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RHA-based Waste Recycling: A Cheap Alternative for Improving Phosphorus Availability While Restoring Acid Soils

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ABSTRACT

Soil acidity constrains crop productivity in the northern floodplain regions of Bangladesh under intensifying cropping, where yields often decline despite increased fertilizer inputs. Acid soil limits the availability of essential plant nutrients and may induce toxicity. Given the inconsistent supply and quality of conventional liming materials, rice husk ash (RHA) was evaluated as an alternative for managing soil acidity and increasing phosphorus availability. A three-month laboratory incubation study (25-30°C); soils maintained at field capacity) was conducted using composite soils from Rangpur (AEZ 2) and Kurigram (AEZ 3) to assess the changes in soil pH and available P following application of RHA and dololime at graded rates 0 to 4.0 t ha^{-1} equivalents with three replications. Treatment effects were analyzed statistically at the end of the incubation period. Soil incubation with Dololime at 2.0 t ha^{-1} delivered the strongest pH correction, raising pH to ~6.8 in Rangpur and in Kurigram. High rates of RHA also increased pH to a favorable range for crop production; @4.0 t ha^{-1}, the pH increased to 6.18 in Rangpur and 6.02 in Kurigram. Incubation results showed a significant increase in soil pH and enhanced P availability after amendment, confirming a strong link between pH correction and improved P dynamics in soil. Long-term trials integrating economic, biological and physical soil indicators are recommended to optimize the amendment strategies (quantify residual effects and application intervals) for the acid soils of Bangladesh.

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Introduction

Soil acidity is one of the most serious challenges to agricultural production worldwide, particularly in developing countries (Temesgen et al., 2017; Ma et al., 2022). Globally, about 30% of the ice-free land, including a large proportion of agricultural land, is affected by soil acidity, which can limit agricultural productivity and cause environmental challenges (Gurmessa, 2021). It is primarily distributed in tropical and subtropical regions, where population growth is rapid and demand for food and fiber is increasing. The primary causes of soil acidification in croplands include cation removal by crop uptake, acid deposition, root-secreted acids, and the excessive application of chemical fertilizers, particularly nitrogen fertilizers (Brady and Weil 2015, Guo et al. 2010). Soil acidification deteriorates soil physical, chemical, biological, and fertility properties, thus reducing crop yield and grain quality (Butterly et al., 2022). Bangladesh's soils generally range from acidic to neutral, with pH values between 4.0 and 7.0, except for the Gangetic alluvial plains, which are mostly alkaline. The Soil Resource Development Institute (SRDI) reported that between 1998 and 2010, approximately 466,540 hectares of land transitioned into strongly acidic categories due to intensified agricultural practices (Bodruzzaman et al., 2014). At present, more than 40% of the country's arable land is affected by acidity constraints, classified as very strongly acidic (pH < 4.5), strongly acidic (pH 4.5-5.5), or slightly acidic (pH 5.5-6.5). The soils in these regions are typically light-textured and low in organic matter content (Zahid et al., 2020). Acidic soils are a major constraint to crop cultivation worldwide, reducing nutrient availability, increasing aluminum toxicity, and hindering plant growth. Soil acidity limits phosphorus uptake and root development, leading to yield decline and poor grain quality (Jeannette et al., 2025). Phosphorus fixation is a major constraint to crop production in acid soils (Gomes et al., 2018). Both acid and alkaline soils cause phosphorus fixation. Formation of aluminium-, iron-, and manganese-phosphates under acid soils makes P unavailable, while formation of calcium-, and magnesium-phosphates under alkaline conditions causes P fixation (Brady and Weil, 2017). Therefore, Brady and Weil (2017) stated that if the soil pH is suitably adjusted for phosphorus, the other plant nutrients, if present in adequate amounts, will be satisfactorily available in most cases.

Liming is a proven agronomic practice for correcting soil acidity and restoring fertility. Application of lime materials such as dolomite or calcite raises soil pH, neutralizes toxic aluminium and manganese ions, and enhances the availability of phosphorus, calcium, magnesium, and molybdenum (Bodruzzaman, 2010; Enesi et al., 2023). Numerous studies have confirmed the positive impact of liming on crop yields and soil health (Shaheb et al., 2014; Boru and Misgan, 2025). However, adoption of liming practices remains limited due to cost barriers, lack of awareness, and poor access to quality lime. As an alternative, rice husk ash (RHA), a byproduct of rice parboiling, has shown promise as a low-cost liming agent. RHA samples have a pH range of 8.0 - 9.5 and are rich in essential nutrients including phosphorus, potassium, sulphur, zinc, calcium, magnesium, and silicon (Ullal et al, 2022). Its dual role as a liming material and nutrient source makes RHA a viable option for restoring acid soils in intensive cropping systems. However, in Bangladesh, the availability and quality of conventional liming materials are often inconsistent, limiting their widespread and effective use. In this context, alternative amendments such as RHA have gained attention for their dual role as liming agents and sources of essential plant nutrients. RHA, a byproduct of rice milling and combustion, is rich in silica and contains appreciable amounts of potassium, calcium, and magnesium that can neutralize soil acidity and improve phosphorus availability (Nwite et al., 2011; Saranya, et al., 2018).

Materials and Methods

Composite soil samples were collected from each agro-ecological zone (AEZ 2 and AEZ 3) at 0-15 cm depth using a stainless-steel auger. At each site, soil from ten randomly selected locations was combined to form a composite sample. Samples were air-dried, gently crushed, passed through a 10-mesh sieve, and stored in airtight plastic containers prior to incubation. Approximately 5 kg of soil was collected from each site and thoroughly mixed to form a composite sample for that site. The collected soil samples were transported to the Soil Health and Food Safety Laboratory in the Department of Soil Science at Bangladesh Agricultural University for processing. In the laboratory, the soil samples were cleaned to remove plant debris and Air-dried at room temperature. The soils were ground using a mechanical grinder, sieved through a 10-mesh sieve, and stored in airtight plastic containers for experimentation.

Initial Soil Analysis

Prior to the initiation of the field experiment, a comprehensive baseline soil characterization was conducted to assess the fertility status of the experimental sites. The soil samples were kept in plastic bags for analysis of physical and chemical properties. Particle size distribution (% sand, % silt, and % clay) was measured by using the hydrometer method (Gee and Bauder 1986). Soil pH was measured in a 1:2.5 soil-to-water suspension using a calibrated glass electrode pH meter at room temperature (Jackson, 1962). Each sample was measured in triplicate to ensure accuracy. Soil pH is a fundamental indicator for shaping nutrient availability. For available phosphorus, extraction was done using 0.03 N NH_4F and 0.025 N HCl. Finally, phosphorus was determined by measuring molybdate blue colour in the ascorbic acid method in a spectrophotometer at 660 nm wavelength (Bray and Kurtz, 1945). Organic carbon was determined by the wet oxidation method. The oxidation of organic C was done with an excess 1.0 N $K_2Cr_2O_7$ in the presence of concentrated H_2SO_4 and concentrated H_3PO_4 and the excess $K_2Cr_2O_7$ was titrated with 1N $FeSO_4$. To obtain the organic matter content, the value of organic C was multiplied by van Bammelen factor (1.73) and the results were expressed in percentage (Walkley & Black, 1934). Exchangeable calcium (Ca) and magnesium (Mg) were extracted by repeated shaking and centrifugation of the soil with neutral 1.0 M NH_4OAc followed by decantation. The Ca & Mg concentrations in the extractant were determined by atomic absorption spectrophotometer (AAS), as outlined by Knudsen et al. (1982).

Laboratory incubation

A three-month incubation experiment was conducted under controlled laboratory conditions (25-30 °C). Soil moisture was maintained at field capacity throughout the incubation period. Two amendments Rice Husk Ash (RHA) and dololime, were evaluated at rates equivalent to 0, 1.0, 2.0, and 4.0 t/ha. The treatments consisted of a control, three RHA rates, and three dololime rates, arranged in a completely randomized design with three replications per treatment for each soil type. Each experimental unit contained 200 g of processed soil placed in a 500 mL plastic container. Amendments were thoroughly mixed with soil, and moisture loss was compensated by periodic weighing and rewetting at five-day intervals. At the end of incubation, soils from the mesocosms were collected, prepared, and analyzed for pH and available phosphorus using the same method described earlier.

Statistical analysis

The significance of treatment effects on soil properties was determined using analysis of variance (ANOVA) for a Complete Randomized Design (CRD). Where the F test was significant, treatment means were separated by Duncan's Multiple Range Test (DMRT) using the statistical package Minitab 17 at 5% level of significance.

Results

Soil and RHA Characterization

Soils collected from Kurigram and Rangpur were silt loam and had similar acidity, with pH 5.0 and 5.1, respectively. The organic carbon content of the two soils did not vary that much, 0.81 in Kurigram and 0.87 in Rangpur. The available P, Ca, and Mg of the soils were 22.69 mg kg-1, 5.85 mg kg-1, and 1.12 mg kg-1, respectively, in Rangpur and 17.5 mg kg-1, 6.22 mg kg-1, and 1.34 mg kg^{-1}, respectively, in Kurigram.

Table 1. Characterization of initial soils

Soil properties	Kurigram	Rangpur
Soil Texture	Silt loam	Silt loam
pH	5.0	5.1
Organic C (%)	0.81	0.87
Available P (mg kg^{-1})	22.69	17.5
Available Ca (mg kg^{-1})	5.85	6.22
Available Mg (mg kg^{-1})	1.12	1.34

RHA was sourced from the rice boiler in Rangpur. The pH of the RHA was strongly alkaline and it is a rich source of P, Ca and Mg, with their concentrations 575mg kg^{-1}, 7868 mg kg^{-1} and 2500 mg kg^{-1}.

Table 2. Characterization of rice husk ash (RHA)

Chemical composition	RHA
pH	8.3
Total P (mg kg^{-1})	575
Total Ca (mg kg^{-1})	7868
Total Mg (mg kg^{-1})	2500

Use of Lime and RHA for managing soil pH

The soils at both study sites are light-textured, strongly acidic, and poor in organic matter, conditions that constrain nutrient availability, particularly phosphorus. This experiment evaluated the capacity of rice husk ash (RHA) and dololime to alleviate soil acidity and the consequent changes in extractable P (Figure 1). Across treatments, soil pH increased significantly relative to the untreated control, with the magnitude of response differing by amendment type and application rate. Dololime consistently produced the largest increase in pH, reflecting the acid-neutralizing action of its calcium and magnesium carbonates. RHA also raised soil pH, likely due to its alkaline reaction and supply of basic cations, although its liming effect was generally smaller than that of dololime. The maximum soil pH (~6.9) was recorded under dololime at 4 t ha^{-1} (T7), whereas the minimum occurred in the control. Notably, dololime at 2 t ha^{-1} (T6) achieved pH values (~6.8) statistically comparable to T7 in both Rangpur and Kurigram, indicating that the higher dololime rate provided little additional benefit. Within the RHA treatments, pH values with 2.0 t ha^{-1} (T3) and 4.0 t ha^{-1} (T4) did not differ significantly at either location; both treatments increased pH (5.8-6.2) above dololime at 1.0 t ha^{-1} (T5) but remained below T6 and T7. Site-specific differences were also observed on a few occasions: while T3 and T4 produced higher pH levels at Rangpur, comparable to those under dolomite treatments, the corresponding pH response in Kurigram was lower, suggesting a stronger buffering capacity and/or differing baseline soil chemical properties at that site.

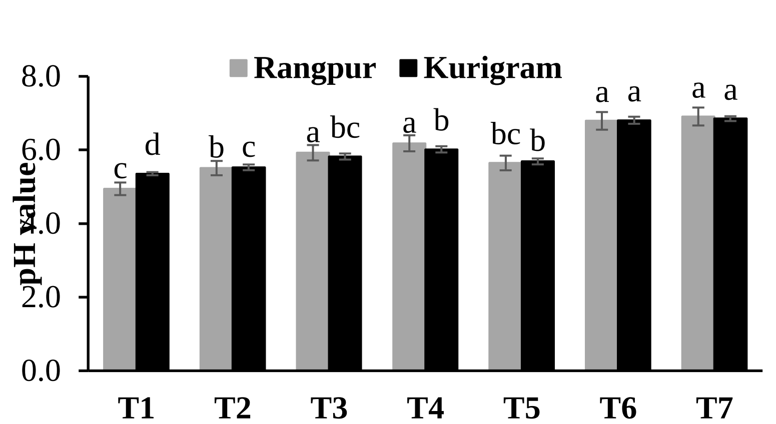

Figure 1. Effect of RHA in comparison to liming material on changes in soil pH in Rangpur and Kurigram soils. T_1= Control; T_2=1 t ha^{-1} RHA; T_3=2 t ha^{-1} RHA; T_4= 4 t ha^{-1} RHA; T_5=1 t ha^{-1} Dololime; T_6=2 t ha^{-1} Dololime; T_7=4 t ha^{-1} Dololime.

Use of Lime and RHA for managing soil P

Figure 2 illustrates the effect of RHA and dololime applications on soil P availability at Rangpur and Kurigram. The control treatment (T0) exhibited the lowest extractable phosphorus concentration at both sites (12.49 mg kg^{-1} at Rangpur and 19.41 mg kg^{-1} in Kurigram), indicating limited phosphorus availability under untreated acidic soil conditions. Application of RHA at increasing rates (T2-T4: 1.0, 2.0, and 4.0 t ha^{-1}) resulted in a progressive increase in soil phosphorus concentration compared with the control, reflecting the contribution of ash- derived phosphorus and the indirect effect of pH improvement on P solubility. Among the RHA treatments, @4.0 t ha^{-1} showed the highest phosphorus availability at Rangpur (17.27 mg kg^{-1}) and Kurigram (25.09 mg kg^{-1}), representing increases of 38.3% and 29.3%, respectively, over the control treatments. However, the magnitude of increase under RHA treatments remained lower than that observed for higher dololime rates. Dololime applications (T5-T7: 1.0, 2.0, and 4.0 t ha^{-1}) produced a more pronounced enhancement in extractable soil phosphorus. Phosphorus availability increased consistently with increasing dololime rate, with the highest concentrations recorded under T7 (4.0 t ha^{-1}) at both locations (22.94 mg kg^{-1} in Rangpur and 26.32 mg kg^{-1} in Kurigram), which are 83.6% and 35.6% increases over the control. Across all treatments, Kurigram consistently showed higher soil phosphorus concentrations than Rangpur, suggesting site-specific differences in baseline soil properties and buffering capacity. Overall, dololime, particularly at 2.0-4.0 t ha^{-1}, was more effective than RHA in enhancing soil phosphorus availability, although RHA also contributed to a measurable improvement over the control.

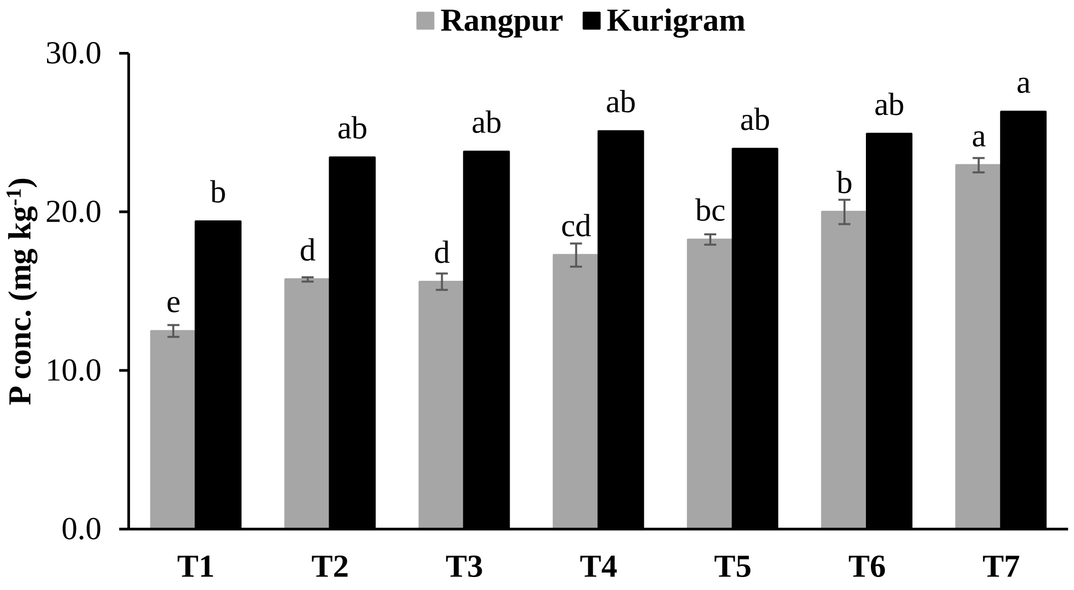

Figure 2. Effect of RHA in comparison to liming material on phosphorus availability in Rangpur and Kurigram soils. T_1= Control; T_2=1.0 t ha^{-1} RHA; T_3=2.0 t ha^{-1} RHA; T_4= 4.0 t ha^{-1} RHA; T_5=1.0 t ha^{-1} Dololime; T_6=2.0 t ha^{-1} Dololime; T_7=4.0 t ha^{-1} Dololime.

Regression Analysis of Soil pH and Available P in Acid Soils

Dololime application increases the soil available phosphorus more in Kurigram soil in comparison to Rangpur soil. The relationship between soil pH and available phosphorus in acid soil at the Rangpur and Kurigram sites is presented in Figure 3. In the Rangpur site, the data points are more widely dispersed, showing moderate variability around the fitted line. In contrast, the Kurigram site shows a more compact clustering of data points around the fitted line. This tighter clustering suggests more consistent responses and a stronger association between the variables in this dataset. A significant positive correlation between soil pH and available phosphorus at both sites (r = 0.56*** in Rangpur and r = 0.508*** in Kurigram), suggests a strong association. The statistically significant positive correlation indicates that improvements in soil pH through the application of soil amendments such as RHA and dololime were crucial to increasing available phosphorus in acid soils. This relationship highlights the importance of soil pH management for improving phosphorus availability. The amelioration of soil acidity is an effective strategy for enhancing phosphorus availability in acid soils, thereby improving crop phosphorus uptake and productivity.

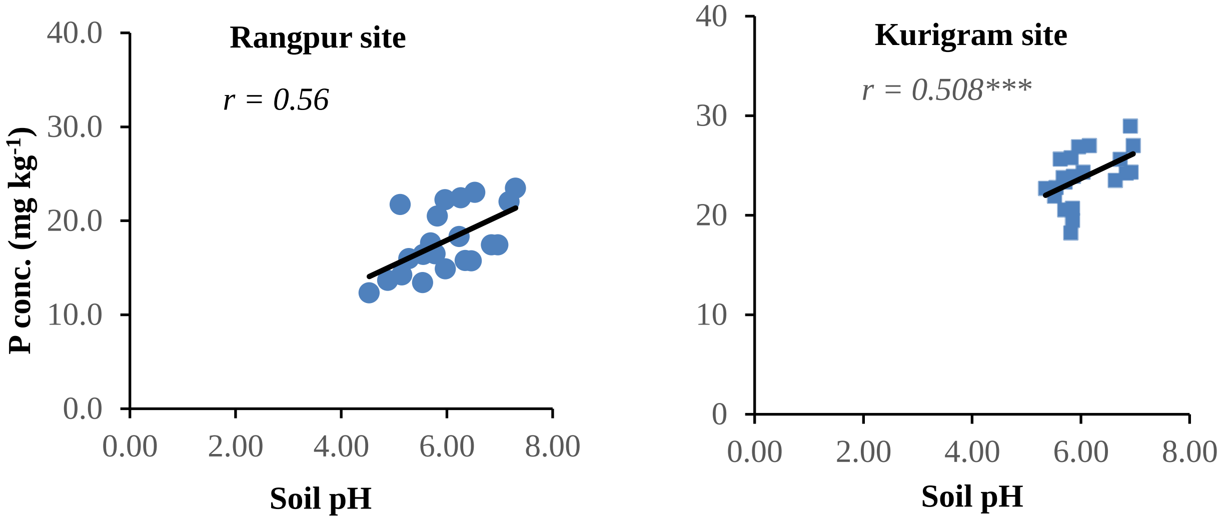

Figure 3. Regression analysis between soil pH and soil available phosphorus concentration in acid soil of Rangpur and Kurigram.

Discussion

The results from the study demonstrate that RHA like dololime can ameliorate soil acidity and thereby improve phosphorus availability in soils of Rangpur and Kurigram, although their effectiveness differed considerably. Initially, the soils were strongly acidic (pH 5.0-5.1) and contained relatively low organic carbon (0.81-0.87%), conditions that can restrict nutrient availability. In contrast, the RHA was alkaline (pH 8.3) and contained appreciable amounts of phosphorus, calcium, and magnesium, indicating its potential to function as both an acidity-amending material and a nutrient source. These characteristics are consistent with reports that RHA contains alkaline constituents and plant nutrients that can improve the chemical properties of acidic soils (Yin et al., 2022).

Soil pH increased markedly following amendment application, with dololime producing a stronger response than RHA. The maximum pH of approximately 6.9 was obtained with 4 t ha^{-1} dololime, while 2.0 t ha^{-1} produced a statistically comparable pH of approximately 6.8 at both locations. In comparison, 2.0-4.0 t ha^{-1} RHA raised soil pH to approximately 5.8-6.2. The superior performance of dololime can be attributed to the neutralising action of its calcium- and magnesium-containing carbonates, which consume acidity and reduce the activity of exchangeable hydrogen and aluminium. Liming is widely recognized as an effective approach for raising the pH of acid soils while supplying calcium and magnesium and reducing aluminum toxicity (Akter et al., 2026). The absence of a significant pH difference between 2.0 and 4.0 t ha^{-1} of dololime is particularly important from a management perspective, as it suggests that 2.0 t ha^{-1} may be sufficient to correct acidity under these soil conditions.

The improvement in soil phosphorus availability closely followed the changes in soil pH. RHA at 4.0 t ha^{-1} increased available phosphorus to 17.27 mg kg^{-1} in Rangpur and 25.09 mg kg^{-1} in Kurigram, representing increases of 38.3 and 29.3%, respectively, over the controls. Dololime produced a greater response, with 4.0 t ha^{-1} increasing available phosphorus to 22.94 and 26.32 mg kg^{-1}, equivalent to increases of 83.6% in Rangpur and 35.6% in Kurigram. In strongly acidic soils, phosphate can be strongly retained by iron and aluminium compounds. Increasing pH reduces the influence of these acidity-related phosphorus-fixation processes and can consequently increase extractable phosphorus. Penn and Camberato (2019) emphasised that soil pH strongly governs phosphorus sorption, precipitation and solubility, with phosphorus availability generally improving as strongly acidic soils approach a moderately acidic to near-neutral range. Similarly, a Bangladesh incubation study reported that lime significantly increased both soil pH and available phosphorus, with 2 t ha^{-1} $CaCO_3$ providing a favourable pH range for phosphorus release (Sarker et al., 2014).

The positive response to RHA probably resulted from two complementary mechanisms. First, its alkaline reaction increased soil pH; second, the RHA itself contained substantial P (575 mg kg^{-1}), Ca (7868 mg kg^{-1}) and Mg (2500 mg kg^{-1}). Thus, RHA can contribute P directly while simultaneously modifying soil conditions that regulate P availability. Comparable increases in soil pH and available P following the incorporation of RHA into acidic red soil have been reported by Yin et al. (2022). Although RHA was less effective than dololime at the tested rates, its ability to improve both pH and P availability suggests considerable potential as a locally available recycling-based soil amendment.

Finally, the significant positive relationships between soil pH and available P at Rangpur (r = 0.56) and Kurigram (r = 0.508) further support the role of acidity correction in increasing P availability. These moderate correlations also indicate that pH is not the only factor controlling P behaviour; differences in initial P status, mineralogy, buffering capacity and amendment-derived nutrients probably contributed to the site-specific responses. Overall, dololime was more effective for rapid acidity correction, whereas RHA showed promise as an alternative amendment capable of simultaneously recycling an agricultural by-product, supplying nutrients and improving acidic soil conditions.

Conclusion

This research evaluated dololime and rice husk ash (RHA) as acidity-managing amendments for restoring acid soils and sustaining phosphorus availability in Rangpur and Kurigram. Both amendments decreased acidity, but their efficiencies differed in terms of outcome. These responses show that rice- husk by-products can partially substitute lime where lime availability is limited, although lime remains superior for rapid Ca-Mg restoration. Available P improved most strongly under RHA @2.0 t ha^{-1} in Kurigram (41.86 mg kg^{-1}), highlighting amendment-specific strengths for rebuilding limiting nutrients alongside acidity correction. Further research should extend the trial duration to quantify residual effects and reapplication intervals, test integrated packages (partial lime + RHA) for cost-effectiveness, and incorporate robust economic, biological, and physical indicators to refine recommendations for Bangladesh's acid-soil zones.

Conflict of interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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Author contributions

Conceptualization, MH; methodology, MRI and MH; validation, MH and MRI; formal analysis, MRI; investigation, MRI; resources, MH and MRI; data curation, MH and MRI; writing-original draft preparation, MRI and MH; writing-review and editing, MH, MRI and MRI; supervision, MRI and MH; funding acquisition, MRI. All authors have read and agreed to the published version of the manuscript.

References

1. Akter M, Mim NJ, Mukta TA, Hosenuzzaman M, Rahman MS and Hoque MA. 2026. Additive effects of lime and phosphorus fertilization on maize yield, nutrient uptake, and soil health in upland acidic soils. Discover Soil, 3: 61.
2. Bodruzzaman M. 2010. Lime requirement of acid soils for sustainable crop production. Ph. D. Thesis. BAU, Mymensingh, Bangladesh. p. 310.
3. Bodruzzaman M, Rahman GKM, Islam MS, Roy MC, Duxbury JM and Lauren JG. 2014. Lime Technology for the Acid Soils Regions of Bangladesh. United States Department of Agriculture. Published by: Food for Progress Program in Bangladesh on August 2014.
4. Boru M and Misgan M. 2025. Response of Application of Lime and Inorganic Phosphorus Fertilizer on Yield and Yield Related Traits of Upland Rice (Oryza sativa L) at Assosa, Benishangul Gumuz Region. International Journal of Applied Biotechnology, 13(1): 31-37.
5. Brady NC and Weil RR. 2017. The Nature and Properties of soils (15th edition). Pearson Education, USA.
6. Bray RH and Kurtz LT. 1945. Determination of Total, Organic, and Available forms of Phosphorus in Soils. Soil Science, 59: 39-45.
7. Butterly CR, Amado TJC and Tang C. 2022. Soil acidity and acidification. In Subsoil Constraints for Crop Production, P 53-81. Springer International.
8. Enesi RO, Dyck M, Chang S, Thilakarathna MS, Fan X, Strelkov S and Gorim LY. 2023. Liming remediates soil acidity and improves crop yield and profitability, A meta-analysis. Frontiers in Agronomy, 5: 1194896.
9. Gee GW and Bauder JW. 1986. Particle-size analysis. In A. Klute (Ed.), Methods of soil analysis: Part 1. Physical and mineralogical methods (2nd ed.). Soil Science Society of America. https://doi.org/10.2136/sssabookser5.1.2ed.c15
10. Gomes EA, Lana UGP, Quensen JF, de Sousa SM, Oliveira CA, Guo J, Guimarães LJ and Tiedje JM. 2018. Root-associated microbiome of maize genotypes with contrasting phosphorus use efficiency. Phytobiomes, 2: 129-137.
11. Guo JH, Liu XJ, Zhang Y, Shen JL, Han WX, Zhang WF, Christie P, Goulding KWT, Vitousek PM and Zhang FS. 2010. Significant acidification in major Chinese croplands. Science 327: 1008-1010.

12. Gurmessa B. 2021. Soil acidity challenges and the significance of liming and organic amendments in tropical agricultural lands with reference to Ethiopia, Environment, Development and Sustainability: A Multidisciplinary Approach to the Theory and Practice of Sustainable Development, Springer, 23(1): 77-99.
13. Jackson ML. 1962. Soil Chemical Analysis. Constable and Co. Ltd., London.
14. Jeannette AC, Ofori P, Sekyi-Annan E, Aryeh SJ, Peprah CO, Afriyie-Debrah C, Ribeiro FP and Asante MD. 2025. The prevalence of acid soils and their effect on rice crop cultivation. In M. E. Çalişkan, A. Bakhsh, & K. Jabran (Eds.), Rice cultivation under abiotic stress: Challenges and opportunities pp. 183198).
15. Knudsen D, Peterson GA and Pratt PF. 1982. Lithium, sodium, and potassium. In AL Page, RH Miller and DR Keeney (Eds.), Methods of soil analysis: Part 2. Chemical and microbiological properties (2nd ed., pp. 225-246). American Society of Agronomy and Soil Science Society of America. https://doi.org/10.2134/agronmonogr9.2.2ed.c13.
16. Ma C, Tu Q, Zheng S, Deng S, Xia Y, Mao W and Chen X. 2022. Soil acidification induced by intensive agricultural use depending on climate. Journal of Soils and Sediments, 22: 2604-2607.
17. Nwite JN, Mbah CN, Okoonkwo CI and Obi ME. 2011. Analysis of Physical Conditions of a Contaminated Typic Haplustult Amended Organic Wastes. International Research Journal of Agricultural Science, 1(2): 123-128.
18. Penn CJ and Camberato JJ. 2019. A critical review on soil chemical processes that control how soil pH affects phosphorus availability to plants. Agriculture, 9(6): 120.
19. Saranya P, Mahendran PP and Kumar PS. 2018. Effect of rice husk ash on soil properties and maize yield. International Journal of Current Microbiology and Applied Science, **7:** 276-284.
20. Sarker A, Kashem MA, Osman KT, Hossain I and Ahmed F. 2014. Evaluation of available phosphorus by soil test methods in an acidic soil incubated with different levels of lime and phosphorus. Open Journal of Soil Science, 4: 103-108.
21. Shaheb MR, Nazrul MI and Rahman MA. 2014. Production potential and economics of wheat as influenced by liming in north eastern region of Bangladesh. Asian Journal of Agriculture and Biology, 2(2): 152-160.
22. Temesgen D, Getachew A, Ayalew A and Tolossa D. 2017. Effect of lime and phosphorus fertilizer on acid soils and barley (Hordeum vulgare L.) performance in the central highlands of Ethiopia. Experimental Agriculture, 53(3): 432-444.
23. Ullal VN, Hivaramu HT and Aveen K. 2022. Rice husk ash utilization, composition and properties: A brief review. Journal of Metals, Materials and Minerals, 32 (4): 37-46.
24. Walkley A and Black IA. 1934. An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. Soil Science, 37(1): 2938.
25. Yin M, Li X and Liu Q. 2022. Rice husk ash addition to acid red soil improves the soil property and cotton seedling growth. Scientific Reports, 12: 1704.