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Dosage Recommendation of Unbalanced Compound Fertilizers for Cabbage (*Brassica oleracea*)

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Abstract. *Fertilization serves as a fundamental component of crop cultivation, wherein the application of mineral nutrients is crucial for plant nourishment, facilitating various physiological processes critical for growth and development. The objective of this study is to establish an optimal recommended dosage that enhances cabbage growth and yield. The experimental design employed in this study was a randomized block design with four replications. The treatments consist of seven fertilization levels, as follows: No fertilization with nitrogen (N), phosphorus (P), or potassium (K) (P0), reference fertilization (P1), 0.5 dose of unbalanced compound fertilizers (P2), 0.75 dose of unbalanced compound fertilizers (P3), 1.0 dose of unbalanced compound fertilizers (P4), 1.25 dose of unbalanced compound fertilizers (P5), and 1.5 dose of unbalanced compound fertilizers (P6). The experiment indicated that the application of unbalanced compound fertilizers enhances cabbage plant growth, as evidenced by increased plant height and leaf number compared to the control treatment. Additionally, fertilization improves yield components relative to untreated plants. The application of 0.5 doses of unbalanced compound fertilizers proves agronomically effective, yielding the highest relative agronomic effectiveness at 169%, meaning a 1.69-fold increase in yield. Economically, the same dosage is also highly beneficial, achieving the highest R/C ratio of 2.35 and generating a profit of Rp. 14,365,150. The study results confirm that unbalanced compound fertilizers were both agronomically effective and economically advantageous. The recommended dosage for cabbage cultivation is 134 kg/ha, applied in two stages: 50% at 1 WAT (weeks after transplanting) and the remaining 50% at 4 WAT.*

Keywords*: Cabbage, Compound Fertilizer, Economic Benefits, Horticultural Crops, Productivity.*

1. INTRODUCTION

Fertilization serves as a fundamental component of crop cultivation, wherein the application of mineral nutrients is crucial for plant nourishment, facilitating various physiological processes critical for growth and development. Nutrients such as nitrogen (N), phosphorus (P), potassium (K), and other micronutrients are pivotal in promoting successful crop production (Uzoh & Odera, 2019). Each stage of a plant's lifecycle is characterized by differing nutritional needs; thus, the accurate and timely application of these nutrients is vital for maximizing crop health (Warncke & Barber, 1974). Mineral nutrient sufficiency throughout the growth stages not only enhances plant development but also significantly influences crop yield and resilience against biotic and abiotic stressors (Quyen et al., 2024; Walker & Peck, 1974).

Macronutrients are unequivocally recognized as the primary essential elements for plant growth and development. Nitrogen (N), phosphate (P), and potassium (K) stand out as the main macronutrients indispensable to plants. Among these, nitrogen plays a critical role, comprising

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about 78% of the Earth's atmospheric gas. However, despite its abundance, atmospheric nitrogen remains inaccessible to plants in this form and must be converted into usable compounds (Masclaux-Daubresse et al., 2010). Plants absorb nitrogen primarily in the forms of ammonium (NH_4^+) and nitrate (NO_3^-), which dissolve in soil water and are assimilated through the plant roots (LI et al., 2008; Xu et al., 2012). The dynamics of nitrogen uptake are closely linked to the active growth phases of plants, wherein their requirement fluctuates depending on developmental stages. Research shows that juvenile plants exhibit the highest nitrogen absorption rates, which progressively decline as they mature (Xu et al., 2012; Li et al., 2020).

Potassium (K) is recognized as a critical macronutrient that significantly contributes to various physiological processes in plants, particularly protein synthesis. K^+ ions are known to serve as activators or coenzymes for several enzymes that enhance leaf nitrate content, thus promoting protein synthesis (Wang et al., 2021). Phosphorus (P) is another essential macronutrient required by plants in substantial quantities. It is absorbed primarily as phosphate ions ($H_2PO_4^-$ and HPO_4^{2-}), playing multiple roles in structural and functional processes (Siedliska et al., 2021). P is integral to various cellular functions, including cell division, respiration, and root development, and is a key component of nucleic acids and energy carriers such as adenosine triphosphate (ATP) (Abdelkader et al., 2019).

Research on unbalanced compound fertilizers has been limited in assessing plant growth, particularly in cabbage cultivation. The varying nutrient compositions in compound fertilizers influence different growth patterns and yield outcomes. Therefore, it is essential to evaluate the commercially available doses of unbalanced compound fertilizers to determine their effects on cabbage plants. The objective of this study is to establish an optimal recommended dosage that enhances cabbage growth and yield.

2. MATERIALS AND METHODS

Materials

The materials used in this experiment include cabbage seeds, unbalanced compound fertilizers being tested for efficacy, as well as Urea, SP-36, and KCl fertilizers. The equipment utilized consists of cultivation tools (hoes, hand weeders, sprayers), sample stakes, measuring tape, and a digital scale. Data processing was carried out using a computer and the SAS statistical analysis software. Based on laboratory analysis, the composition of the unbalanced compound fertilizers consists of total nitrogen (12.29%), total P_2O_5 (6.92%), and total K_2O (22.42%).

Testing Methodology

The experimental design employed in this study was a randomized block design with four replications. The treatments consist of seven fertilization levels, as follows: No fertilization with nitrogen (N), phosphorus (P), or potassium (K) (P0), reference fertilization (P1), 0.5 dose of unbalanced compound fertilizers (P2), 0.75 dose of unbalanced compound fertilizers (P3), 1.0 dose of unbalanced compound fertilizers (P4), 1.25 dose of unbalanced compound fertilizers (P5), and 1.5 dose of unbalanced compound fertilizers (P6). The experiment consists of four replications, resulting in a total of 28 experimental units. Each unit is a plot of land measuring 25 m². The detailed treatments applied in this effectiveness test are presented in Table 1.

Table 1. Detailed dosage treatment for unbalanced compound fertilizers.

Treatments	Dosage of unbalanced compound fertilizers (kg/ha)	Dosage of urea (kg/ha)	Dosage of KCl (kg/ha)	Dosage of SP-36 (kg/ha)
Control	-	-	-	-
Reference	-	200	100	100
0.5 dosages unbalanced compound fertilizers	134	63	-	24
0.75 dosages unbalanced compound fertilizers	201	95	-	36
1.0 dosage unbalanced compound fertilizers	268	127	-	49
1.25 dosages unbalanced compound fertilizers	335	159	-	61
1.5 dosages unbalanced compound fertilizers	401	190	-	73

Experimental Implementation Method

The land was thoroughly prepared through two rounds of hoeing to ensure optimal conditions for planting. The second tillage process was followed by the construction of raised beds measuring 1 meter in width and 5 meters in length, with an inter-bed spacing of approximately 50 cm. Each experimental unit consisted of five raised beds.

Seedlings were transplanted 21 days after sowing, with one seedling per planting hole. The planting distance used was 60 cm × 40 cm, with one plant per hole. Base fertilizers (urea, SP-

36, and KCl) were applied according to the designated treatment dosage one week after transplanting (WAT). The unbalanced compound fertilizers were applied twice, 50% of the dosage in 1 WAT and the remaining 50% at 4 WAT.

Pest and disease management was carried out according to the level of infestation, using limited pesticide applications to ensure effective control while minimizing environmental impact.

Observations

Plant growth parameters, including plant height and leaf count, were observed. These measurements were conducted on five randomly selected sample plants. Yield and yield component assessments encompassed yield per plant, yield per plot, and yield per hectare, with the latter being converted from the yield per plot.

Data Analysis

The data were analyzed statistically using analysis of variance (ANOVA) and the Duncan Multiple Range Test (DMRT) at a 5% significance level. The farm business analysis was conducted using economic calculations, incorporating profit and R/C ratio variables. The fertilizer was deemed to pass the technical effectiveness test if its treatment results were statistically comparable to the control treatment or significantly better than the untreated control at a 5% significance level. Additionally, fertilizer was considered economically effective if the economic farm analysis indicated profitability.

3. RESULTS AND DISCUSSION

Effect of Unbalanced Compound Fertilizers on Cabbage Growth

The application of unbalanced compound fertilizers had a significant effect on cabbage plant height at 3, 4, and 6 weeks after transplanting (WAT) (Table 2). At 3 WAT, treatments with 0.75 – 1.25 doses of unbalanced compound fertilizers resulted in greater plant height compared to the control treatment. At 4 WAT, the application of 0.75 – 1.5 doses of unbalanced compound fertilizers also led to better plant height than the control treatment. At the final observation at 6 WAT, 0.5 – 1.5 doses of unbalanced compound fertilizers demonstrated superior plant height compared to the control treatment.

Table 2. The effects of unbalanced compound fertilizer application on cabbage plant height.

Treatments	Plant Height (cm)			
	3 WAT	**4 WAT**	**5 WAT**	**6 WAT**
Control	13.4b	17.7c	24.2a	28.6b

Reference	12.6a	16.2ab	23.0a	30.0ab
0.5 dosage unbalanced compound fertilizers	14.4b	16.8bc	23.0a	29.4a
0.75 dosage unbalanced compound fertilizers	13.4a	16.8a	23.0a	31.6a
1.0 dosage unbalanced compound fertilizers	13.8a	17.8a	24.4a	30.5a
1.25 dosage unbalanced compound fertilizers	14.0a	18.0a	24.4a	31.8a
1.5 dosage unbalanced compound fertilizers	13.8b	18.2ab	24.8a	30.7a

Note*: Numbers within the same column followed by the same letter indicate no significant difference based on Duncan's Multiple Range Test (DMRT) at the 5% significance level.*

The application of unbalanced compound fertilizers exhibited a significant effect on cabbage leaf count (Table 3). At the initial observation (3 weeks after transplanting (WAT)), treatments with 1.25 – 1.5 doses of unbalanced compound fertilizers resulted in a greater number of leaves compared to the control treatment. In the following weeks, the application of 1.5 doses of unbalanced compound fertilizers led to higher leaf counts than the control at 4 and 5 WAT. By the final observation (6 WAT), all fertilizer dosage levels (0.5 – 1.5 doses) demonstrated a greater number of leaves compared to the control plants.

Table 3. The effects of unbalanced compound fertilizer application on cabbage leaf count.

Treatments	Leaf Count			
	3 WAT	**4 WAT**	**5 WAT**	**6 WAT**
Control	5.5b	7.1b	9.2b	13.4c
Reference	5.6a	7.6ab	9.7ab	12.6ab
0.5 dosage unbalanced compound fertilizers	5.5ab	7.5ab	9.7ab	14.4ab
0.75 dosage unbalanced compound fertilizers	5.5ab	7.7ab	9.6ab	13.4ab
1.0 dosage unbalanced compound fertilizers	5.5ab	7.5ab	9.5ab	13.8a
1.25 dosage unbalanced compound fertilizers	5.6a	7.4b	9.5ab	14.0ab
1.5 dosage unbalanced compound fertilizers	5.8a	7.9a	9.9a	13.8b

Note*: Numbers within the same column followed by the same letter indicate no significant difference based on Duncan's Multiple Range Test (DMRT) at the 5% significance level.*

Application of unbalanced compound fertilizers enhances cabbage plant growth. Observations indicated that applying 0.5–1.5 doses of unbalanced compound fertilizers can improve cabbage plant height and leaf number compared to the control treatment. The application of unbalanced compound fertilizers increases plant height by approximately 2.8–

11.2% relative to the control. Similarly, in terms of leaf count, fertilization also leads to a greater number of leaves than the control treatment. Growth components such as leaf count are critical in influencing plant growth and development, primarily through their role in enhancing photosynthetic activity. An increased number of leaves correlates with a higher rate of photosynthesis, leading to greater biomass production when comparing plants with varying leaf counts under identical environmental conditions. Observations confirm that higher leaf mass contributes significantly to photosynthetic efficiency, ultimately affecting the overall growth dynamics of the plant (Setyowati, 2025; Hu et al., 2024; Hayati et al., 2023). This phenomenon can be attributed to the expanded surface area for light capture and gas exchange, both essential for photosynthesis, which drives growth (Givnish, 1988; Arantes et al., 2016). For example, studies demonstrate that plants with increased leaf counts, such as certain cabbage varieties, show enhanced biomass accumulation as they engage more effectively in photosynthesis (Rui et al., 2016; Alharbi et al., 2024). Additionally, the stored photosynthetic products, or assimilates, are directed towards sink organs, with the cabbage head being a primary site of accumulation in cabbage plants (Rui et al., 2016).

Effect of Unbalanced Compound Fertilizers on Cabbage Yield

The application of unbalanced compound fertilizers exhibited a significant effect on cabbage yield, including yield per plant, yield per plot, and yield per hectare (Table 4). Treatments with 0.5 – 1.5 doses of unbalanced compound fertilizers resulted in higher yield per plant, ranging between 823.3 – 893.3 g, whereas control plants produced only 726.7 g. At the same dosage range, the yield per plot increased to 40.0 – 41.7 kg, compared to the control treatment, which yielded 32.7 kg. Variations in these two yield parameters also influenced total yield per hectare, where treatments with 0.5 – 1.5 doses of unbalanced compound fertilizers led to a significantly higher yield compared to the control.

Table 4. The effects of unbalanced compound fertilizer application on cabbage yield.

Treatments	Yield per Plant (g)	Yield per Plot (kg)	Yield per Hectare (kg/ha)
Control	726.7b	32.7b	13080.0b
Reference	850.0a	38.0ab	15200.0ab
0.5 dosage unbalanced compound fertilizers	823.3a	41.7a	16666.7a
0.75 dosage unbalanced compound fertilizers	870.0a	40.0a	16000.0a

1.0 dosage unbalanced compound fertilizers	883.3a	41.3a	16533.3a
1.25 dosage unbalanced compound fertilizers	893.3a	41.0a	16400.0a
1.5 dosage unbalanced compound fertilizers	860.0a	40.3a	16133.3a

***Note**: Numbers within the same column followed by the same letter indicate no significant difference based on Duncan's Multiple Range Test (DMRT) at the 5% significance level.*

Application of unbalanced compound fertilizers has also been shown to enhance cabbage yield, with early-stage growth improvements leading to better overall yield components. The application of 0.5–1.5 doses of unbalanced compound fertilizers increases yield per plant by 13.3–22.9% compared to the control, while the same dosage also boosts plot yield by 22.3–27.5% over untreated plants. This effect extends to yield per hectare, where fertilizer application results in an improvement of 22.3–27.4% relative to the control. These findings suggest that different dosage levels of unbalanced compound fertilizers can enhance cabbage yield, even though the response variations between doses are not statistically significant. Unbalanced compound fertilizers contain complete macro-nutrients, with nitrogen playing a vital role as a primary component of proteins, hormones, chlorophyll, vitamins, and essential enzymes required for plant growth. Nitrogen metabolism significantly affects vegetative growth, including stem and leaf development (Munawar, 2018), with adequately supplied nitrogen producing greener plants. Nitrogen deficiency, on the other hand, results in stunted growth, restricted root development, leaf yellowing, and premature leaf drop (Hardjowigeno, 2007). Additionally, potassium in unbalanced compound fertilizers plays a critical role in plant metabolism by regulating osmotic pressure, cell pH, enzyme activity, cation-anion balance, transpiration control, and assimilate transport (Marschner, 1995). According to Ispandi and Munip (2004), potassium is crucial for seed formation and filling, besides its essential function in metabolic processes. Similarly, phosphorus is fundamental to photosynthesis, carbohydrate conversion, glycolysis, protein and lipid metabolism, and energy production (Leiwakabessy & Sutandi, 2004). Tisdale et al. (1985) noted that phosphorus stimulates plant growth, root development, fruit and seed formation, especially in cereals, and is vital for cell division, flowering, crop maturation, lodging resistance, quality improvement, and disease tolerance.

Relative Agronomic Effectiveness

Relative agronomic effectiveness is one of the key indicators of fertilizer efficiency. A fertilizer is considered agronomically effective when its relative agronomic effectiveness value exceeds 100. This indicates that fertilizer contributes to a greater yield increase compared to the yield improvement observed in the control treatment using standard fertilization. The results of the relative agronomic effectiveness analysis for unbalanced compound fertilizers are presented in Table 5.

Table 5. Relative agronomic effectiveness of unbalanced compound fertilizer application.

Treatments	Relative Agronomic Effectiveness (%)
Control	-
Reference	-
0.5 dosage unbalanced compound fertilizers	169
0.75 dosage unbalanced compound fertilizers	138
1.0 dosage unbalanced compound fertilizers	163
1.25 dosage unbalanced compound fertilizers	157
1.5 dosage unbalanced compound fertilizers	144

The calculated values indicate that the application of 0.5 – 1.5 doses of unbalanced compound fertilizers was agronomically effective, as it resulted in values greater than 100. Among these treatments, the 0.5-dose application demonstrated the highest relative agronomic effectiveness, increasing yield by up to 1.69 times (169%) compared to the yield increase achieved through standard fertilization.

Farm Business Analysis

The economic effectiveness of unbalanced compound fertilizers was assessed using profitability and R/C ratio variables. These metrics help determine the economic feasibility of farming operations. Table 6 presents the results of the farm business analysis for various treatments in the effectiveness trial.

Table 6. Farm business analysis of unbalanced compound fertilizer application.

Treatments	Cost (Rp)	Revenue (Rp)	Profit (Rp)	R/C
Control	9,425,000	19,620,000	10,195,000	2.08
Reference	11,435,000	22,800,000	11,365,000	1.99
0.5 dosage unbalanced compound fertilizers	10,634,900	25,000,050	14,365,150	2.35
0.75 dosage unbalanced compound fertilizers	11,241,000	24,000,000	12,759,000	2.14
1.0 dosage unbalanced compound fertilizers	11,849,600	24,799,950	12,950,350	2.09
1.25 dosage unbalanced compound fertilizers	12,455,700	24,600,000	12,144,300	1.97
1.5 dosage unbalanced compound fertilizers	13,052,000	24,199,950	11,147,950	1.85

The experimental results indicated that all tested fertilizer dosage levels were economically effective, as they produced an R/C ratio greater than 1. The treatment with 0.5 doses of unbalanced compound fertilizers exhibited the highest R/C ratio, reaching 2.35, surpassing other treatments. This dosage level also generated a profit of Rp. 14.365.150.

4. CONCLUSION

The experiment indicated that the application of unbalanced compound fertilizers enhances cabbage plant growth, as evidenced by increased plant height and leaf number compared to the control treatment. Additionally, fertilization improves yield components relative to untreated plants. The application of 0.5 doses of unbalanced compound fertilizers proves agronomically effective, yielding the highest relative agronomic effectiveness at 169%, meaning a 1.69-fold increase in yield. Economically, the same dosage is also highly beneficial, achieving the highest R/C ratio of 2.35 and generating a profit of Rp. 14,365,150. The study results confirm that unbalanced compound fertilizers were both agronomically effective and economically advantageous. The recommended dosage for cabbage cultivation is 134 kg/ha, applied in two stages: 50% at 1 WAT (weeks after transplanting) and the remaining 50% at 4 WAT.

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