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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

From Practice to Science: Assessment Soil Nutrient Status Using "Minus One Element Technique (MOET)" for Early Growth of Maize

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Abstract

Soil nutrient deficiency will influence maize growth, so it is necessary to add nutrients based on the fertility status of the soil. One way to find out the nutrient soil status using a simple method is using the minus one element technique (MOET). The minus one element technique (MOET) determines which element is the limiting factor. This study was carried out to confirm the nutrient soil status using the minus one element technique (MOET) with the early growth of maize as the indicator. The research was conducted in greenhouse, Polytechnic of Lamandau, Central Borneo, Indonesia, at an altitude of 50 m above sea level. The research used a non-factorial design arranged in a completely randomized block design and five fertilizer treatments based on the minus one element technique consisting of control (without fertilization), PK, NP, NK, and NPK with three replications. The results showed that the deficiency of nitrogen, potassium, and phosphorus reduced the growth of maize, leaf greenness, photosynthetic rate, and especially the total dry weight of the plant. The dry weight of maize roots decreased by 18.85% - 75.47% when N, P, and K fertilizer were not applied. Then the decrease in photosynthesis rate ranged from 18.23% to 46.21% when N, P, and K fertilizer were not applied. The low of photosynthesis rates resulted in the accumulation of plant dry weight was hampered, and there was a decrease of 8.00% -74.43%. The results of the evaluation of fertility status are based on the results of the relative dry weight of the plant, which was <80% in the PK and NP fertilization treatments, meaning that nitrogen and potassium were deficient in the soil.

Keywords: Nutrient deficiency, Nitrogen, Phosphorus, Potassium, Soil

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1. Introduction

Maize is one of the most important food commodities after rice because it has a strategic role in agricultural and economic development in the world, especially in developed countries. Maize is included in multipurpose commodities (4F) for food, feed, fuel, and fiber (Shiferaw et al., 2011; Law-Ogbomo and Ekunwe, 2011; Mardhiana et al., 2021). Maize production in Indonesia has had an increasing trend since 2010-2018 with total national production in 2018 reaching 30.25 million tones. However, maize production decreased in 2019 by 25% to 22.59 million tons and production decreased again by 0.38% in 2020 (FAO, 2022). One of the factors influencing the decline in national maize production is the level of soil fertility (Dawar et al., 2022).

Soil fertility in optimizing maize productivity is related to the availability of nutrients in the soil. By the right balance of nutrients soil, that is support the healthy growth and development of maize, leading to higher productivity and maximizing yield (Yessoufou et al., 2023). Insufficient soil nutrient can have detrimental effects on plant (Öner and Demirkıran, 2023). Without an adequate of nutrients, maize may experience stunted growth, resulting in lower yields (Aliyu et al., 2021; Putra and Ismoyojati, 2021). In previous studies found that insufficient soil nutrients such as N, P, K can reduce the physiological conditions and growth of maize (Studer et al., 2017; Basal and Szabo, 2020). These deficiencies manifest through symptoms such as yellowing or discoloration of leaves, stunted growth, decreased photosynthesis rate, decreased biomass and yield (Ding et al., 2005; Jezek et al., 2015; Attia et al., 2022). To deal with the latter issue, soil nutrient testing can be carried out before the maize cultivation is carried out on the field. Determining the level of nutrient availability in the soil requires soil analysis in the laboratory. However, soil analysis requires high costs, and farmers do not have access to soil analysis, so practical techniques are needed to be adopted by farmers in the analysis of soil nutrients status (O'Connell and Osmond, 2022). A method that can be used to analyze soil nutrients status developed by the Philippine Rice Research Institute, namely the minus one element technique (MOET) (Magahud et al., 2019).

MOET is easy to perform, providing a user-friendly method for assessing soil nutrients status. MOET can be conducted in areas where soil testing laboratories are not available. Its effectiveness is comparable to soil lab analysis. In the previous study, Cagasan et al. (2020) found that rice fields in Central Luzon State University were deficient in nitrogen and sulfur after conducting MOET. Azhiri-Sigari et al. (2003) also used MOET to evaluate 118 rice fields in the Philippines and found 60% were deficient in nutrients, especially nitrogen, phosphorus, and potassium in Ifugao rice field. Because these advantages make MOET a practical and reliable option for farmers seeking cost-effective and accessible soil diagnostic solutions. However, so far, no scientific researchers have conducted soil tests using MOET on maize fields. Maize is generally planted in dry land while rice is in wet land. Dry land and wet land have different physical, chemical and biological characteristics (Mujiyo et al., 2022). Then the nutritional needs of maize and rice plants are also different (Yin et al., 2019; Berge et al., 2021; Nasseri, 2021). It is estimated that these differences will affect the effectiveness of soil nutrient status analysis using MOET on maize fields. Therefore, a study is needed to try to test soil nutrients using MOET. Overall, this study was carried out to confirm the nutrient soil status using the minus one element technique (MOET) with the early growth of maize as the indicator.

2. Materials and Methods

2.1. Experimental Site

The research was conducted in greenhouse at Polytechnic of Lamandau, Central Borneo, Indonesia at an altitude of 50 m above sea level. The average minimum and maximum temperatures in greenhouse were 21 °C and 35.8 °C respectively, and the average relative humidity in greenhouse was 73% during the experimental period of March to April 2021.

2.2. Experimental Design

The study used a non-factorial design arranged in a completely randomized block design. The study used five fertilization treatments with three replications based on the minus one element technique using maize cultivar (cv. Bisi-2) as a plant indicator. The soil used is soil on former oil palm plantations taken at a depth of 20 cm (top soil). Then the soil was put into pots with a size of 15 cm x 30 cm, each experimental plot consisted of 5 pots so that the total pots used were 75 pots. The fertilizers used in this study were urea as a source of nitrogen, SP36 as a source of phosphorus, and KCl as a source of potassium (*Table 1*).

Table 1. Treatment fertilizer with minus one element test (MOET) method

Treatment	Fertilizer Dosage (kg. ha^{-1})*		
	Urea	SP-36	KCl
Without Fertilizer (Control)	0	0	0
PK	0	150	100
NK	350	0	100
NP	350	150	0
NPK	350	150	100

Note: Determination of dosage is based on site-specific fertilizer recommendations in Lamandau, Central Borneo, Indonesia.

2.3. Determination of Leaf Greenness Index and Photosynthesis Rate

A quick and non-destructive method of determining the nutritional status of plants concerning nitrogen is frequently used in agricultural practice (Argenta et al., 2004; Shah et al., 2017). It involves employing an N-Tester or a SPAD-502 optical instrument (Soil and Plant Analysis Development) to measure the intensity of leaf greenness (Uddling et al., 2007). The top four fully formed leaves have a SPAD value. There were three locations where SPAD readings were taken: (a) 1/3, (b), 1/2, and (c) 2/3 of the distance from the leaf base. The average of the SPAD data across all leaves was then calculated (Yuan et al., 2016). In addition, Li-Cor 6400 (USA) machine measured the photosynthesis rate at maximum vegetative stage conditions in all treatments.

2.4. Determination of Biomass

Maize biomass was harvested at silking. At the time of biomass harvesting, leaf area measurements (dm^2) were carried out using the Cl 202 portable leaf area meter. The shoot was divided into two parts: leaf and stalk of maize. It was determined that 80 to 90% of root dry weight is distributed in the top 0 to 20 cm of soil (Osaki et al., 1995; Dwyer et al., 1996), thus determining the sampling depth. The limiting nutrients of soil determined using the method of percent dry weight total relative is used as follows:

$$\%\text{TDW} = \frac{\text{TDW on minus one element treatment}}{\text{TDW on completed fertilizer}} \text{ x } 100\% \quad \text{(Eq. 1)}$$

Where TDW is total dry weight of plant. If %TDW value was < 80% is classified as deficient for the corresponding nutrient element (Descalsota et al., 2000).

2.5. Data analysis

An analysis of variance (ANOVA) based on a complete randomized design based on ms was used to analyze the observational data obtained. An error rate of 5% was applied to the Excel macro add-ins (DSAASTAT version 1.101), which were further tested with the Tukey HSD test if a significant difference was found after the variance analysis (Onofri and Pannacci, 2014).

3. Results and Discussion

3.1. Root surface area of maize

Based on the evaluating method of the nutrient status using the minus one element technique on the root surface area of maize, it was found that nitrogen was slightly available in the soil, followed by potassium and phosphorus. The results showed that the fertilization of the minus one element technique significantly affected the surface area of maize roots (*Table 2*). *Table 2* showed that the without fertilizer appeared to have the lowest root surface area of maize compared to other treatments, namely 82.06 dm^2. In the NPK, maize's highest root surface area was 334.49 dm^2. NP showed a significant decrease in root surface area of 50.82% compared to NPK.

The maize without potassium will experience a decrease in root surface area between 13.33%-31.17% (Du et al., 2017). NK showed an insignificant decrease in the root surface area of maize, which was only 18.85%. Then when PK was carried out or without nitrogen, it showed a significant decrease in root surface area, namely 59.43%. The crops that are not given nitrogen resulted in a 15%-40% reduction in root surface area (Guo et al., 2022; Chen et al., 2020). This demonstrates how nitrogen can encourage the development of roots. However, too much nitrogen fertilizer treatment prevents the growth of the root surface area. Plant roots are directly affected by the nitrogen in urea (Wang et al., 2019; Yang et al., 2019). Urea in this study contains nitrate, which involves several root development processes, such as proliferation in the root system (formation of new roots). A study by Saito et al. (2014) shows that nitrogen plays a crucial role in crop development.

Table 2. Root Surface Area (dm^2)

Treatment	Root Surface Area (dm^2)	% Decreased of RSA
Control	82.06 ± 39.47 b	75.47
PK	135.71 ± 6.50 b	59.43
NK	271.43 ± 20.33 a	18.85
NP	164.49 ± 10.32 b	50.82
NPK	334.49 ± 48.03 a	-
C.V. (%)	14.92	
LSD ($P < 0.01$)	80.79	

Note: Based on the Tukey HSD test 0.05, there is no discernible difference between the values in the same column followed by the same letter.

The deficiency of nitrogen and potassium can have detrimental effects on the root surface area of crops, impacting root growth. Research has shown that potassium deficiency inhibits root growth in maize (Guo, 2023). For instance, under potassium deficiency, root length, surface area, and diameter were found to decrease in maize (Du et al., 2017). Similarly, in peanut, nitrogen and potassium deficiencies were shown to affect root growth and development (Li et al., 2021). Additionally, potassium-deficient stress can lead to reductions in root growth and alterations in ion balance, nitrogen metabolism, and photosynthesis in maize (Qu et al., 2011). Furthermore, studies have indicated that changes in nitrogen availability can affect the concentration of amino acids in maize root exudates, potentially influencing transcriptional profiles and root development (Carvalhais et al., 2013).

3.2. Plant height and leaf area of maize

The MOET significantly affected plant height growth (*Figure 1*) and leaf area of maize (*Figure 2*). The application of NPK showed the highest growth of plant height, 164.70 cm (*Figure 1*). When applied with NP without potassium, there was a significant decrease in plant height, 9.64%, compared to NPK. The decrease in plant height due to the absence of potassium in the soil occurred in the study of Amanullah et al. (2016) and Kandil et al. (2020), which is 4.67%-6.21%. The deficiency of potassium in plants significantly impacts their growth, particularly in terms of height. Potassium is a crucial macronutrient that plays a vital role in various physiological processes, including photosynthesis, enzyme activation, and water regulation within plant cells (Thornburg et al., 2020). A deficiency in potassium may result in stunted growth, reduced leaf size, and, ultimately, a decrease in overall plant height (Hasanuzzaman et al., 2018). Research has shown that potassium deficiency leads to a reduction in plant height due to its essential role in cell elongation and division. For instance, noted that the application of potassium, particularly in conjunction with low-use elements, significantly enhances plant height, suggesting that potassium is critical for optimal growth conditions (Aghdam, 2023). Similarly, found that increasing potassium levels positively correlated with the height of kenaf plants, indicating that adequate potassium supply is essential for achieving maximum growth potential (Salih et al., 2014).

The application of NK showed an insignificant decrease in plant height, namely 1.82%, compared to the application of NPK. At the time of application of PK, there was a significant decrease in plant height, namely 23.19%, compared to NPK. Then when not given fertilizer, there was a significant decrease in plant height compared to NPK which was 35.90%. This follows the opinion of Law-Ogbomo and Law-Ogbomo (2009) and Ahmadu et al. (2020) that the plant provides better plant height growth when given NPK. The deficiency of nitrogen and phosphorus in plants significantly reduces plant height, impacting overall growth and development. Both nutrients play critical roles in various physiological processes essential for plant health. A study by demonstrated that nitrogen deficiency leads to decreased crop height, leaf area, and overall biomass in wheat plants, indicating that insufficient nitrogen directly hampers vegetative growth (Liu et al., 2020). Furthermore, highlighted that early-season nitrogen deficiencies can slow down plant maturity and growth rates, leading to shorter plants (Zhang et al., 2010). Additionally, research on maize indicated that phosphorus deficiency resulted in shorter plant heights and reduced leaf area index, as phosphorus enhances root development and nutrient absorption (Khaleeq, 2023).

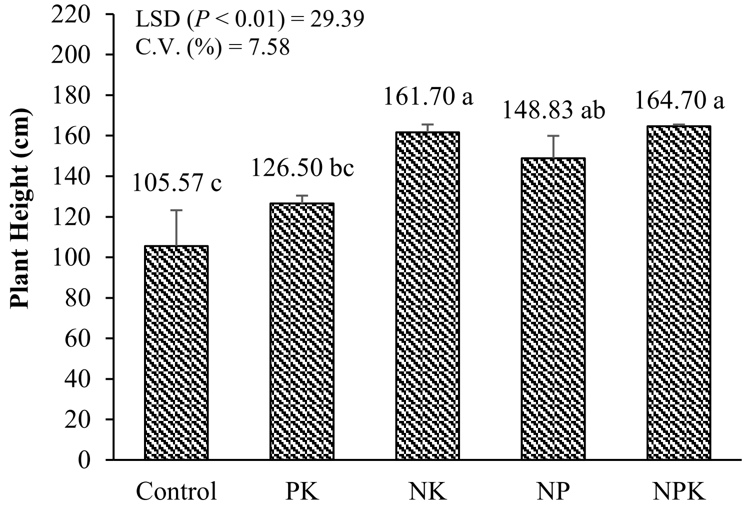

Figure 1. Plant height of maize

The variable leaf area of maize showed that NPK was able to form the highest leaf area of maize compared to other fertilization, namely 1,234.77 dm^2 (Figure 2). However, when NP was given, the plant leaf area decreased significantly compared to the NPK of 33.08%. The application of NK without phosphorus experienced a significant decrease in the leaf area of maize compared to NPK of 14.67%. Then when given PK and control (without fertilizer), the leaf area of maize experienced a very significant decrease compared to NPK which was 48.54% and 75.28%, respectively. The growth of the leaf area of maize is very sensitive to nutrient deficiency. The deficiency of nitrogen, potassium, and phosphorus in plants leads to a significant reduction in leaf area, which adversely affects overall plant health and productivity. Each of these nutrients plays a distinct yet interconnected role in leaf development and expansion. Research has shown that nitrogen deficiency results in a marked decrease in leaf area. nitrogen deficiency often leads to the redistribution of nitrogen from older leaves to younger parts, which can reduce the photosynthetic capacity of lower leaves, further contributing to decrease leaf area (Živčák et al., 2014). Then, potassium deficiency has been linked to reduced leaf area and chlorosis, as it impairs the plant's ability to maintain turgor pressure and conduct photosynthesis effectively (Song, 2023). And research has shown that potassium and phosphorus deficient plants exhibit dwarfing and a decrease in leaf area, which ultimately inhibits growth and yield (Kavanová et al., 2008; Song, 2023). The decrease in leaf area of crop reached 97.08% when NPK was not given (Law-Ogbomo and Law-Ogbomo, 2009).

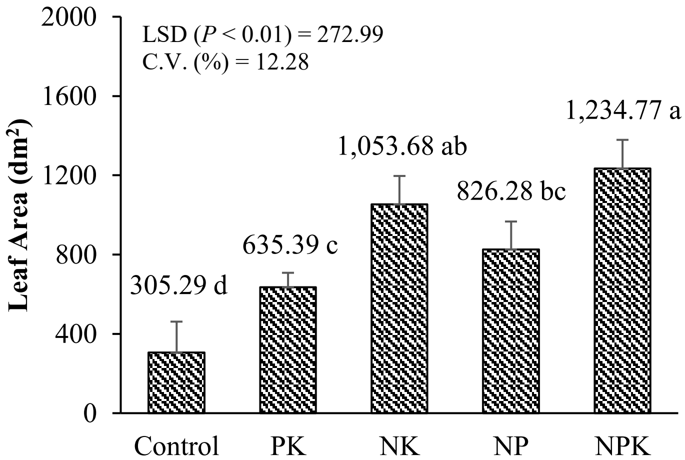

Figure 2. Leaf area of maize

3.3. Leaf greenness index and photosynthetic rate

The leaf greenness index in maize under all treatments MOET significantly decreased when compared to the NPK (*Figure 3*). About 18.18% - 62.01% leaf greenness index decreased due to missing nutrients like N, P, and K than NPK. The highest decrease in the leaf greenness index was found in maize leaves with PK, namely 62.01%. For maize, leaf chlorophyll content, biomass yield, and yield observations are linearly correlated with the leaf greenness index (SPAD) (Rostami et al., 2008; Kandel, 2020). Chlorophyll content has a connection to plant nitrate nutrition and can be used as a timely and accurate indication of crop nitrate nutrient status (Cendrero-Mateo et al., 2015). According to Wu et al. (2019), N stress may have harmed internal chloroplast structure and reduced chlorophyll concentration, leaving plants more susceptible to light damage. In our experiments, PK significantly decreased the chlorophyll contents.

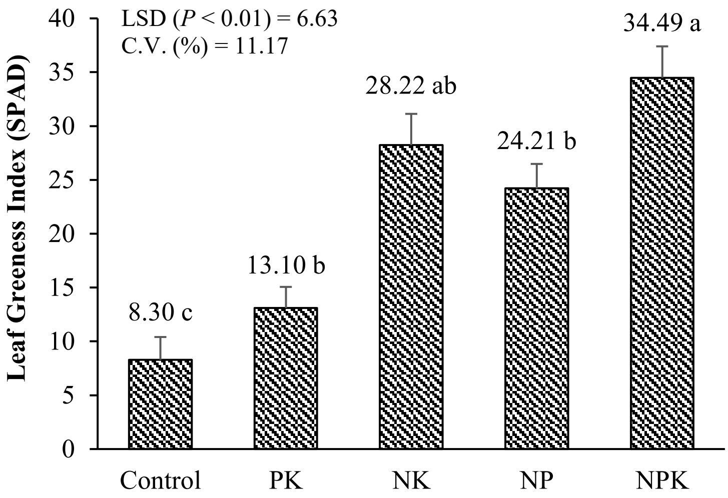

Figure 3. Leaf greenness Index of maize

In NK and NP, the leaf greenness Index decreased by 18.18% and 29.81%. A by product of photosynthesis, ATP, is produced through phosphate metabolism, catalyzed by potassium (Wang and Wu, 2013). A drop in leaf greenness Index was anticipated in the absence of N and K. Due to low chlorophyll content, crop leaves capacity to receive and transmit light was compromised under low N and K levels, inhibiting photosynthesis (Rey-Caramés et al., 2016).

Maize photosynthetic rate was higher when it received NPK than when just one nutrient element was absent (*Figure 4*). When nutrients like N, P, and K are lacking, the photosynthetic rate decreases by about 18.23% to 46.21% compared to NPK. With the PK, maize showed the greatest reduction in photosynthetic rate (42.61%). The deficiency of nitrogen in plants leads to a significant decrease in the photosynthetic rate, which can be attributed to several physiological and biochemical mechanisms. Nitrogen is a fundamental component of chlorophyll, the pigment responsible for capturing light energy during photosynthesis, and it is also a critical element in the structure of various proteins, including those involved in the photosynthetic process (Han, 2011). Low N stress impacted leaf N concentration, reducing the photosynthetic rate (Hiratsuka et al., 2015). This observation aligns with the findings of, who reported that higher nitrogen fertilization levels corresponded with increased net photosynthetic rates in wheat, indicating that nitrogen availability is crucial for maintaining optimal photosynthetic activity (Olszewski et al., 2014; Mu et al., 2017). Similarly, demonstrated that N deficiency in sweetpotato resulted in decreased chlorophyll content, which was linked to reduced photosynthesis (Meng et al., 2015). The decrease in pigment contents, particularly chlorophyll, is a critical factor contributing to the decline in photosynthetic activity following nitrogen deficiency (Zhao et al., 2017).

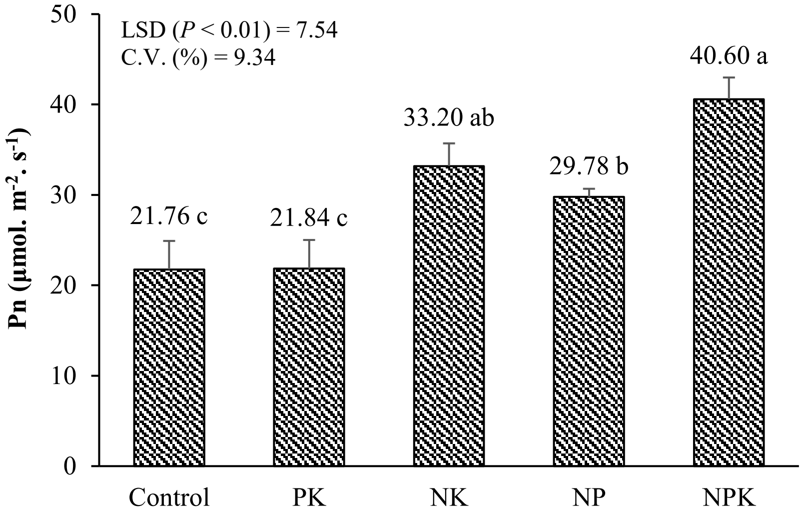

Figure 4. Photosynthetic rate of maize

In the NK and NP, the photosynthesis rate decreased by 18.23% and 26.65%. Haque et al. (2019) explained that there was a decrease in the rate of photosynthesis of 10-28% when plants experienced a shortage of macronutrients. The soil's nutrient ratios are altered when a certain nutrient is missing, causing plants to experience either excess or deficiency and diminished physiological activity (Veazie et al., 2020; Wu et al., 2019). So, depending on the absent elements, we have discovered varying photosynthetic rates. The photosynthetic rate was also boosted by adding the missing nutritional element (Haque et al., 2019).

3.4. Biomass dry weight of maize

The results showed that the MOET significantly affected root dry weight, stem dry weight, leaf dry weight, and total dry weight of maize (*Table 3*). The NPK showed the highest root dry weight, stem dry weight, leaf dry weight, and total dry weight of maize. This is after the reduction of one nutrient in the fertilization process, the dry weight of maize decreases. A significant decrease in total dry weight occurred in the PK, which was 58.55% of the total dry weight of the NPK. Cagasan et al. (2020) showed that in the deficiency nitrogen, the dry weight of the plant declined up to 70% from the NPK. This is related to soils lacking nitrogen which will directly affect the form of dry matter in plants during the vegetative phase. The deficiency of N, P, K significantly decreases the biomass dry weight of plants, which is a critical indicator of overall plant health and productivity. Each of these macronutrients plays a vital role in various physiological processes that contribute to biomass accumulation (Khan et al., 2023; El-Sheekh et al., 2024). The combined deficiency of N, P, K creates a compounded effect that severely limits biomass accumulation. It finds that the interaction of these nutrients are critical for maximizing growth and biomass efficiency, as deficiencies in any of these macronutrients can lead to significant reductions in plant dry weight (Akgül and Akgül, 2022). Furthermore, indicated that nutrient deficiencies impact crop yield and quality, emphasizing the necessity of balanced fertilization for optimal biomass production (Sobhana et al., 2022).

Table 3. The dry weight of maize biomass (g)

Treatment	Root Dry Weight (g)	Stem Dry Weight (g)	Leaf Dry Weight (g)	Total Dry Weight (g)
Control	2.17 ± 1.05 c	5.86 ± 3.73 b	3.62 ± 1.76 c	11.62 ± 6.51 b
PK	3.52 ± 0.64 bc	9.07 ± 1.07 b	6.24 ± 1.53 bc	18.84 ± 3.03 b
NK	9.01 ± 1.41 ab	20.58 ± 1.65 a	12.16 ± 1.10 a	41.81 ± 3.63 a
NP	6.01 ± 2.73 abc	13.94 ± 4.99 ab	9.24 ± 2.94 ab	29.18 ± 10.48 ab
NPK	10.66 ± 3.76 a	20.92 ± 5.46 a	13.87 ± 0.81 a	45.45 ± 9.35 a
C.V. (%)	31.47	27.21	18.88	23.19
LSD ($P < 0.01$)	5.41	10.49	4.67	18.67

Note: Based on the Tukey HSD test 0.05, there is no discernible difference between the values in the same column followed by the same letter.

3.5. Evaluation of soil nutrient status with biological yield

Based on the estimation of soil fertility in *Table 4*, it is clear that the control and PK was only able to form a total dry weight of 25.56% and 41.45% compared to the NPK. Then the NP and NK formed a total dry weight of 64.20% and 91.99%, respectively. The MOET method results show that the soil in Lamandau is deficient in nitrogen and potassium. Because the total plant dry weight relative value of maize without nitrogen (PK) and potassium (NP) is less than 80%. In contrast, maize without phosphorus (NK) has a total plant dry weight relative value is more than 80%. Descalsota et al. (2000) believe that if the total dry weight relative value is less than 80%, the soil is deficient in a nutrient element.

Table 4. Biological soil nutrient status based on maize biomass

Treatment	Total Dry Weight (g)	%TDW	Criteria*
Control	11.62	25.56	Deficient
PK	18.84	41.45	Deficient
NK	41.81	91.99	Undeficient
NP	29.18	64.20	Deficient
NPK	45.45	100.00	-

4. Conclusions

In conclusion, nutrient deficiency causes decreased plant growth, such as root growth area, plant height, leaf area, and dry weight of maize plant biomass. PK and NP fertilizers resulted in a total plant dry weight of 41.45% and 64.20%, respectively. Then NK fertilizer resulted in a total plant dry weight relative to 91.99%. Based on this, the fertility status of soil in Lamandau Regency is a deficiency of nitrogen (N) and potassium (K) because the total dry weight of the relative plants that are not given nitrogen (N) and potassium (K) fertilizers is <80%. Future research by confirming the soil test method with MOET in maize fields is compared with the results of laboratory analysis and observing N, P, and K uptake in maize so that the MOET method becomes more valid for the development of maize yield.

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Ethical Statement

There is no need to obtain permission from the ethics committee for this study.

Conflicts of Interest

We declare that there is no conflict of interest between us as the article authors.

Authorship Contribution Statement

Concept: Putra, F.P.; Design: Putra, F.P., Sas, M.G.A.; Data Collection or Processing: Putra, F.P., Sas, M.G.A., Rosyida, R.; Statistical Analyses: Putra, F.P., Subrata, B.A.G.; Literature Search: Putra, F.P., Subrata, B.A.G., Rosyida, R.; Writing, Review and Editing: Putra, F.P., Subrata, B.A.G., Sas, M.G.A.

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