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Status of nitrogen, phosphorus and potassium nutrient elements in rice fields in Rejosos District, Nganjuk Regency

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Abstract. Shallots *(Allium ascalonicum L.)* are a key horticultural commodity in Nganjuk Regency, where continuous monocropping poses a risk of nutrient depletion and soil degradation. However, information on macronutrient dynamics under different rotation practices remains limited. This study aims to quantify the soil macronutrient status (N, P, K) in shallot fields with and without rotation in Rejoso District and identify the major limiting nutrient for fertilizer management. A total of 16 composite soil samples were collected purposively from six villages representing contrasting cropping patterns. Samples were taken at 0–20 cm depth prior to harvest and analyzed using the Paddy Soil Test Kit (PUTS). Nitrogen levels were predominantly moderate (56%), followed by high (31%) and very high (13%). Phosphorus remained high across all locations, while potassium was mostly low (56%). Slightly acidic pH (5.6–6.0) corresponded with high P availability, whereas persistent K deficiency indicated nutrient mining under intensive cultivation. These findings emphasize potassium as the key limiting factor and highlight the need for balanced, site-specific fertilization through liming, organic amendments, and implementation of the 5R fertilization principle. Integration of yield response trials is recommended to support sustainable soil fertility improvement in shallot production systems..

1 Introduction

Agriculture serves as a cornerstone of national food security and continues to support the majority of rural livelihoods in Indonesia. Among various horticultural crops, shallots (*Allium ascalonicum* L.) hold substantial economic significance and occupy a dominant share of the market supply chain [1]. The demand for shallots has increase steadily increased alongside rising consumption trends, positioning Nganjuk Regency particularly Rejoso district as one of the key production centers in East Java. Strong market incentives have encouraged farmers to intensify cultivation, with cropping cycles reportes to reach up to five times per year [2]. However, Sustain monocropping systems, however, raise serious concerns regarding the depletion of soil nutrients and the long-term resilience of agricultural land[3].In continous shallot production, the absence of crop rotation accelerates nutrient extraction, leading farmers to increase cemical fertilizer application as a compensatory measure. Although thi approach maintains yields temprarily, it may also trigger fertilizer dependency, higher production costs, and progressive soil degradation over time [4].

Nitrogen (N), Phophorus (P), and Pottasium (K) are the primary macronutrients influencing shallot growth dynamics. Nitrogen stimulates vegetative development, phosphorus supports biochemical energy transfer and root establishment, while potassium regulate photosynthesis, assimilate transport, and bulb formating [5]. The availability of these nutrient is highly dynamic, being affected by leaching, mineralization rates, and extensive nutrient removal duing harvest. When fields are continously planted without rotation, nutrient extratction patterns tend to repeat, thereby increasing the risk of imbalance[6].

Crop rotation is widely recognized as an effective ecological strategy to maintain soil quality. Incorporating crops with different nutrient requirements and rooting characteristic can enhance soil structure, regulate nutrient cycling, and suppress pest disease build up [7]. Semi-intensive rice shallot rotation systems are therefore expected to exhibit different nutrient profiles compared to fully intensive systems without rotation. While previous studies have examines fertilizer inputs and intensification impacts on shallot productivity, limited research has compared macronutrient availability in rotated versus non rotated fields in major production zones. This gap highlights the need for empirical evaluation of nutrient status under varying cultivation intensities in Rejoso District.

Based on these issues, research on the nutrient status of nitrogen, phosphorus, and potassium in several fields in Rejoso District, Nganjuk Regency, is crucial. This study aims to assess the macronutrient status of N, P, and K in intensive shallot fields with rotation-based cultivation. Specifically, it quantifies the availability of these nutrients and identifies nutrient imbalances across different cultivation intensities, providing empirical evidence for sustainable soil fertility management in the district. The results are expected to offer a comprehensive overview of soil fertility and serve as a basis for developing more efficient, environmentally friendly, and sustainable nutrient management strategies.

2 Materials and Methods

2.1 Materials

This research was conducted from July to August 2025 in irrigated rice fields located in Rejoso District, Nganjuk Regency Indonesia. Soil sampling was carried out across six villages namely Kedung Pandang, Talang, Ngadiboyo, Mojorembun, Sukorejo, and Wengkal. Geographically, the study area lies at 7°28′35.8″S and 111°53′46.8″ E, with an elevation of approximately 65 m above sea level. The dominant soil types within the sampling area were latosol, regosol and Litosol.The materials used in this study included soil samples, reagents (N-1, N-2, N3, N-4, P-1, P-2, K-1, K-2, and K-3), indicator color charts, and distilled water. The equipment comprised a Paddy Field Soil Testing Kit (PUTS), soil auger, plastic containers,sample labels, 10mL test tubes, test tube rack, glass stirer, drying tissues, test tube cleaning brush and Phyton application.

2.2 Methods

This study was conducted using a field survey method and direct soil testing in the field using PUTS. The activity began with coordination with the head of the farmer group, followed by a field survey to determine the soil sampling locations. The soil sampling locations were divided into 16 locations, chosen intentionally, taking into account different planting patterns. Sampling activities were conducted before the harvest time of the cultivated crops.Samples were taken at a depth 20 cm because this layer is main root zone and nutrient utilization area for annual plants [8] , then composited and analyzed using the PUTS. The procedure for NPK analysis using the PUTS is as follows:

1. Collect approximately 0.5 mL of soil sample (equivalent to ½ spatula) into a test tube.
2. Add the extracting solution, then homogenized the mixture using a glass stirrer
3. Add the appropriate reagent solution corresponding to the nutrient being analyzed (N,P, or K).
4. Allow the mixture to stand for approximately 10 minutes until a clear supernatant and sediment layer are visibly separated
5. Compare the color of the clear supernatant with the nutrient status color chart to determine the soil nutrient level [9].

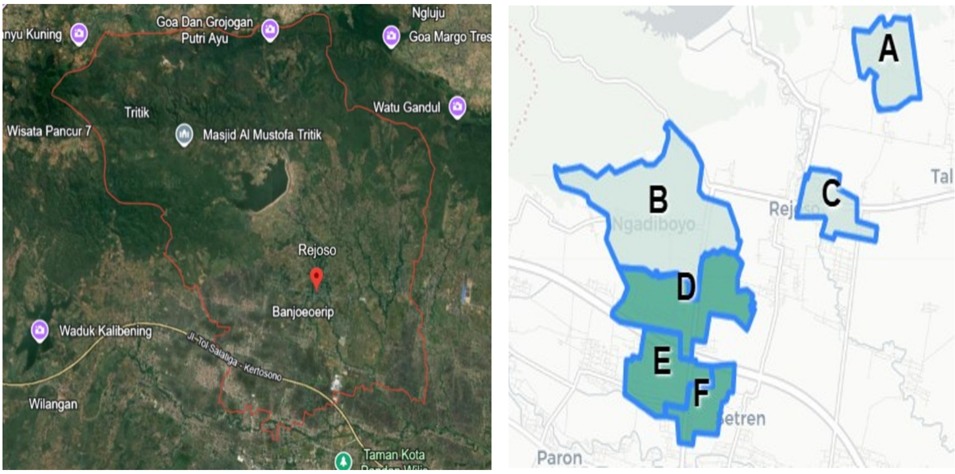


Fig. 1. Map showing the spatial distribution of soil sampling sites across six villages in rejoso district, Nganjuk Regency, East java

3 Results and Discussion

Soil nutrient levels, including Nitrogen (N). Phosphorus (P), and Potassium (K), were analyzed using the Paddy Field Soil Testing (PUTS), which operates based on a colorimetric reaction principle. In this method, soil samples are mixed with element specific reagent, and the resulting color intensity reflects the relative nutrient concentration. Nitrogen availability is classified into four categories low, medium, high, and very high while Phosphorus and Pottassium are grouped into low, medium and high classes. Intepetation follows the standardized color chart provided in the PUTS guideline to ensure uniformity and reliability in nutrient assessment.

All analyses were conducted on site in Rejoso District, comparising six villages. Direct field testing was performed to minimize nutrient alteration during handling and storage. The N-P-K status obtanied from PUTS evaluation is presented in Table 1, forming the basis for comparing soil fertility across cultivation areas.Table 1.

Table 1. Status of N, P and K nutrients based on PUTS in rice fields in Rejoso District, Nganjuk Regency

No	Kode Sample	Status Nutirient			cropping patterns
		N	P	K	
1	A	Medium	High	Low	Paddy –paddy- corn
2	B	High	High	Low	Paddy –paddy- corn
3	C	Medium	High	Low	Chili
4	D	Medium	High	Low	Onion-onion-onion-onion
5	E	High	High	Low	Onion-onion-onion
6	F	High	High	Low	Onion-onion
7	G	Medium	High	High	Onion-onion
8	H	High	High	Medium	Onion-onion-onion-onion
9	I	Very high	High	Low	Onion-onion-onion-onion
10	J	Very high	High	High	Onion-onion-onion
11	K	High	High	Medium	Onion-onion-onion-onion
12	L	Medium	High	High	Onion-onion-onion-onion
13	M	Medium	High	High	Raddy-Paddy-Paddy
14	N	Medium	High	Medium	Raddy-Paddy-Paddy
15	O	Medium	High	Low	Corn – corn -corn
16	P	Low	High	Low	Corn – corn -corn

Based on the results of the N, P, and K analysis in the soil of Rejoso District, the nitrogen content was generally classified moderate, phosphate levels were predominantly high, whereas potassium levels were comparatively low. Soil pH across most sampling point tended to be acidic, with only a few locations approching neutral conditions.

Overall, soil fertility assesment showed that 56% of the observed sites exhibited moderate nitrogen availabillity, followed by 31% high, 13% very high, and no sites fell into the low category. Although nitrogen availability was moderate to high at most locations, the overall N status remains relatively constrained, which is closely associated with limited organic matter input. This observation align with farmer interviews, ndicating that organic matter replenishment has not been evenly adopted. This finding is consistent with previous studies reporting that soil organic matter strongly influences total nitrogen content and contributes to nitrogen retention when organic amandements are applied [10].

The relatively low N availability in some areas is also attributed to the soil's acidic pH which slows organic matter mineralization and restrich nitrogen release. Furthermore, nitrogen limitation can be accelerated by its high mobility and suspectibility to leaching through rainfall or irrigation, removal through crop harvest, adsorption by soil minerals, and microbial immobilization processes [11].

The soil nutrient status also showed 31% high and 13% very high. This happened because in several locations, farmers had implemented organic fertilizer applications and there were indications of excessive nitrogen fertilizer applications. Excessive nitrogen accumulation carried out by farmers could cause a decrease in fertilizer efficiency and also increase the risk of environmental pollution. Furthermore, according to [12] application nitrogen would increase soil acidity, leached nitrate could pollute groundwater, resulting in a decrease in water quality and reducing the impact of biodiversity on local water areas. This difference in nitrogen nutrient status also occurred because each sampling location had different soil processing and planting patterns depending on the preferences of the farmers themselves

Nitrogen plays a crucial role in supporting plant growth, particularly during the vegetative phase, which increases yields. Plants that receive sufficient nitrogen are able to produce larger yields with optimal quality. This is due to optimal plant growth and development, as nitrogen availability increases plant resilience and oxygen excretion. The oxygen produced by plants is also utilized by soil microorganisms, and plants require oxygen [13].

The results of Phosphorus (P) nutrient testing in Rejoso sub-district are dominated by high status, 100% of the total points used as sampling locations. Even though P fertilizer shows a high status, the low pH means that the fertilizer cannot be absorbed by plants. This is generally caused by the process of P fixation by soil minerals such as calcium in alkaline soils or by iron and aluminum in acidic soils so that availability in a usable form is limited. As a result, even though soil P levels are high, plants still experience a lack of phosphorus because this element is not in an available form. Furthermore, according to [14], the application of phosphate fertilizer in large quantities over time will have a high binding capacity, can accelerate the formation of aluminum phosphate and iron phosphate fractions, thereby causing a reduction in the solubility and availability of phosphate originating from the fertilizer source applied by farmers. Apart from that, the availability of phosphate is also influenced by soil pH, at low pH phosphate ions form compounds that are insoluble with iron and aluminum.

Based on the results of interviews with farmers, the cause of this high P nutrient element is due to excessive fertilizer application or at each planting season farmers will add SP-36 fertilizer to the cultivated land so that continuous and excessive application causes some phosphorus to be left behind and bound by the soil because the soil pH conditions tend to be acidic. The high P element is also caused by the nature of P nutrients which have low solubility and are easily fixed [15].

Phosphorus plays a vital role in plant growth, stimulating root growth and development, triggering flowering and fruit ripening, increasing the number of shoots or clumps, and increasing the nutritional content of plant seeds [16]. Furthermore, according to [14], phosphorus is also a component of fat and protein.

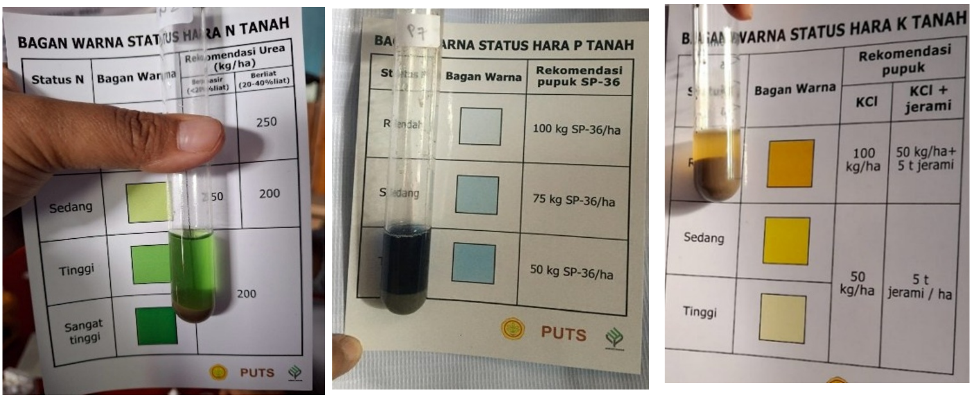
Based on analysis using the Paddy Field Soil Testing Kit, the majority of the potassium (K) content in the soil, or 56%, is in the low category, 25% in the high category, and 19% in the medium category. This indicates that the availability of K in the land in Rejoso District is predominantly in the low category.

Potassium is one of the essential macronutrients for plants because it plays several roles, including maintaining water balance, maintaining cell turgor pressure, regulating the opening and closing of stomata, and is also required for the accumulation and translocation of carbohydrates [17]

Furthermore, according to [18], potassium acts as a catalyst in the transformation of sugar, starch and plant fat, supports smooth photosynthesis, enzyme activator, stimulates root growth and balances nitrogen and phosphorus nutrients.

In this research area, the condition of Potassium nutrient elements varies from high, medium and low, the high potassium in the soil is closely related to the application of organic materials. According to Badar, et al., the process of decomposition of organic materials in the soil will increase the K content of the soil due to the process of releasing Potassium elements, high levels of potassium in the soil are also influenced by the habits of farmers in returning the harvested stumps to the soil, because of the difference in the K element, more than 80% will be absorbed by the soil and stored in the straw as a vegetative part while the N and P nutrients will mostly be transported by the seeds [19].

Meanwhile, the low potassium content in plant cultivation activities is influenced by several factors including the planting patterns carried out by farmers, soil processing because if cultivation activities are carried out without tillage, K is only available near the soil surface and becomes unavailable, the fertilizer application technique carried out by farmers is spread or on the surface causing the K element to only be available on the surface, especially supported by less than optimal soil processing practices causing K to be unavailable in the root zone of plants in clay-rich soils and low cation exchange capacity. The lack of practice in returning plant litter to the land, lost due to the leaching process, especially if the amount of potassium given exceeds the soil's ability to retain it and the needs of the plant [20]. The chemical parameters of the soil are a) Total nitrogen, b. Available phosphorus and c. Exchangeable potassium are presented in Figure 2.



a. Total Nitrogen test b. Phosphorus Test c. Potasium Test

Fig 2. Results of in situ soil cehmical analysis using the PUTS.

Information : the test includes (a). total nitrogen analysis, classified into low, medium, high, and very high categories; (b). phosphorus avaibility determination, analyzed through a colorimetric comparison chart with three classification levels (low, medium,high); and (c) pottasium assesment using a similar color-based scale. The figure ilustrated the visual nutrient status obtained through direct colorimetric interpretation at the fiels sampling site

Analysis of soil nutrient status in Rejoso District indicates that the availability of macronutrients (N, P, K) is unbalanced. Most land has moderate nitrogen (N) status (56%), high phosphorus (P) (100%), and low potassium (K) (56%). Furthermore, the soil pH is in the slightly acidic range (5.6–6.0). This situation indicates the need for improved fertilization strategies that are more adaptive to actual soil conditions, thus ensuring more efficient fertilizer use and minimizing environmental degradation.

To achieve this, balanced fertilization can be achieved, supported by analysis using PUTS. PUTS provides recommendations for appropriate fertilizer dosages and types for the next planting season, based on nutrient status measurements from the previous period. Therefore, PUTS can be used as a basis for developing more efficient, location-specific fertilization strategies that can increase soil productivity.

The moderate to high nitrogen (N) status indicates a relatively sufficient nitrogen (N) supply, in line with farmers' practice of applying large amounts of urea during the vegetative and generative phases. However, excessive use of synthetic N fertilizers has the potential to reduce uptake efficiency (only 30–50%) due to losses through leaching, denitrification, and volatilization[21]. This nitrogen loss not only reduces production costs but also increases the risk of environmental pollution[22]. Therefore, nitrogen fertilization recommendations in this area should be directed toward the urea dosage according to soil nutrient status. For clay textured soil with low N status, the recommended dosage is 250 urea Kg/ha. For soil with moderate N status, the recommended dosage is 200 urea Kg/ha, whereas for soils with high to very high N status, the urea application should be maintained at 200 kg/ha to prevent excessive nitrogen input, which may lead to nutrient loss and negative environmental impacts.

Conversely, the relatively high phosphorus (P) status indicates an accumulation of P fertilizer due to excessive application from the previous season. However, effective P availability in the soil is relatively low because acidic soil conditions cause P to bind to Fe and Al ions. In this context, increasing the P fertilizer dose is not the primary solution, but rather increasing existing P availability through liming. Liming can raise the pH to a range of 5.8–6.5 while simultaneously reducing Al toxicity, thereby increasing P solubility. With, the increased solubility of phosphorus and the enhancement of the exchangeable phosphate fraction, the efficiency of phosphorus uptake by plants will improve without requiring excessive fertilizer application. The stategy not only optimizes the utilization of soil phosphorus but also helps minimixze potential environmental pollution doe to the accumulation of unused phospohorus [23]. P fertilizer recommendations based on PUTS for low P nutrient status are recommended at 100 kg Sp-36/ha, for medium nutrient status are recommended at 75 kg Sp-36/ha and for high P nutrient status are recommended at 50 kg/ha.

Meanwhile, potassium (K) is the main limiting factor, given that most observation points show low status. Potassium plays a crucial role in plant physiological regulation, particularly in photosynthesis, water balance, and carbohydrate formation[24]. A K deficiency can potentially make plants susceptible to lodging, reduce photosynthetic efficiency, and reduce crop quality. Therefore, increasing K fertilizer application requires special attention. The recommended KCl fertilization rate is around 100 kg/ha for low soil status, while for medium-high soil status, 50 kg/ha is sufficient. In addition to inorganic fertilizers, alternative K sources include returning rice straw to the field and utilizing rice husk ash or biochar, which can increase K availability while improving soil chemical properties [25].

In general, the soil pH in Rejoso District is still in the slightly acidic category (5.6–6.0), which is relatively close to optimal conditions for rice plants. However, in locations with a pH <5.5, selective liming is necessary to increase fertilizer efficiency, particularly for P and K. This strategy will improve nutrient balance and reduce the risk of fertilizer accumulation that is not utilized by plants. Therefore, fertilizer recommendations in Rejoso District should focus on balanced fertilization, adhering to the 5T principles (correct type, dosage, timing, method, and location). This principle is the basis for the application of balanced fertilization, namely fertilization that is adjusted to soil conditions (nutrient status) and plant needs, thereby minimizing fertilizer waste and minimizing negative impacts on the environment. Nitrogen needs to be reduced and managed efficiently, phosphorus should be maintained through selective liming and organic matter, and potassium should be increased with a combination of inorganic and organic fertilizers. This strategy is expected to increase of cultivated plants productivity while maintaining sustainable soil fertility.

4 Conclusion

Conclusion

- In general, the 16 soil sampling locations showed moderate levels of nitrogen, high levels of phosphate, and high levels of potassium.
- Based on the PUTS, recommendations include: In areas with moderate to very high nitrogen levels, the recommended dose of urea is 200 kg/ha, while in areas with low nitrogen levels, the recommended dose is 250 kg/ha., . SP-36 fertilizer should be

applied for maintenance at a dose of 50 kg, and an increase in KCl application is necessary. Land with low soil status should be 100 kg/ha, and land with medium to high soil status should be 50 kg/ha.

- A balanced fertilization strategy should be implemented according to the 5T principle (correct type, dose, time, method, and location), this is the main recommendation.

Suggestions

Based on the results of research on soil nutrient status using the PUTS test tool, which plays an important role in carrying out early detection of N, P and K nutrient status, which focuses on providing recommendations for the amount of fertilizer to be applied in the next planting period as a basis for compiling balanced fertilization recommendations.

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References

[1] R. Fauziah, A. D. Susila, and E. Sulistyono, “Budidaya Bawang Merah (Allium ascalonicum L .) pada Lahan Kering Menggunakan Irigasi Sprinkler pada berbagai Volume dan Frekuensi,” *Hort. Indones. 7(1)*, vol. d, no. April, pp. 1–8, 2016.

[2] M. I. Fitrianata and F. Rozci, “Potensi Komoditi Bawang Merah di Desa Musir Kidul Kecamatan Rejoso Kabupaten Nganjuk,” *J. Community Serv.*, vol. 1, no. 3, pp. 224–230, 2023.

[3] T. Belete and E. Yadete, “Effect of Mono Cropping on Soil Health and Fertility Management for Sustainable Agriculture Practices : A Review,” *J. Plant Sci.*, vol. 11, no. 6, pp. 192–197, 2023, doi: 10.11648/j.jps.20231106.13.

[4] H. Walida, F. S. Harahap, B. A. Dalimunthe, R. hasibuan, A. P. Nasution, and S. H. Sidabuke, “Pengaruh Pemberian Pupuk Urea Dan Pupuk Tanah Dan Hasil Tanaman Sawi Hijau,” *J. Tanah dan Sumberd. Lahan*, vol. 7, no. 2, pp. 283–289, 2020, doi: 10.21776/ub.jtsl.2020.007.2.12.

[5] T. Prakoso, H. Alpandari, and H. H. H. Sridjono, “Respon Pemberian Unsur Hara Makro Essensial Terhadap Pertumbuhan Tanaman Jagung (zea mays),” *Muria J. Agroteknologi*, vol. 1, pp. 8–13, 2022.

[6] Y. Hasanah, L. Mawarni, F. Wirawan, and I. Kurniawan, “The Content of Nitrogen, Phosphorus and Potassium of Shallot (Allium ascalonicum L.) Varieties With Different Method of Cultivation and Altitude,” 2023, doi: 10.1088/1755-1315/1241/1/012034.

[7] M. D. Patria, D. Bakri, and A. Z. Siregar, “Uji Ketahanan Berbagai Varietas Tanaman Kedelai (Glycine max) Terhadap Hama Lamprosema indicata,” *J. Agroteknologi*, vol. 11, no. 2, pp. 61–66, 2021.

[8] I. Purwanto *et al.*, *Petunjuk Teknis Pelaksanaan Penelitian Kesuburan Tanah*. Jakarta: IAARD Press, 2014.

[9] T. Thamrin, I. S. Marpaung, and T. Arief, *Penggunaan Perangkat Uji Tanah Sawah (PUTS)*. Balai Pengkajian Teknologi Pertanian Sumatera Selatan, 2011. [Online]. Available: https://repository.pertanian.go.id/server/api/core/bitstreams/c0374feb-

0265-45b9-8a72-228c69ff6b90/content

[10] S. I. R. Wamnebo, E. Kaya, and A. Siregar, “Status Hara Nitrogen, Fosfor, dan Kalium pada Lahan Sawah di Desa Savana Jaya Kecamatan Waeapo Kabupaten Buru,” *J. Agrosilvopasture-Tech*, vol. 2, no. 2, pp. 531–538, 2023.

[11] D. A. Putra, D. H. Adam, N. E. Mustamu, and F. S. Harahap, “Analisis Status Nitrogen Tanah Dalam Kaitannya Dengan Serapan N Oleh Tanaman Padi Sawah Di Kelurahan Ujung Bandar, Kecamatan Rantau Selatan, Kabupaten Labuhan Batu,” *J. Pertan. Agros*, vol. 24, no. 1, pp. 387–391, 2022.

[12] Syafruddin, “Manajemen Pemupukan Nitrogen Pada Tanaman Jagung,” Maros: Balai Penelitian Tanaman Serealia, 2015, pp. 105–116.

[13] E. Tando, B. Pengkajian, T. Pertanian, and S. Tenggara, “Review : Upaya Efisiensi Dan Peningkatan Ketersediaan Nitrogen Dalam Tanah Serta Serapan Nitrogen Pada Tanaman Padi Sawah (Oryza Sativa L.),” *Buana Sains*, vol. 18, no. 2, pp. 171–180, 2018.

[14] S. E. Sarief, *Kesuburan dan pemupukan tanah pertanian*. Bandung: Pustaka Buana, 1986.

[15] C. Anam, M. Qibtiyah, and D. E. Kusumawati, “Analisis Status Unsur Hara (N, P, K) pada Lahan Sawah Irigasi di Kabupaten Lamongan,” *J. Kelitbangan Kabupaten Lamongan*, vol. 7, pp. 1–10, 2024.

[16] S. K. De Datta, *Principles and Practices of Rice Production*. New York, N.Y. (USA), 1981.

[17] R. Erwiyono and A. A. Sucahyo, “Keefektifan Pemupukan Kalium Lewat Daun Terhadap Pembungaan dan Pembuahan Tanaman Kakao,” *Pelita Perkeb.*, vol. 22, no. 1, pp. 13–24, 2006.

[18] W. A. Barus, “Peningkatan Toleransi Padi Sawah Di Tanah Salin Menggunakan Anti Oksidan Asam Askorbat dan Pemupukan PK Melalui Daun,” 2016.

[19] I. U. Sarkar, N. Isalm, A. Jahan, A. Islam, and J. C. Biswas, “Rice Straw as a Source of Potassium for Wetland Rice Cultivation,” *Geol. Ecol. Landscapes*, no. August, pp. 1–6, 2017, doi: 10.1080/24749508.2017.1361145.

[20] Q. Ma, R. Bell, C. Scanlan, and A. Nauhaus, “Long-term rundown of plant-available potassium in Western Australia requires a re-evaluation of potassium management for grain production : a review,” *Crop Pasture Sci.*, 2022, doi: 10.1071/CP21612.

[21] R. Suminar and H. Purnamawati, “Penentuan Dosis Optimum Pemupukan N , P , dan K pada Sorgum (Sorghum bicolor [L .] Moench) (Determination of N , P , and K Fertilizer Optimum Rates for Sorghum (Sorghum bicolor [L .] Moench)),” *J. Ilmu Pertan. I*, vol. 22, no. April, pp. 6–12, 2017, doi: 10.18343/jipi.22.1.6.

[22] R. P. Ilahi and M. A. Safeno, “Pengaruh Efek Sisa Kombinasi Biochar Sekam Padi Dan Dolomit Terhadap Pencucian Unsur N Pada Budidaya Tanaman Jagung (Zea Mays L.),” *J. Arunasita*, vol. 2, pp. 103–113, 2025.

[23] R. L. Toledo, Marino Pedro Reyes Martín, L. Celi, and Emilia Fernández Ondoño, “applied sciences Phosphorus Dynamics in the Soil – Plant – Environment Relationship in Cropping Systems : A Review,” *mpdi*, 2021, doi: https://doi.org/10.3390/app112311133.

[24] N. K. Fageria and J. P. Oliveira, “Nitrogen , Phosphorus and Potassium Interactions in Upland Rice,” *J. Plant Nutr.*, no. September, pp. 37–41, 2014, doi: 10.1080/01904167.2014.920362.

[25] M. Siedt, A. Schäffer, K. E. C. Smith, M. Nabel, M. Roß-nickoll, and J. T. Van Dongen, "Science of the Total Environment Comparing straw , compost , and biochar regarding their suitability as agricultural soil amendments to affect soil structure , nutrient leaching , microbial communities , and the fate of pesticides," *Sci. Total Environ.*, vol. 751, p. 141607, 2021, doi: 10.1016/j.scitotenv.2020.141607.