences as seen in the case of chlorophyll 'a' was not observed for chlorophyll 'b'. The lowest chlorophyll content was observed in the absolute control treatment, but was improved when ameliorants alone or with fertilizers were applied. Fe and Mn contents of rice in non ameliorated treatments were significantly higher than that of ameliorated ones (data not presented). Bridgit and Potty (1992) have reported that high concentration of Fe in the leaf led to low content of chlorophyll 'a' which contributed to low yield.

The treatment which received POP for rice nutrition (T_8) resulted in steady improvement in rice dry matter production at all growth stages, and was significantly higher than the other treatments. The dry matter production in 'Mangala setright' @ 774 kg ha^{-1} and CaO @ 377 kg ha^{-1} with fertilizer application (T_3 and T_1) were on par at 60 DAT and harvest and significantly greater than that with dolomite, an ameliorant which contains Mg too. Apart from the amelioration effects, the presence of all the secondary nutrients viz., Ca, Mg and S might have contributed to the better performance of 'Mangala setright' than CaO, though both were on par.

The enhanced dry matter production is the result of higher root growth and root spread and leaf chlorophyll content. The volume of soil explored for nutrients is increased when the root spread is increased. The increase in root weight is the resultant of greater number, length and thickness of roots. Only a favourable soil environment with an optimum pH and nutrient content can result in greater nutrient uptake by crop and consequent chlorophyll development, enhanced photosynthesis and ultimately higher dry matter production. Soil amelioration positively influences the physiology and growth of rice.

The study revealed the lower efficiency of dolomite, which is the recommended soil ameliorant in acid soils of Kerala, due to its delayed solubility. 'Mangala setright' at the recommended calcium carbonate equivalent can be used as a liming material for correction of soil acidity and improving rice growth in acidic lowlands.

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