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Industry and Plantation Collaboration: The Production of Chemical Fertilizer at CV Tabita Jaya and Its Chemical Compositions

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ABSTRACT

This study aimed to formulate and evaluate an NPK compound fertilizer with a target ratio of 10:6:20 to enhance green mustard (Brassica juncea) productivity. At CV Tabita Jaya, standardized production methods were used to prepare the fertilizer by mixing Urea, triple superphosphate, and potassium chloride, with analytical confirmation of the nutrient content. Results showed nitrogen (N) content of 10.8%, phosphorus (P_2O_5) at 6.5%, and potassium (K_2O) at 20.8%, closely aligning with the target formulation. Moisture content was low at 2.48%, ensuring product stability and ease of application. Analytical techniques employed included Kjeldahl titrimetry for nitrogen, molybdate-vanadate spectrophotometry for phosphorus, and flame photometry for potassium. These methods demonstrated high reliability, with parameters such as repeatability, reproducibility, and recovery meeting international standards. The fertilizer is expected to support green mustard growth by enhancing critical metrics, including plant height, leaf number, and biomass accumulation. The study highlights the agronomic benefits of balanced NPK fertilization for green mustard, emphasizing enhanced nutrient absorption and sustainable agricultural practices. Furthermore, integrating this fertilizer with organic amendments may help mitigate potential soil degradation associated with prolonged use of inorganic fertilizers. The findings highlight the potential of precision-formulated fertilizers to enhance crop productivity while promoting environmental sustainability.

Keyword: NPK Fertilizer, N-Total, P2O5, K2O, Moisture Content

1. Introduction

Fertilizer is an organic or inorganic material containing numerous nutrients that are added to growing media or plants to support their growth. Fertilizers can be categorized into two types based on their origin: inorganic (synthetic) and organic fertilizers [1]. Inorganic fertilizers, commonly used in crop cultivation, come in various forms, including Urea, TSP (Triple Superphosphate), NPK compound fertilizers, and other types. Compound fertilizers, classified as inorganic or "complete fertilizers," contain multiple macro and micronutrients. These fertilizers primarily consist of three key compounds: nitrogen, phosphorus, and potassium [2].

In Indonesia, compound fertilizers have gained significant attention among farmers due to their practical application and effectiveness as an alternative for enhancing plant growth [3]. However, the prolonged and continuous use of compound fertilizers without organic amendments to aid nutrient absorption can adversely affect soil health, reducing both soil fertility and crop productivity. Negative impacts include soil compaction, hardening, reduced water retention capacity, and increased soil acidity, ultimately leading to declining plant yields [4]. Elucidated that the application of compound NPK fertilizer combined with foliar fertilizer had a significant positive impact on the growth of green mustard plants. The study demonstrated notable effects on plant height at 5, 20, and 25 days after planting (7.85 cm, 30 cm, and 36.73 cm, respectively), leaf count at 10 and 20 days after planting (8.56 leaves), leaf area per plant (230.24 cm^2), fresh weight per plant (230.42 g), and shoot fresh weight (138.22 g). These findings underscore the efficacy of integrated fertilizer management in optimizing plant growth and productivity.

Green mustard (Brassica juncea) is a highly consumed leafy vegetable in Indonesia, and its cultivation heavily depends on an adequate nutrient supply. The application of NPK fertilizers has proven effective in enhancing the growth and yield of green mustard. Research has shown that balanced fertilization enhances various growth parameters, including plant height, leaf number, and biomass accumulation [4]. However, achieving an optimal nutrient balance in fertilizers remains a challenge, as deviations from the target nutrient composition can affect the fertilizer's performance and the plant's growth. Despite the availability of commercial NPK fertilizers, there is a need to develop formulations tailored to specific crop requirements and to optimize their chemical composition for better efficacy. The collaboration between CV Tabita Jaya and academic researchers aims to address this challenge by producing high-quality NPK fertilizers with precise nutrient ratios. Additionally, this research provides a scientific foundation for analyzing the chemical properties of fertilizers and evaluating their impact on the growth of green mustard, among other plants. The urgency of this research lies in the need to ensure sustainable agricultural practices while meeting the growing demand for efficient fertilizers. By optimizing fertilizer formulations and ensuring their quality through advanced analytical techniques, this study contributes to enhancing crop productivity, improving soil health, and supporting the economic growth of the agricultural sector.

2. Methods

2.1. Materials

Potassium chloride (KCl), sulfuric acid (H_2SO_4), distilled water, sodium hydroxide (NaOH), Ammonia, hydrochloric acid (HCl), boric acid, ammonium molybdate, vanadate solutions, distilled water, Urea, triple superphosphate.

2.2. Production of Compound Fertilizer

The raw materials were weighed to achieve the desired 10:6:20 NPK ratio. For a total weight of 1 kg, Urea Was Used as the nitrogen source, triple superphosphate as the phosphorus source, and potassium chloride as the potassium source. The materials were mixed in a non-corrosive container using a mechanical mixer to ensure uniform distribution, as shown in Figure 1(a). A filler material, an additive material, was added gradually until a total weight of 1 kg was achieved. The mixing process was carried out carefully to prevent any unintended reactions. The final mixture was inspected for homogeneity and consistency. Analytical testing confirmed that the N, P, and K contents matched the specified ratio.

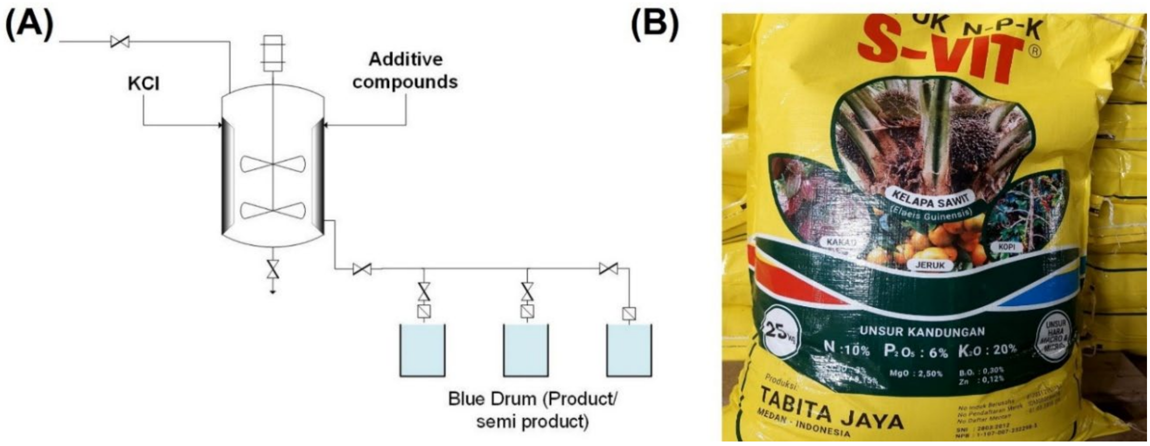

Figure 1. (a) Design of reactor fertilizer chemical compound, and (b) CV Tabita Jaya Fertilizer compound products

2.3. Nitrogen (N) Analysis – Kjeldahl Titrimetry Method

The nitrogen content in compound fertilizers can be determined using the Kjeldahl method with the following procedure. A precisely weighed 0.7-gram sample of the compound fertilizer is placed into a digestion flask. Two Kjeldahl catalyst tablets and 15 mL of concentrated sulfuric acid (H_2SO_4) are added. The mixture is heated at 420°C for 120 minutes until the solution becomes clear, indicating complete digestion. Once digestion is complete, the solution is allowed to cool to room temperature, after which 70 mL of distilled water is carefully added while mixing thoroughly to achieve a homogeneous solution. The digested solution is then transferred to the distillation unit of the Kjeldahl apparatus. Subsequently, 70 mL of 32% sodium hydroxide (NaOH) is slowly added to the solution. The distillation process is carried out for 1.5 hours to release ammonia, which is captured in a 2% boric acid solution containing a suitable indicator. The distillate is titrated with a 0.1 N hydrochloric acid (HCl) solution until the endpoint is reached, as indicated by a color change in the solution [5]. The nitrogen content is calculated using the formula: **Eq.1**

$$\text{Nitrogen (\%)} = \frac{(V_{HCl} - V_{blank}) x N_{HCl} x 1.401}{W_{sample}} \quad (1)$$

Where:

- V_{HCl}: Volume of HCl used for titration (mL),
- V_{blank}: Volume of the blank (mL),
- N_{HCl}: Normality of HCl,
- W_{sample}: weight of sample.

2.4. Phosphorus (P_2O_5) Analysis – Spectrophotometry (UV-Vis) Method

Organo-mineral fertilizer samples were analyzed for total phosphorus content using a standardized molybdate-vanadate spectrophotometric method. A 2.5 g sample was accurately weighed and subjected to acid digestion with a mixture of concentrated HNO_3 (65%), HCl (37%), and H_2SO_4 (95-97%) in equal proportions. The digested sample was heated on a sand bath until the solution was clear, cooled, and diluted to a known volume with distilled water. Standard solutions with phosphorus concentrations ranging from 0.00 to 0.05 mg/mL were prepared by serial dilution of a 1000 mg/L phosphorus standard, acidified with HCl, and treated with 5% ammonium molybdate and 0.25% ammonium vanadate solutions. After a 30-minute reaction period, the absorbance of both standard and sample solutions was measured at 470 nm using a UV-VIS spectrophotometer, and phosphorus content was determined from the calibration curve [6].

2.5. Potassium (K_2O) Analysis – Flame Photometry Method

Fertilizer samples containing potassium were analyzed using flame photometry. A 2.5 g sample was dissolved in 1000 mL distilled water, filtered, and diluted. Potassium standards (5–25 ppm) were prepared from a 1000 ppm stock solution. The flame photometer (PFP7, Jenway) was used at a flow rate of 2–6 mL/min with a continuous air supply of 14–30 psi. Potassium content was determined using a calibration curve. Validation included repeatability (0.33% RSD), reproducibility (0.40% RSD), LOD (0.87%), LOQ (2.88%), and recovery (98%). Measurement uncertainty was calculated by combining contributions from sample preparation, instrument calibration, and environmental factors, ensuring method reliability for potassium analysis in fertilizers [7].

2.6. Moisture Content – Gravimetric (Oven-Dry) Method

The moisture content in fertilizers can be determined using the gravimetric method, a direct and reliable approach. In this method, approximately 20 grams of the fertilizer sample are collected and weighed to determine the initial weight (W_i). The sample is then dried in a convection oven at 105°C for 48 hours to remove all moisture. After drying, the sample is cooled in a desiccator to prevent moisture absorption and reweighed to obtain the final weight (W_f) [8]. The moisture content is calculated using the formula: **Eq.2**

$$\text{Moisture Content} = \frac{W_i - W_f}{W_f} x100 \quad (2)$$

where W_i is the initial weight and W_f is the final weight after drying. This process ensures accurate measurement of moisture levels, which is critical for assessing the quality and storage stability of fertilizers. To maintain precision, analyses are typically conducted in triplicates, and drying conditions are kept consistent across all samples. This method is widely recognized for its simplicity and effectiveness in fertilizer quality control.

3. Result and Discussion

The production and analysis of compound fertilizers at CV Tabita Jaya demonstrate a systematic approach to ensuring product quality through precise formulation and robust analytical techniques. The fertilizer, with a target NPK ratio of 10:6:20, was developed to provide balanced nutrients critical for plant growth. Analytical results showed nitrogen content slightly exceeding the target at 10.8%, phosphorus content at 6.5%, and potassium content accurately meeting the target at 20.8%. as shown in Table 1. These deviations, though minor, highlight the need for strict quality control during raw material preparation and mixing to ensure homogeneity in the final product.

Table 1. Result Analysis of Chemical Fertilizer

Parameter tested	Result	Unit	Test Method
N Total	10.8	%	Titrimetry
P_2O_5 Total	6.5	%	Spectrophotometry
K_2O Total	20.8	%	Flamephotometry
Moisture	2.4	%	Gravimetry

Nitrogen, a vital component of this formulation, plays a fundamental role in protein synthesis and chlorophyll production in plants, directly influencing their growth and development. nitrogen influences root architecture and shoot growth [9]. It is involved in the synthesis of phytohormones and other growth regulators that modulate these processes. The plant required N in the form of NO_3^- or NH_4^+ for high-yield crop production [10]. The slightly elevated nitrogen content in this fertilizer is likely beneficial for crops like green mustard (*Brassica juncea*), which require sufficient nitrogen to promote leaf expansion and vegetative growth. Research has shown that adequate nitrogen levels enhance the photosynthetic capacity of mustard plants, leading to increased yield and better-quality foliage, a crucial aspect for leafy vegetable production.

Phosphorus, analyzed using the molybdate-vanadate spectrophotometric method, is essential for energy transfer and root development in plants. While the phosphorus content in the fertilizer was slightly below the target, it remains within a range suitable for supporting mustard growth. Phosphorus contributes significantly to early plant establishment by strengthening root systems, thus enabling efficient water and nutrient uptake. Studies have indicated that phosphorus deficiencies in mustard plants can lead to stunted growth and poor leaf quality, underscoring its importance in fertilizer formulations [11].

Potassium, analyzed using flame photometry, met the target ratio and exhibited high reliability with validation parameters such as an LOD of 0.87%, LOQ of 2.88%, and a recovery rate of 98%. Potassium is particularly crucial for green mustard, as it regulates stomatal opening and closing, enhancing water use efficiency and tolerance to abiotic stresses. It also improves the plant's resistance to diseases and contributes to the synthesis of carbohydrates, which are vital for leaf production. Adequate potassium levels have been shown to improve the overall quality, size, and taste of mustard leaves [12] making it a critical component in fertilizers for this crop.

Moisture content, determined through gravimetric analysis, was found to be low (2.48%), ensuring the fertilizer's stability during storage and reducing the risk of caking or degradation. This low moisture level is beneficial for maintaining the physical properties of the fertilizer, facilitating its application in the field, and ensuring consistent nutrient delivery to crops. This result applies to the green mustard plant to obtain the performance of a growth plant, as shown in Fig.2

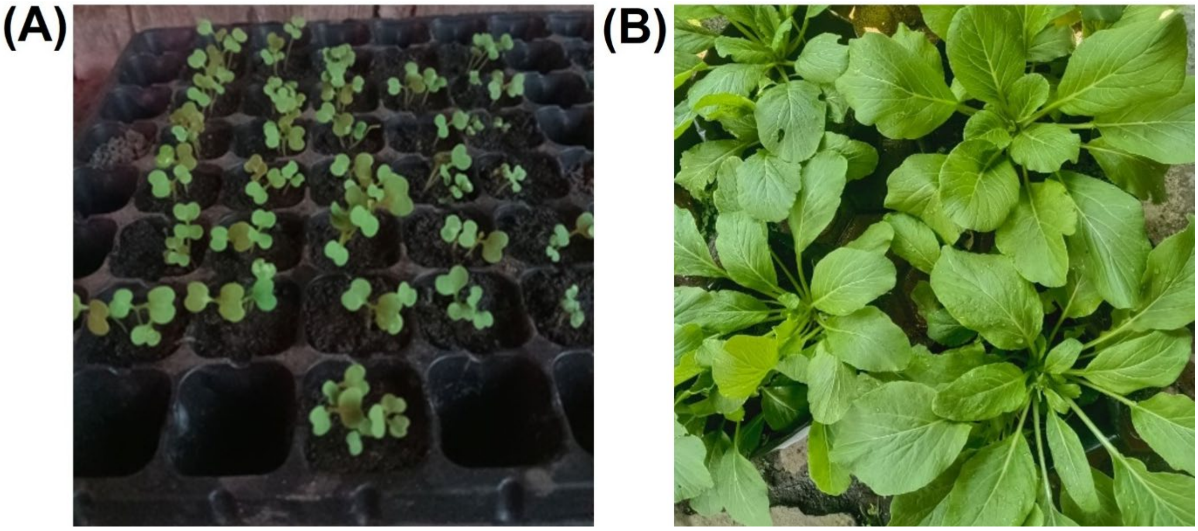

Figure 2. (a) The green mustard seedlings in the nursery tray are approximately 3 days old after sowing under optimal conditions, and (b) the green mustard plants in the vegetative growth phase are 3 weeks old after transplanting, depending on the care and growth environment.

The application of this fertilizer to green mustard crops offers significant agronomic benefits. Balanced NPK fertilizers are known to enhance plant growth metrics, including height, leaf area, and biomass accumulation. For green mustard, the targeted nutrient composition promotes rapid vegetative growth, resulting in larger, more vibrant leaves that meet market demands. Furthermore, the integration of this fertilizer with organic amendments, such as compost or biochar, could mitigate potential soil health issues associated with prolonged use of inorganic fertilizers, such as compaction and reduced fertility.

4. Conclusion

This study successfully formulated an NPK fertilizer with a target ratio of 10:6:20 using standardized production methods at CV Tabita Jaya. Analysis results showed nitrogen (N) content of 10.8%, phosphorus (P_2O_5) of 6.5%, and potassium (K_2O) of 20.8%, which closely matched the target formulation. The low moisture content of the fertilizer (2.48%) ensures product stability during storage and facilitates field application. The analytical methods employed, including Kjeldahl titrimetry for nitrogen, molybdate-vanadate spectrophotometry for phosphorus, and flame photometry for potassium, demonstrated high reliability with validation parameters such as repeatability, reproducibility, and recovery meeting international standards. These analyses provided strong evidence of the quality and consistency of the produced fertilizer. The application of this fertilizer on green mustard (Brassica juncea) is expected to support optimal growth by enhancing key parameters such as plant height, leaf number, and biomass. With precise formulation and validated analysis results, this fertilizer has significant potential to improve green mustard productivity while supporting sustainable agricultural practices.

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