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The Effect of Phosphate Fertilizer and Lime in Ultisol Soil on Phosphate and Protein Leaf Levels of Corn (Zea *mays* L.) and Soybean (Glycine *max* L. (Merr))

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A B S T R A C T

This research aimed to examine the impact of phosphate fertilization and liming on phosphate and protein levels in the leaves of corn (Zea mays L.) and soybeans (Glycine max L. (Merr)) grown on ultisol soil. Increased phosphorus absorption enhances starch translocation and phosphorus distribution within plants, optimizing photosynthesis and increasing carbohydrate and protein formation, which in turn raises leaf phosphate and protein levels. However, the specific effects of phosphate fertilization, liming, or a combination of both on leaf phosphate and protein levels in ultisol soils remain uncertain, necessitating this study. Conducted in Halong Village, Baguala District, Ambon City, from March to July 2024, the study involved soil and plant analysis at the Soil Laboratory, Faculty of Agriculture, Pattimura University. A completely randomized design with a factorial pattern and three replications was used, with phosphate fertilizer and lime as the main factors. Results showed that applying phosphate and lime to ultisol soil significantly increased the phosphate and protein levels in corn and soybean leaves. The optimal combination for efficient increases in leaf phosphate and protein levels was achieved with 92.6 kg P_2O_5/Ha and 1.5 x Al-dd.

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INTRODUCTION

Corn (Zea *mays* L.) yield can be improved by proper fertilization, both dosage and timing and the type of fertilizer given. Nutrients P is an essential nutrient that needed by plants. The important function of P in plants is in the process of photosynthesis, transfer and energy storage, helping root development and increased production plants (Saragih and Sabrina, 2019). The same thing is experienced by soybean plants (Glycine *max* L. (Merr)), where productivity does not only depend on the type of soil used but also must pay attention to the nutrients contained in the soil (Subaedah *et al.*, 2021). Observing the above phenomenon, land management that is oriented towards efforts to increase and maintain the organic matter content of the soil, especially in ultisol soil, is a solution to improve the quality of soil fertility and plant productivity.

Ultisol is a soil that has several problems including soil acidity, low organic matter and low macro nutrients, especially very low P availability. Efforts are made to improving the properties of ultisol soil is by how to add organic materials to improve the physical, chemical and biological properties of the soil, as well as fertilization to provide nutrients macro. Phosphate fertilization and lime in ultisol soil will increase soil pH where high soil pH causes an increase in nutrients (Apriadi *et al.*, 2022).

The provision of phosphate fertilizer can increase soil pH which causes an increase in the growth rate of soybeans. The P element is a component of lecithin which plays an important role in membrane integrity (Subaedah, 2020). Liming of ultisol soil can increase soil pH, add Ca and Mg elements, add P and Mo elements, reduce Fe, Mn, and Al toxicity. This causes the available phosphate to increase and its absorption also increases. The efficiency of phosphate absorption can be assessed from the leaf phosphate content and leaf protein content. Increased absorption of P nutrients causes starch translocation and phosphorus distribution in plants. In addition, P nutrient also optimizes the photosynthesis process in plants, thereby increasing the formation of assimilates in the form of carbohydrates and proteins. Both of these things cause an increase in leaf phosphate levels and leaf protein levels. It is not yet known for certain the levels of leaf phosphate and leaf protein levels due to P fertilization, liming, or a combination of P fertilization and liming on ultisol soil, so it is necessary to conduct research aimed at determining the effects of phosphate fertilization and liming on ultisol soil on phosphate and protein levels in corn leaves (Zea *mays* L.) and soybeans (Glycine *max* L. (Merr))

THEORITICAL REVIEW

Phosphate Fertilizer and Its Role in Plant Growth

Phosphorus (P) is an essential macronutrient in plants, critical for numerous biochemical processes, including energy transfer, photosynthesis, and nutrient movement within the plant. Phosphorus availability promotes the translocation of starch and the synthesis of vital compounds like ATP and nucleic acids, which are crucial for cellular growth and energy. It also supports root development, flower formation, and seed and fruit production. In leaves, phosphorus directly influences the production of assimilates, such as carbohydrates and proteins, which are essential for overall plant health and productivity. Phosphate fertilizers are often applied to meet plant phosphorus demands, particularly in phosphorus-deficient soils, as they enhance phosphorus availability, promoting healthier plant growth and higher yields.

Importance of Liming in Soil Management

Liming is a common agricultural practice to amend acidic soils by adding materials, typically calcium or magnesium compounds, which neutralize soil acidity. Acidic soils, like ultisols, often have high levels of aluminum and iron, which can hinder phosphorus availability by binding it in forms that plants cannot readily absorb. Liming not only raises soil pH, making it more favorable for plant growth, but it also helps to reduce aluminum toxicity and improve nutrient availability. By increasing soil pH, lime application enhances the effectiveness of phosphorus fertilizers, allowing for better phosphorus uptake and utilization by plants.

Characteristics of Ultisol Soil and Challenges for Crop Cultivation

Ultisols are highly weathered, acidic soils predominantly found in tropical and subtropical regions. These soils are often low in essential nutrients, especially phosphorus, due to high levels of iron and aluminum oxides that bind phosphorus, making it less available for plant uptake. The acidic nature of ultisol soil also inhibits root growth and nutrient absorption, which can severely impact crop productivity. To cultivate crops effectively in ultisol soils, appropriate soil management practices, such as liming and phosphorus fertilization, are essential to improve soil fertility and crop yield.

Phosphorus and Protein Levels in Leaves

Phosphorus application is directly related to the accumulation of phosphorus and proteins in plant leaves. Higher phosphorus availability enhances photosynthesis, leading to increased production of carbohydrates and proteins, which accumulate in leaves. Proteins, which are fundamental for plant structure and metabolism, require adequate nitrogen and phosphorus levels. Increased protein synthesis is often linked with better photosynthetic efficiency and growth. In crops like corn and soybeans, which require significant amounts of nutrients, improved leaf phosphorus and protein levels lead to healthier plants with potentially higher productivity.

Combined Effects of Phosphate Fertilizer and Lime on Crop Yield

The application of phosphate fertilizers in conjunction with lime on ultisol soils can enhance phosphorus availability and uptake efficiency. Lime raises the soil pH, reducing the fixation of phosphorus by aluminum and iron, which makes phosphorus more accessible for plants. As a result, crops grown in limed soils with added phosphate fertilizer typically exhibit increased phosphorus content in leaves and improved protein levels, leading to better plant vigor and higher yields. Optimal doses of both lime and phosphorus fertilizer can create a synergistic effect, improving soil conditions and maximizing nutrient availability for crops like corn and soybeans.

Importance of Phosphate and Protein Levels in Crop Production

The phosphate and protein levels in plant leaves are indicators of nutrient status and health, which are essential for assessing crop quality and productivity. Phosphorus levels reflect the plant's energy status and capacity for growth, while protein levels indicate the plant's ability to synthesize structural and functional components required for photosynthesis and overall metabolism. Increased levels of these nutrients in leaves generally correlate with improved crop performance, stress resistance, and yields. Understanding the impact of soil amendments, such as phosphate fertilization and liming, on these parameters is crucial for optimizing crop production in challenging soils like ultisols.

METHODOLOGY

Place, Tools and Materials, and Research Design

This research was conducted in a plastic house in Halong Village, Baguala District, Ambon City. Soil and plant analysis were conducted at the Soil Laboratory, Faculty of Agriculture, Pattimura University. The research was conducted from March to July 2024.

The materials used are ultisol soil, hybrid corn seeds of C-1 variety and soybean seeds of Willis variety, as basic fertilizer used fertilizer (46% N) and KCL (60% K_2O), as treatment materials used TSP fertilizer (46% P_2O_5) and dolomite lime materials, pesticides are used when plants are attacked by pests, water for watering, and other materials for laboratory analysis purposes. While the tools used are hand sprayer, pH meter, scales, soil maps, destructive tools, hoes, shovels, plastic buckets, PVC pipes, 2 mm sieves, field knives, nameplates, and stationery.

The experimental design used in this study was a completely randomized design with a factorial pattern with three replications. The factors studied were P fertilizer and lime. The dose of P fertilizer was determined based on the results of Sitaneley's (1993) study, namely 278.04 kg P_2O_5 / Ha, while the lime dose was based on the Al_{dd} of the soil used.

1) The P fertilizer dosage consists of four levels, namely:

P0	=	Without P fertilizer
P1	=	92.6 kg $_{P2O5}$ / Ha
P2	=	185.3 kg $_{P2O5}$ / Ha
P3	=	278 kg $_{P2O5}$ / Ha

2) Lime treatment consists of four levels, namely:

P0	=	Without chalk
P1	=	0.5 x Al_{dd}
P2	=	1.0 x Al_{dd}
P3	=	1.5 x Al_{dd}

Thus, there are 16 treatment combinations. Each treatment is repeated 3 times (4 x 4 x 3) so that there are 48 experimental units for both corn and soybeans. The mathematical model is:

$$Y_{ijk} = u + P_i + K_j + PK_{ij} + E_{ijk}$$

Where:

Yes	=	Response variables
u	=	Average effect of treatment
P_i	=	Effect of P fertilizer treatment i
K_j	=	Effect of jth lime treatment
PK_{ij}	=	The interaction effect of the i-level fertilizer treatment with the j-level lime
it_{is}	=	Trial error

If the F test is real, it is continued with the BNJ test at the 5% level. In addition, regression and correlation tests are carried out.

Response Variables and Research Implementation

The response variables to be measured are:

1) P content of corn and soybean leaves
2) Protein content of corn and soybean leaves

The implementation of the study began with soil preparation. Soil was taken from a depth of 0-30 cm, allowed to air dry and sieved with a 2 mm sieve. 1 kg of soil was taken to analyze pH (H2O1: 2.5), Al + H, P2O5, available, accompanied by taking whole soil samples to determine the bulk density using a sample ring. The results of this initial analysis were also used to determine the amount of lime that should be added according to the treatment, and for the treatment of regulating the uniformity of the bulk density or soil density in the experimental pot. 8 kg of soil was put into the pot and the volume of the pot was adjusted in such a way that the same soil bulk density was achieved as in the field.

After soil preparation, liming was carried out 2 weeks before planting. Lime was put into the experimental pot according to the treatment and then mixed until evenly distributed. Urea and KCL fertilization as basic fertilizers were given simultaneously at the time of planting and given individually to all plants in each experimental pot with a distance of 10 cm from the plant and a depth of 5 cm. Likewise with the provision of TSP as a treatment. The fertilizer dose used was 49.06 kg N per hectare and 50.01 kg K_2O per hectare.

Planting is done with a 3 cm deep hole system and 3 seeds are inserted for each hole. Before planting, soybean seeds are inoculated with rhizobin A according to the dose of 5 g kg $^{-1}$ soybean seed.

Plant embroidery is done after 1 week, along with thinning the plants by leaving one best plant per pot. The intention is to prevent competition for nutrients and sunlight. Weeding is done 2 times, namely the first at the age of 15 days after planting and is taken care not to damage the roots of the plant. The second weeding is done when the plants are 30 days old and is done at the same time as loosening as needed to maintain good soil aeration and drainage.

Irrigation can be given at the same time as planting, and the water content is maintained at field capacity. To prevent pest attacks on plants, sevin 85 S pesticide is used with a concentration of 2.5 cc liter $^{-1.}$

Soil and Plant Analysis

Plant analysis to measure the efficiency of P absorption was carried out after the plants flowered. P absorption efficiency was obtained from the results of leaf P content and leaf protein content analysis. For this purpose, the third and fourth leaves of corn, and several soybean leaves that had opened perfectly were taken and put into the laboratory. P2O5 analysis was only carried out on 16 soil samples which were a combination of each experimental replication from corn and soybean pots. For plant analysis needs, 1 plant sample was taken from each experimental pot (48 samples from corn pots and 48 samples from soybean pots). Leaf P content and leaf protein analysis were carried out on 16 corn leaf samples and 16 soybean leaf samples, each of which was a combination of 3 replications.

At the end of the study, soil was taken from each experimental unit and allowed to air dry and sieved with a 2 mm sieve to analyze the available P content (Olsen) and pH (H2O $_{1:}$ 2.5). Soil analysis was carried out after the corn and soybeans were harvested. For analysis purposes, 1 sample was taken from each experimental pot (48 samples from corn pots and 48 samples from soybean pots). Soil pH analysis was carried out on 48 soil samples which were a combination of corn and soybean pot experimental units, to create ANOVA and BNJ.

RESULTS AND DISCUSSION

Phosphate content of corn and soybean leaves

In Figure 1, the dose of p3 with increasing lime levels in phosphate fertilization decreases phosphate absorption. This is thought to occur because the increased availability of phosphate in the p3 treatment is not balanced by the availability of other nutrients, especially N, and N is a limiting factor for corn. So even though there is an increase in soil pH and the availability of phosphate in the soil, if N is low or absent, there is a decrease in phosphate absorption in corn plants. This is in line with the results of Aswiguna's research (2019), which shows that plant P will increase with increasing N in the soil, but if the N nutrient is low, there is a decrease in P in plants (Melati *et al.*, 2020). Meanwhile, in the combination of lime with p0, p1, and p2, there is an increase in phosphate absorption because available phosphate also increases. According to Wang *et al* ., (2007) *In* Aini *et al* ., (2022), P fertilizer plays a role in increasing N transported by the stubble, because the availability of P in the soil will affect plant absorption of N. Nitrogen will increase root development so that plants are able to absorb P more effectively and besides that, N is also the main component of the phosphatase enzyme involved in the P mineralization process in the soil.

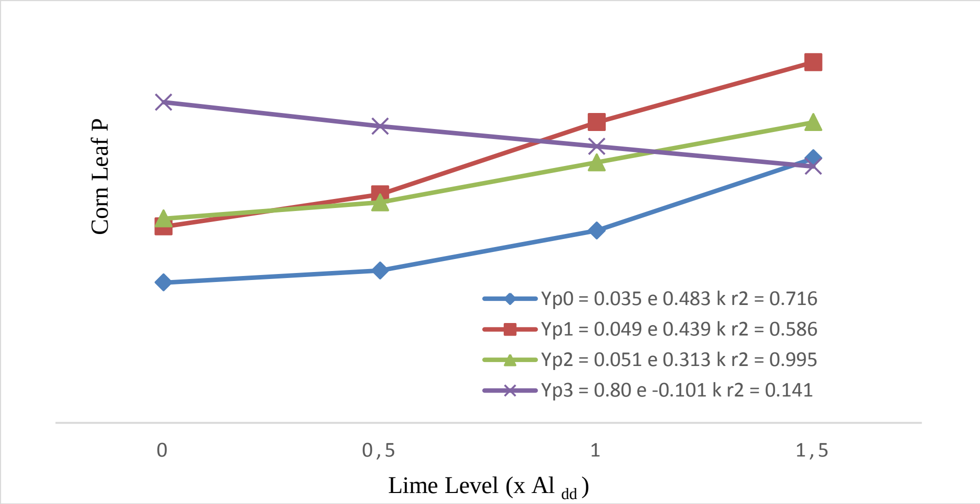

Figure 1. Relationship between lime levels and phosphate levels in corn leaves at various doses of phosphate fertilization.

At doses of fertilizer p0, p1, and p2, there was an increase in the phosphate levels of corn leaves. This indicates that the provision of phosphate fertilizer plays a role in dissolving the P element absorbed in the soil so that it becomes available and has been able to meet the nutrients for corn plants (Edy and Ibrahim, 2022). With the increase in available P in the soil and the elongation of the roots, there is greater contact by diffusion between the plant roots and the P in the soil, so that more P is absorbed by the plants, causing the phosphate levels in corn leaves to increase. This is in line with the research of Aini *et al.*, (2022), which found that the provision of P fertilizer can increase P absorption. Increased absorption of P nutrients causes starch translocation and phosphorus distribution in plants to also increase, resulting in increased phosphate levels in plant organs including corn leaves.

Figure 2 shows that in all phosphate fertilization treatments (p0, p1, p2, and p3) increasing lime levels causes an increase in soybean leaf phosphate levels. The results of the study showed that by providing phosphate fertilizers, it will increase the absorption of phosphate elements from the soil because phosphate fertilization increases soil pH and increases the availability of phosphate in the soil. Fertilization of 278 kg P2O5 $_{/}$ Ha $_{(p}$3) without lime, the soil pH is 6.10 and the available phosphate level is 20.106 ppm. If the lime dose is increased to 1.5xAl $_{dd}$ (k3), the soil pH is 6.43 and the available phosphate level increases to 23.855 ppm. In soybean plants, increasing soil pH and phosphate availability like this increase's phosphate absorption so that leaf phosphate levels increase. Increasing the level of liming in phosphate fertilization in this study is useful for increasing pH, causing the mineralization process so that the elements N, P and K which were initially in organic form (bound) become inorganic (released) and available. In general, increasing pH has a positive effect on base saturation (KB), a condition that occurs where the decrease in H+ ion levels (pH increases) causes easy release of absorbed base cations such as calcium (Ca), Magnesium (Mg), Potassium (K) and Phosphate (P) so that the content of these bases increases in the available form (Rahman *et al.*, 2021). The large amount of P absorption causes P to be distributed throughout the soybean plant including the leaves so that soybean leaf phosphate increases, causing increased soybean growth. significantly (Sahuri, 2017).

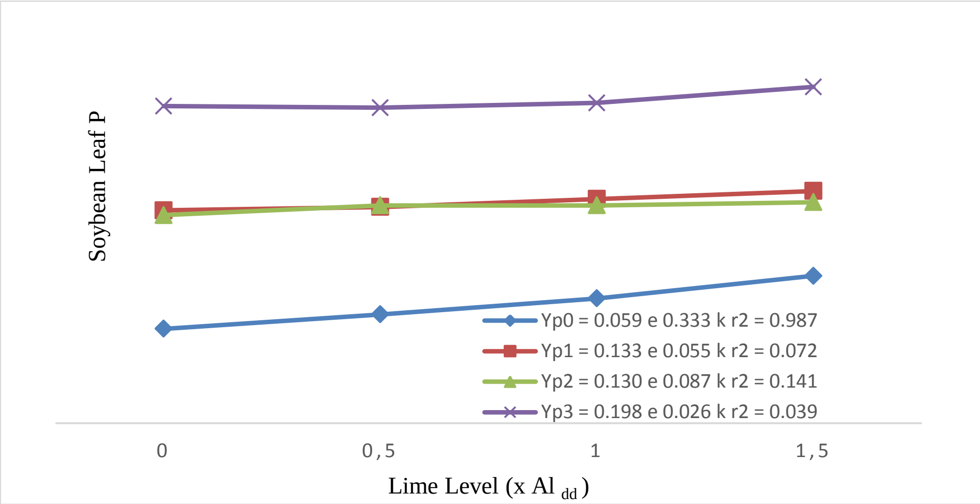

Figure 2. Relationship between lime levels and phosphate levels in soybean leaves at various doses of phosphate fertilization.

Protein content of corn and soybean leaves

Regression between corn leaf protein content and lime treatment levels at various doses of phosphate fertilization showed that at fertilizer doses p0, p1, p2, increasing lime levels caused an increase in corn leaf protein content (Figure 3). Liming is useful for increasing pH, adding Ca and Mg elements, increasing the availability of P and Mo elements and improving the life of microorganisms in the soil. Changes in soil pH towards neutral result in reduced Al concentration in the soil solution. This condition causes root poisoning by Al to also decrease and causes phosphate absorption and protein levels to increase. Phosphate absorption causes an increase in corn leaf protein, because phosphate is a raw material needed by plants for the formation of a number of proteins and helps plant assimilation and respiration (Novisan 2002 *in* Siregar *et al.*, 2017).

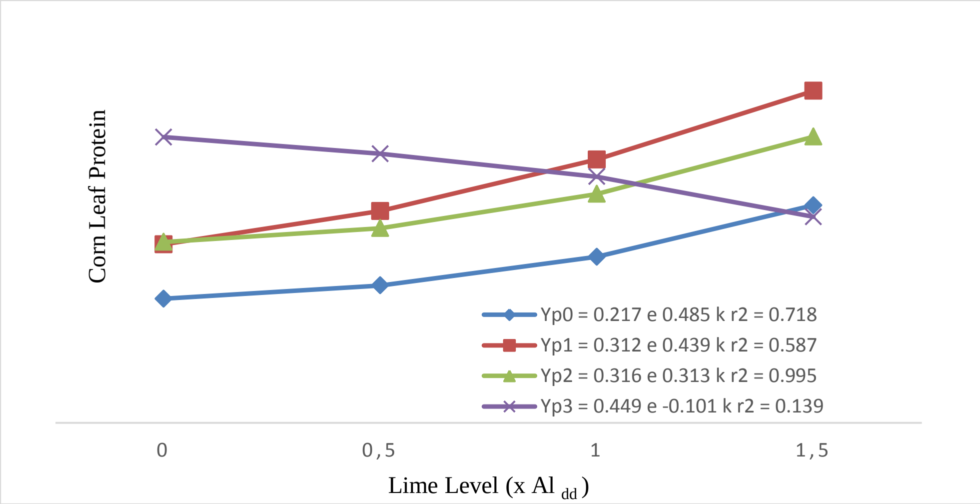

Figure 3. Relationship between lime levels and corn leaf protein levels at various doses of phosphate fertilization.

At a dose of p3 fertilizer, an increase in lime levels causes a decrease in the protein content of corn leaves. This is thought to be due to the low N content in corn, whereas N is needed by plants in the phosphate absorption process where high phosphate absorption causes an increase in protein in plants. Meanwhile, the provision of phosphate at doses p1, p2, and p3 showed increased phosphate availability. Phosphate fertilization affects the increase in protein levels in corn leaves. Phosphate plays a role in almost all biochemical reaction processes. According to Solihin *et al.*, (2019), the very important role of phosphate since the early phase of the plant is in the process of capturing sunlight energy and transforming it into biochemical energy. In addition, phosphate is a component of plant cell membranes, a component of enzymes, a component of co-enzymes, and increases plant resistance so that plants do not fall easily. The availability of P elements will support the development of young roots which will then support plants in absorbing nutrients. Increased absorption of P nutrients will optimize the photosynthesis process in plants, thereby increasing the formation of assimilates in the form of carbohydrates and proteins (Nuryani *et al.*, 2019).

Phosphate fertilization treatment (p0, p1, p2, and p3), which was given an increase in lime levels caused an increase in soybean leaf protein levels (Figure 4). According to Lusiana and Adiwijaya (2022), lime application can increase soil pH, reduce acidity levels and increase soil fertility. Increasing soil pH causes an increase in nutrients that affect plants in increasing their growth. According to Sumbayak and Gultom (2020), the supply of nutrients available to plants is used in the process of photosynthesis, then the results in the form of carbohydrates and proteins will be transferred to all plant organs. This condition causes an increase in soybean leaf protein.

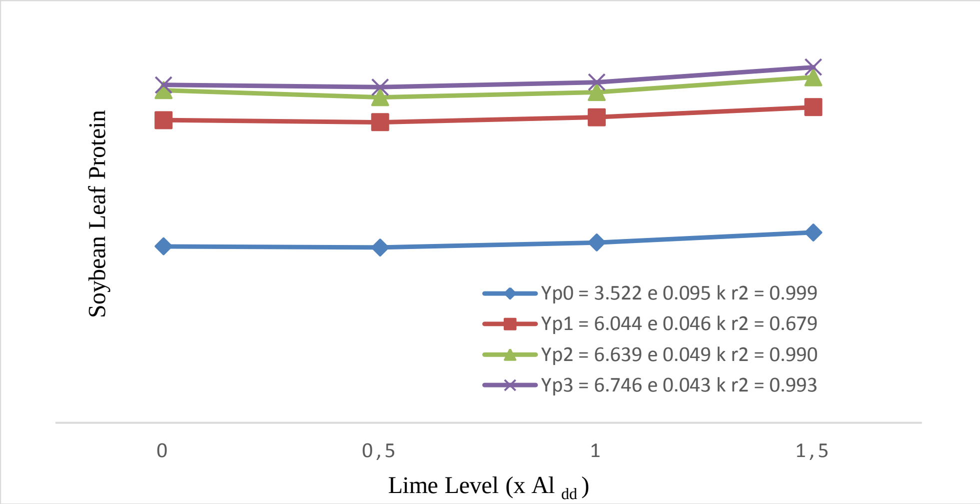

Figure 4. Relationship between lime levels and soybean leaf protein levels at various doses of phosphate fertilization.

The increase in phosphate levels in soybean leaves is influenced by soil pH and available phosphate also affects the protein levels in soybean leaves. Soybean plants absorb nutrients from the soil or fertilizers given to the soil. The P element stimulates the physiological and metabolic processes of plants so that photosynthate from photosynthesis and various organic compounds from metabolism increase in plants (Antoro and Nelvia, 2018), including increasing the formation of assimilates in the form of carbohydrates and proteins that are distributed to all parts of the plant including soybean leaves (Subaedah *et al.*, 2021). This is what causes soybean leaf protein to increase.

CONCLUSIONS AND RECOMMENDATIONS

1. Providing phosphate and lime fertilizers to ultisol soil can increase phosphate levels and protein levels in corn leaves. and soybeans.
2. The best combination of phosphate and lime fertilizer doses on ultisol soil to ensure the phosphate and protein levels of corn leaves... and soybeans are more efficient at 92.6 kg P_2O_5 /Ha and 1.5 x Al_{dd}.

FUTURE STUDY

Future studies could also investigate how varying climatic conditions, such as temperature and precipitation, affect the efficacy of phosphate and lime amendments. Research could simulate different environmental scenarios to understand how climate variability influences nutrient availability and uptake in ultisols.

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