Determination of phosphorus status on duku (*lansium domesticum*) seedling

D Hernita¹, R Poerwanto², AD Susila² and S Anwar³

¹ Jambi Assessment Institute for Agricultural Technology, Indonesia
² Department of Agronomy and Horticulture, Bogor Agriculture University, Indonesia
³ Department of Soil Science and Land Resource, Bogor Agriculture University, Indonesia

E-mail: desi_hernita@yahoo.com

Abstract. Phosphorus, one of the major plant nutrients that is a constituent of plant cells, is essential for cell division and the development of its growing tip. Symptoms of P deficiency or excessive can be seen mainly in the leaves. The sign can be detected visually and can be done by identifying P concentration in each condition. The P status study was conducted in Jambi Provinces, which was applied to duku seedlings planted in sand culture. The study was conducted in randomized complete block design, with five treatments consisting of three plants, each treatment, and three replications. The treatments consisted of five P levels: 0, 50, 100, 200, and 400 ppm. The results showed that P deficiency symptoms were characterized by stunted growth of seedlings, green-brownish and lusterless discoloration, the number of leaves < 4.56, and leaf P concentration < 0.09% (very low nutrient status) and 0.09 ≤ P < 0.14% (low nutrient status). Normal growth, shiny green leaves characterized the sufficient P concentration, number of leaves 4.56 – 7.00, and leaf P concentration of 0.14 ≤ P < 0.25% (medium nutrient status). Symptoms of excessive P was showed by stunted growth of seedlings, green leaves with yellow and necrotic spots on the leaf blade, the number of leaves < 4.56, P concentrations in the leaf ≥ 0.25% (high and very high nutrient status). The maximum growth of duku seedling for very low nutrient status was 195 ppm P, equivalent to 115 g SP-36/year or 58 g SP-36/6 month.

1. Introduction

Phosphorus (P) is essential for plant growth and is found in every living plant cell. Phosphorus is involved in energy transfer in ATP, photosynthesis, the transformation of sugars and starches, the movement of nutrients in plants, and the transfer of genetic characters from one generation to the next [1]. Phosphorus is an essential component of DNA and RNA to form proteins; ATP is formed during photosynthesis and plays a vital role in phosphorylation reactions, enzyme activities, and plant metabolism [2, 3]. According to [4], the essential function P is its role in nucleic acids, building blocks for genetic code material in plant cells.

Phosphorus is absorbed by plants in the form of orthophosphate ions (H₂PO₄⁻) and is highly mobile in plants [4]. Transformers of P into plant cells through the efflux and influx plasma membranes are the main mechanisms of maintaining P homostasis [3]. The concentration of P in plants is 0.1% - 1.0% of the dry weight, with a sufficiency value of 0.2% - 0.4% on newly mature leaves. P deficiency is less than 0.2% and over 1.0% [5].

Content from this work may be used under the terms of the Creative Commons Attribution 3.0 licence. Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI.
Published under licence by IOP Publishing Ltd
Symptoms of phosphorus deficiency and excess can be detected by visual observation and leaf analysis. Leaf analysis helps detect symptoms of nutrient deficiency before affecting plant growth and yield. [6, 7] states that leaf analysis can also be used to confirm visual symptoms, whether there is a deficiency or excess nutrients. Certain levels of nutrients in the leaves can be used as an indicator of deficiency, adequacy, or excess nutrients in plants [8]. Nutrient deficiency is usually recognized by special symptoms that mostly occur on the leaves. In some cases, symptoms of deficiency, excess, or a combination of both are difficult to identify visually, so in this case, leaf analysis can provide a more accurate identification [9].

The optimal amount of P for maximum growth of each fruit plant is different. Information about the symptoms of deficiency and excess P in duku plants is not yet known, so research is needed to determine these symptoms visually and based on plant leaf analysis. These symptoms are more easily detected by the treatment of P nutrient administration in duku stadia seedlings than in mature plants in the field. This study aims to detect symptoms of deficiency, adequacy, and excess P, determine the leaf P nutrient status in all three conditions, and determine the recommendation of P fertilization for maximum growth in duku seedlings.

2. Materials and methods
The P fertilizer application experiment consisted of five concentration treatments arranged in a complete randomized block design. P fertilizer concentration is sourced from Ca (H2PO4) + CaSO4. Consists of 0, 50, 100, 200, and 400 ppm P. Each treatment consists of three plants and is repeated three times so that a total of 45 duku seedlings are two years old. Duku seedlings used were transferred into a black polybag measuring 30 cm with sand media weighing seven kg. Seed transfer is carried out by removing the original growth media. The roots are washed thoroughly and replanted in the polybags provided. Application of fertilizer in addition to treatment is also given basic fertilizer that is 200 ppm N, 100 ppm K, and compound fertilizer as much as 1 g/l consisting of elements Ca: 0.03%, Mg: 2.60%, Fe: 0.74%, S: 0.30%, B: 0.085%, Mn: 0.14%, Zn: 0.55%, Cu: 0.006% and Mo: 0.02%. The treatment fertilizer and basic fertilizer are given every two days by pouring into a polybag, each with a volume of 50 ml. Detection of symptoms of deficiency and excess P is carried out on the leaves because most occur in the leaves. Leaf sampling was carried out at 07.00 - 09.00 WIB on the leaves of the third adult who experienced symptoms of P deficiency. Total P analysis was carried out by the wet ashing method, then measured by an ultraviolet-visible spectrophotometer.

Growth observation consisted of plant height, stem diameter, and the number of leaves. P nutrient content was analyzed on leaves that were deficient, adequate, and excess P based on visual detection of symptoms. Observation data were analyzed by analysis of variance and polynomial contrast tests. P nutrient status is calculated based on the relative growth value (increase in plant height), with the following formula:

\[
\text{Relative growth} = \frac{Y_i}{Y_{\text{max}}} \times 100\%
\]

where: \(Y_i\) = Growth in the i P nutrient treatment
\(Y_{\text{max}}\) = Maximum growth in P nutrient status

The relative growth value as the dependent variable (Y) is then associated with the leaf P nutrient content value as an independent variable (X) to be analyzed by linear and quadratic regression models. The model that has the highest R2 value is used to determine the P nutrient status of the duku seedlings.

Based on the predetermined model, a line is drawn to connect the leaf P nutrient content with relative growth to determine the nutrient availability class. [10] divides into five categories of nutrient availability based on relative growth percentages, namely: (1) very low (<50%), (2) low (50 ≤ Y <75%), (3) sufficient (75 ≤ Y <100%), (4) high (100%), and (5) very high (<100%).
3. Results and discussion

3.1. The response of plant growth to provision of phosphorus

Plant height and number of leaves showed significant differences with quadratic response patterns, whereas stem diameters did not show significant differences. The increase in plant height and number of leaves is in line with the increasing concentration of P and reaches a maximum at a concentration of 200 ppm, then decreases at a concentration of 400 ppm. The application of P 200 ppm fertilizer provides the best growth in duku seedlings compared to lower concentrations and higher concentrations (table 1).

Table 1. Effect of P administration on plant height, number of leaves, and stem diameter of duku seedlings after 12 months.

| Treatment (ppm P) | Plant height (cm) | Number of Leaves (sheet) | Diameter of stem (cm) |
|------------------|-------------------|--------------------------|-----------------------|
| 0                | 35.60             | 4.56                     | 0.70                  |
| 50               | 39.02             | 5.22                     | 0.70                  |
| 100              | 40.53             | 5.44                     | 0.67                  |
| 200              | 45.85             | 7.00                     | 0.81                  |
| 400              | 35.48             | 4.56                     | 0.74                  |

F test: **  
Response Pattern: Q**  

*: significant at the level 5%, **= significant at the level 1%, ns = non significant, Q = quadratic.

At concentrations lower than 200 ppm, the plant growth rate decreases, and the number of leaves is lower. This is because the P needed for the plant to grow optimally is not met. P deficiency and excess produce limited growth. This can be seen in figure 1. Phosphorus is a component of the complex nucleic acid structure of plants, which regulates protein synthesis because it is essential in cell division and the development of new plant tissues. An adequate supply of P is necessary for developing new cells and transferring genetic code from one cell to another newly formed cell. These processes can take place optimally if sufficient P is available in plants so that plant growth and development will appear normal (figure 1). If the P supply is low, the process will be hampered, and plant growth will be slow. This is also caused by the transfer of energy through the formation and reduction of phosphate bonds (ATP) is reduced. Simultaneously, the movement of nutrients in plants depends mainly on transport through cell membranes that require energy in the form of ATP and other high-energy P compounds to resist osmotic pressure. Phosphorus also plays a role in storing and transferring energy produced by photosynthesis to be used in plant growth and reproductive processes. P deficiency will also inhibit plants’ vegetative growth because one of P’s roles in plants is to encourage root vigor and canopy growth [5,11].

Another factor that causes slow growth in Puku deficiency plants is related to the role of P in stimulating root development. P concentrations that are too low or too high in plants cause fewer roots to form (figure 2), P which can be absorbed by roots through diffusion and mass flow is also lower, resulting in slower plant development. Phosphorus that enters plant roots, according to [1], can be stored in the roots or transformed to the top of plants, through various chemical reactions, integrated with organic compounds, including nucleic acids (DNA and RNA), phosphoproteins, phospholipids sugar-phosphate, enzymes, and high-energy phosphate compounds (ATP). Phosphorus plays an important role in these processes, and its supply will be reduced if the plant is in a state of deficiency or excess P, which at an advanced stage will hinder plant growth and development.
This symptom is first seen in old leaves, and this is because P is transplanted through the phloem from old leaves to young leaves or active meristem tissue. [12] report that most plants that are deficient in P size will be reduced. Research conducted on corn plants, P deficiency, inhibits carbohydrates’ translocation in plants to slow down utilizing carbohydrates produced continuously through photosynthesis. This will add to carbohydrates, and the development of green leaves becomes darker. The leaves’ color is dark green to bluish-green with a purplish color on the petiole and lower leaf bone of young leaves. In summary, the appearance of deficiency symptoms, adequacy, and excess P in duku seedlings can be seen in table 2.
Table 2. Visual symptoms of deficiency, sufficiently and excessive on duku seedlings.

| Plant organs | Symptoms                      |
|--------------|-------------------------------|
|              | Deficiency | Sufficiently | Excessive                      |
| Old leaves   | The leaves turn brownish or purplish-green on the leaf blade and appear blurry (not radiant) (figure 3A). | Dark green and the top surface of the shiny leaf blade (figure 3B). | Irregular spherical shape, yellow, then change color to white and brown on the edges, and the outside is yellow again. These patches begin to appear from the tips and edges of the leaves (figure 3C). |
| Bone leaves  | Brownish green | Dark green | Dark green |
| Petiole      | Yellowish green | Dark green | Yellowish green |
| First appeared | Tips and edge of old leaf | - | Tips and edge of old leaf |
| Root         | Fewer root fibers (figure 2A) | More fiber roots (figure 2B) | Fewer roots, brittle and break easily (figure 2C) |

Excess P causes irregular spherical yellow symptoms, then changes color to white with brown (necrotic) on the edges and then yellow on the outside. These symptoms appear from the leaves' tips and edges, leading to the leaf base (figure 3C). Excess P can also result in slower root development (figure 2C) than roots that get enough P (figure 2B), fragile, and easily broken roots. [4] reported that excess P in the root zone could reduce plant growth because excess P will reduce Zn, Fe, and Cu's absorption, resulting in the three elements' deficiency.

P deficiency can also be detected by leaf analysis in addition to visual observation. Leaf analysis provides information on the occurrence of deficiency and the amount of absorption of plant nutrients. Leaf analysis is used to obtain a high level of accuracy in fertilizer management. The actual level of nutrients in plants, namely deficiency, adequacy, and excess, can be obtained from leaf analysis. The range of nutrient adequacy is the minimum concentration needed to maintain plant growth and productivity. Circumstances below and above the range of nutrient adequacy will cause damage the plant’s overall appearance [13,14]. Leaf analysis performed on visual symptoms can be seen in table 3.

Table 3. The average leaf P concentration is based on visual symptoms.

| Treatment (ppm P) | P Concentration Daun (%) | The level of symptoms visually |
|-------------------|--------------------------|------------------------------|
| 0                 | 0.07                     | Very less                    |
| 50                | 0.09                     | Less                         |
| 100               | 0.13                     | Less- enough                 |
| 200               | 0.21                     | enough                       |
| 400               | 0.43                     | over                         |

F test: **

Response Pattern L**

**: Significant at the level 1%, L: linear.

Leaf P concentration increases with increasing P concentration with a linear response pattern, as shown in table 3. Increased P concentration is also followed by an increase in plant growth, to a concentration of 200 ppm and decreases at 400 ppm (table 1). The leaf analysis results in table 3, when linked to duku seedling growth (table 1), the P concentration value was obtained less than <0.13%, sufficient 0.13 ≤ P ≤ 0.21%, and excess when >0.21%.
Leaf P concentration increases with increasing P concentration with a linear response pattern, as shown in table 3. Increased P concentration is also followed by an increase in plant growth, to a concentration of 200 ppm and decreases at 400 ppm (table 1). The leaf analysis results in table 3, when linked to duku seedling growth (table 1), the P concentration value was obtained less than <0.13%, sufficient 0.13 ≤ P ≤ 0.21%, and excess when > 0.21%.

3.2. Nutrient Status and Recommendations for Phosphorus Fertilization in Duku Seedlings

P leaves' nutrient status with relative growth follows a quadratic regression model with an R² of 0.77. The nutrient status of P was very low (<0.09%), low (0.09 ≤ P <0.14%), moderate (0.14 ≤ P <0.25%), high and very high (≥ 0.25%), as can be seen in figure 4.

![Figure 4](image_url)

**Figure 4.** Correlation between leaf P concentration and relative height increase of duku seedlings.

Increasing leaf P concentration to 0.25% can increase relative growth, but more than 0.25% concentrations cause the growth rate to decrease. When the P concentration is below optimal or above optimal, there will be symptoms of deficiency or excess P, as shown in figure 4.

The concentration of nutrient P is sufficient if plant growth is normal and relatively constant. Critical concentrations occur when plants’ relative growth is reduced by 10% of maximum growth and is a transition zone between adequacy and nutrient deficiency. Deficiency zones occur when leaf nutrient concentration falls below the transition zone, and plant growth decreases dramatically, while excess zones occur when nutrient concentrations are greater than adequate concentrations [4].

Low or high P concentrations will inhibit growth, where P is an essential element in stimulating the formation of roots and leaves and plays a role in metabolizing energy carriers in ATP, and has a crucial role in various enzymatic reactions. P deficiency will cause a reduction in multiple metabolic processes, including cell division and elongation, respiration, and photosynthesis [5, 11].

P concentration based on nutrient status for maximum growth of duku plants was 0.14 ≤ P <0.25% higher than the optimum requirement for mangosteen plants, which was 0.10-0.19%. P concentration of duku leaves> 0.25% will decrease relative growth while mangosteen growth will decrease at P concentration> 0.19%. Maximum duku seedling growth at very low nutrient status can be achieved by administering 195 ppm P, equivalent to 115 g/year or 58 g/6 months (figure 5).
Figure 5. The effect of P fertilizer concentration on the relative height increase of duku seedlings in nutrient status is very low.

Conclusions
1. Symptoms of P deficiency in duku seedlings are characterized by slow growth and dark brownish-old leaves; P sufficiently shows normal growth and shiny green leaves; symptoms of excessive P can be seen from stunted growth of seedlings, green leaves with yellow and necrotic spots on the leaf blade.
2. The nutrient status of P is very low on duku seedlings if leaf P concentration <0.09%, low: 0.09 ≤ P <0.14%, medium: 0.14 ≤ P <0.25%, high and very high: ≥ 0.25%.
3. The maximum growth of duku seedlings was obtained at concentration 195 ppm P, equivalent to 115 g SP-36/year or 58 g SP-36/6 months.

Acknowledgment
Acknowledgments are extended to the Indonesian Agency for Agricultural Research and Development Ministry of Agriculture Indonesia and Jambi Assessment Institute for Agricultural Technology has facilitated and supported this activity.

References
[1] Armstrong DL 1999 Functions of phosphorus in plant Better Crop. 83: 6–7
[2] Ammann A, Armengaud P 2009 Effect of N, P, K, and S on metabolism: new knowledge gained from multi-level analysis Plant Biol. 12: 275–283
[3] Jones EV 2004 Phosphorus in Environmental Technologies: Principle and Application IWA Publishing
[4] Hochmuth G, Maynard D, Vavrina C, Hanlon E, Simonne E 2009 Plant Tissue Analysis and Interpretation for Vegetable Crops in Florida Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida
[5] Jones JB 1998 Plant Nutrition Manual New York: CRC Press
[6] Heckman J 2001 Leaf Analysis for Fruit Trees Rutgers Cooperative Research & Extension N.J. Agricultural Experiment Station Rutgers The State University Of New Jersey New Brunswick
[7] Lan, T D, Xiong, Q Chu, Y. Feng, L. Kou, W Dou, X. Zhou and S Deng 2019 Establishment and application demonstration of standards for agricultural biogas slurry returning to field in citrus orchard International conference on oil & gas engineering and geological science IOP Conf. Series: Earth and Environmental Science
[8] Hochmuth GJ 2008 Fertilizer Management for Greenhouse Vegetable-Florida-Florida Greenhouse Vegetable Production Handbook Vol 31 Florida: IFAS Extension, University of Florida

[9] Zekri M and TA Obreza 2009 Macronutrient Deficiencies in Citrus: Nitrogen, Phosphorus, and Potassium. Soil and Water Science Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida. http://edis.ifas.ufl.edu. [diakses 26 Oktober 2011], p 1-3

[10] Kidder G 1993. Methodology for calibrating soil test. Soil and Crop Sci. Soc. 52:70–73

[11] Marschner H 1995 Mineral Nutrition in Higher Plants New York: Academic Press. 889 p

[12] Rehm G, Schmitt M 2002 Understanding Phosphorus in Minnesota Soil Reagent of the University of Minnesota

[13] Wall, B 2010 Leaf analysis helps optimize yields. ProQuest Agric J 30:22

[14] Bell PF, Boquet DJ, Millhollon E, Moore S, Ebelhar W, Mitchel CC, Varco J, Funderburg ER, Kennedy C, Breitenbeck GA, Craig C, Holman M, Baker W, McConnel JS 2003 Relationship between leaf-blade nitrogen and relative seedcotton yield Crop Sci. 43: 1367–1374