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The Effects of Chitosan Organic Fertilizer and Urea Inorganic Fertilizer Application on the Growth of Pakcoy Mustard Plants (*Brassica rapa* L.)

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Abstract: This study aimed to evaluate the effects of inorganic urea fertilizer, organic chitosan fertilizer, and their interaction on the growth and yield of pakcoy mustard (*Brassica rapa* L.). The experiment used a factorial randomized block design (RBD) with two factors: urea fertilizer dose, consisting of U0 (0 g plant^{-1}), U1 (0.8 g plant^{-1}), U2 (1.2 g plant^{-1}), and U3 (1.6 g plant^{-1}), and chitosan concentration, consisting of K0 (0%), K1 (20%), K2 (30%), and K3 (40%). Each treatment combination was replicated three times. Data were analyzed using analysis of variance (ANOVA), followed by Duncan's Multiple Range Test (DMRT). The results showed that urea fertilizer significantly affected plant height, number of leaves, stem base diameter, fresh weight, and chlorophyll content. The best responses were generally obtained at 1.6 g plant^{-1} urea, while stem base diameter and chlorophyll content showed optimal responses at 1.2 g plant^{-1} and 0.8–1.2 g plant^{-1}, respectively. Chitosan application also significantly improved pakcoy growth, with the best overall response observed at 40%. The interaction between urea and chitosan significantly affected plant height, stem base diameter, and fresh weight. The U3K3 treatment produced the highest plant height from 1 to 4 weeks after transplanting, as well as the highest stem base diameter and fresh weight. Meanwhile, the highest number of leaves and chlorophyll content were obtained in U2K2. Overall, the combined application of urea and chitosan enhanced pakcoy growth and yield performance.
Keywords: Pakcoy mustard; urea fertilizer; chitosan fertilizer

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INTRODUCTION

Pakcoy (*Brassica rapa* L.) is an important leafy vegetable widely consumed in Indonesia due to its high nutritional value, including proteins, carbohydrates, minerals, and vitamins A, B, C, and K (Perdana et al., 2022). Pakcoy is also recognized as a nutrient-rich Brassica vegetable that provides essential metabolites and bioactive compounds important for human nutrition (Wang et al., 2023). The demand for pakcoy continues to increase along with the growing need for vegetable consumption in Indonesia, which is closely associated with population growth (Sari et al., 2024). In addition to its nutritional importance, pakcoy also has promising economic value. According to the Central Statistics Agency of North Sumatra Province, the selling price of mustard greens in 2022 reached approximately IDR 10,000 per kg, indicating that this commodity has the potential to contribute to farmers' income.

Despite its economic potential, mustard production in North Sumatra remains unstable. Data from the Central Statistics Agency showed that mustard production in 2021, 2022, and 2023 was 74,908, 74,370, and 77,970 tons per year, respectively. The decline in production in 2022, followed by an increase in 2023, indicates fluctuations in productivity that may affect the continuity of vegetable supply. Therefore, improved cultivation practices are required to support stable and optimal pakcoy production. Among these practices, appropriate fertilization management is essential because nutrient availability directly influences vegetative growth, biomass accumulation, and overall crop yield.

Fertilization strategies generally involve the use of organic and inorganic fertilizers. Inorganic fertilizers are commonly applied because they provide nutrients in readily available forms, whereas organic fertilizers contribute to long-term improvements in soil quality. The combined application of organic and inorganic fertilizers is considered an effective approach to enhance crop productivity because organic amendments can improve soil physical, chemical, and biological properties, thereby creating a more favorable environment for plant growth (Kahar et al., 2022).

Urea is one of the most widely used inorganic nitrogen fertilizers and contains approximately 45% nitrogen. Because of its high solubility, urea can provide nitrogen that is readily absorbed by plant roots and transported to leaves. Nitrogen is a key element required for chlorophyll formation, photosynthesis, and vegetative development (Amalia & Fajri, 2020; Fathi, 2022). In leafy vegetables, adequate nitrogen availability is particularly important because it supports chlorophyll accumulation, leaf expansion, and biomass formation. However, continuous and excessive use of urea without proper management may reduce fertilizer efficiency and cause nitrogen losses through leaching and volatilization. These losses can reduce nitrogen-use efficiency and may contribute to environmental problems and declining soil quality (Motasim et al., 2024). Therefore, strategies that improve nitrogen-use efficiency while maintaining plant growth are necessary for sustainable pakcoy cultivation.

Chitosan is an organic biopolymer derived from chitin, which is commonly obtained from the shell waste of crustaceans such as shrimp, crabs, and lobsters. In agriculture, chitosan has received increasing attention because of its biodegradable, biocompatible, and bioactive properties. It has been reported to improve soil conditions, support nutrient availability, and enhance plant physiological responses (Stasińska-Jakubas & Hawrylak-Nowak, 2022). Chitosan can also assist in the remediation of contaminated soils by binding cationic and anionic heavy metals. In addition, chitosan functions as a plant growth promoter by stimulating root development, improving nutrient uptake, regulating metabolic processes, and enhancing plant tolerance to environmental stress (Kahar et al., 2022; Stasińska-Jakubas & Hawrylak-Nowak, 2022; Sun et al., 2023). Its nitrogen content may also contribute to plant growth and development.

Previous research reported that the application of NPK fertilizer combined with chitosan improved the growth and yield of mustard plants (Letahiit et al., 2022). However, because that study used compound NPK fertilizer, the specific contribution of nitrogen as a single nutrient source was not clearly distinguished. Nitrogen is particularly important in leafy vegetables because it supports chlorophyll synthesis, leaf expansion, and vegetative biomass formation (Fathi, 2022). Urea, as a high-nitrogen fertilizer, may therefore play a central role in improving pakcoy growth. Meanwhile, chitosan may act as an organic fertilizer and biostimulant that enhances nutrient uptake, physiological activity, and plant tolerance to environmental stress (Stasińska-Jakubas & Hawrylak-Nowak, 2022; Sun et al., 2023). These complementary functions suggest that the combined application of urea and chitosan may produce a synergistic effect on pakcoy growth and yield.

Nevertheless, information on the interaction between urea fertilizer dosage and chitosan concentration in pakcoy cultivation remains limited. In particular, the combined effects of these treatments on key growth and yield parameters, including plant height, number of leaves, stem base diameter, fresh weight, dry weight, and chlorophyll content, have not been widely reported (Rachman et al., 2024). Addressing this knowledge gap is important to support the development of more efficient and sustainable fertilization practices for pakcoy production. Therefore, this study aimed to evaluate the effects of urea fertilizer, chitosan, and their interaction on the growth and yield of pakcoy (*Brassica rapa* L.). Specifically, this study examined the responses of pakcoy to different urea doses and chitosan concentrations based on plant height, number of leaves, stem base diameter, fresh and dry biomass, and chlorophyll content.

METHOD

Study Site and Experimental Period

This study was conducted in the Greenhouse and Botany Laboratory of Universitas Islam Negeri Sumatera Utara Medan, located at Jalan Lapangan Golf No. 120, Kampung Tengah, Pancur Batu District, Deli Serdang Regency, North Sumatra Province, Indonesia. The experiment was carried out for two months, from September to October 2025.

Tools and Materials

The equipment used in this study included containers, knives, stirrers, watering cans, sprayers, analytical balances, polybags, hand shovels, measuring cylinders, rulers, calipers, ovens, stationery, observation sheets, label papers, and a camera. The materials consisted of pakcoy mustard seeds (*Brassica rapa* L.) of the Nauli F1 variety, chitosan organic fertilizer, urea inorganic fertilizer, burned rice husk, and humus soil.

Experimental Design

This study was arranged as a factorial experiment using a randomized block design (RBD) with two treatment factors. The first factor was the dose of urea inorganic fertilizer, consisting of four levels: U0 = without urea, U1 = 0.8 g plant^{-1}, U2 = 1.2 g plant^{-1}, and U3 = 1.6 g plant^{-1}. The second factor was the concentration of chitosan organic fertilizer, consisting of four levels: K0 = without chitosan, K1 = 20%, K2 = 30%, and K3 = 40%.

The combination of the two factors resulted in 16 treatment combinations. Each treatment was replicated three times, producing 48 experimental units. Each experimental unit consisted of four plants, of which two plants were used as observation samples. Therefore, the experiment used a total of 192 plants, with 96 plants selected as samples. Each plant was grown individually in one polybag.

Seed Preparation and Planting Medium

The research procedure began with seed selection and seedling preparation. Seeds of pakcoy mustard, Nauli F1 variety, were selected by soaking them in water for 60 min. Seeds that sank were considered viable and were used for sowing. The selected seeds were sown in fine soil medium and maintained until the seedlings reached 14 days of age.

The planting medium consisted of humus soil and burned rice husk mixed at a ratio of 2:1 (w/w). Before use, the medium was sieved and sterilized by drying it under direct sunlight for 2–3 days to reduce potential pathogens. The use of humus soil and burned rice husk was intended to improve nutrient availability, aeration, and water-holding capacity, thereby supporting optimal plant growth. The prepared medium was placed into 30 cm × 30 cm polybags, with approximately 2 kg of medium in each polybag.

Seedlings were transplanted carefully into the polybags to prevent root damage. Only uniform, healthy, and vigorous seedlings were selected for the experiment. Each experimental unit was labeled according to its treatment combination to facilitate treatment application and observation.

Plant Maintenance and Fertilizer Application

Plant maintenance included watering twice daily, in the morning and afternoon, and was adjusted according to weather conditions and the moisture level of the planting medium. Weeding was conducted manually whenever weeds emerged. Pest and disease control was performed preventively by maintaining sanitation around the experimental area.

Urea fertilizer was applied twice, at 7 and 21 days after transplanting (DAT), according to the assigned treatment doses. Chitosan fertilizer was applied twice, at 14 and 28 DAT, using a foliar spraying method. The chitosan solution was sprayed evenly onto all plant parts, particularly the leaves, until the plant surface was uniformly wet.

Harvesting and Observed Parameters

Harvesting was conducted at 30 DAT by carefully removing the entire plant from the planting medium. The harvested plants were placed in a shaded area before measurement to minimize water loss prior to observation.

The observed parameters included plant height, number of leaves, stem base diameter, fresh weight, and dry weight. Plant height was measured from the base of the stem to the highest shoot using a ruler at 7, 14, 21, and 28 DAT. The number of leaves was determined weekly by counting fully expanded leaves. Stem base diameter was measured at harvest using a caliper. Fresh weight was measured at the end of the observation period using an analytical balance. Dry weight was obtained by oven-drying the plants at 85°C for 24 h, followed by weighing. Drying and weighing were repeated until a constant weight was achieved.

Data Analysis

The data were analyzed using analysis of variance (ANOVA) based on the factorial randomized block design to determine the effects of urea fertilizer, chitosan fertilizer, and their interaction on the observed growth and yield parameters. When significant differences were detected, further mean comparison tests were conducted at the 5% significance level.

RESULTS AND DISCUSSION

Plant Height (cm)

The observation results and analysis of variance showed that urea fertilizer significantly affected pakcoy plant height at 1, 2, 3, and 4 weeks after planting (WAP). Chitosan fertilizer significantly affected plant height at 1, 2, and 4 WAP. The interaction between urea and chitosan fertilizers showed a significant effect only at 1 WAP, whereas no significant interaction effect was observed at 2, 3, and 4 WAP.

Table 1. Mean plant height of pakcoy mustard as affected by organic chitosan fertilizer and inorganic urea fertilizer

WAP	Urea Treatment	K0 (0%)	K1 (20%)	K2 (30%)	K3 (40%)	Mean
1	U0 (0 g)	3.98 g	3.63 g	5.75 def	5.30 ef	4.67 c
1	U1 (0.8 g)	6.17 def	5.65 def	4.92 fg	5.75 def	5.62 b
1	U2 (1.2 g)	5.50 def	6.45 def	5.33 def	5.67 def	5.74 b
1	U3 (1.6 g)	6.75 de	8.42 b	7.83 bc	9.87 a	8.21 a
1	**Mean**	**5.60 b**	**6.04 b**	**5.96 b**	**6.65 a**	

WAP	Urea Treatment	K0 (0%)	K1 (20%)	K2 (30%)	K3 (40%)	Mean
2	U0 (0 g)	6.15	5.67	6.73	6.88	6.36 c
2	U1 (0.8 g)	7.73	7.12	6.50	6.83	7.05 c
2	U2 (1.2 g)	7.57	7.58	7.37	9.20	7.93 b
2	U3 (1.6 g)	9.55	10.08	10.01	11.22	10.21 a
2	**Mean**	**7.75 ab**	**7.61 b**	**7.65 b**	**8.53 a**	
3	U0 (0 g)	6.83	8.00	8.82	9.15	8.20 d
3	U1 (0.8 g)	10.18	11.17	9.37	8.75	9.87 c
3	U2 (1.2 g)	9.73	11.53	11.77	12.72	11.44 b
3	U3 (1.6 g)	13.30	14.28	15.35	16.75	14.92 a
3	**Mean**	**10.01**	**11.25**	**11.33**	**11.84**	
4	U0 (0 g)	10.55	11.45	14.75	14.70	12.86 d
4	U1 (0.8 g)	14.67	16.20	16.33	17.17	16.09 c
4	U2 (1.2 g)	16.50	18.82	19.25	22.33	19.23 b
4	U3 (1.6 g)	20.20	21.42	22.50	23.13	21.81 a
4	**Mean**	**15.48 c**	**16.97 b**	**18.20 ab**	**19.33 a**	

Note: Values followed by different letters in the same row or column are significantly different according to Duncan's Multiple Range Test (DMRT) at the 5% level.

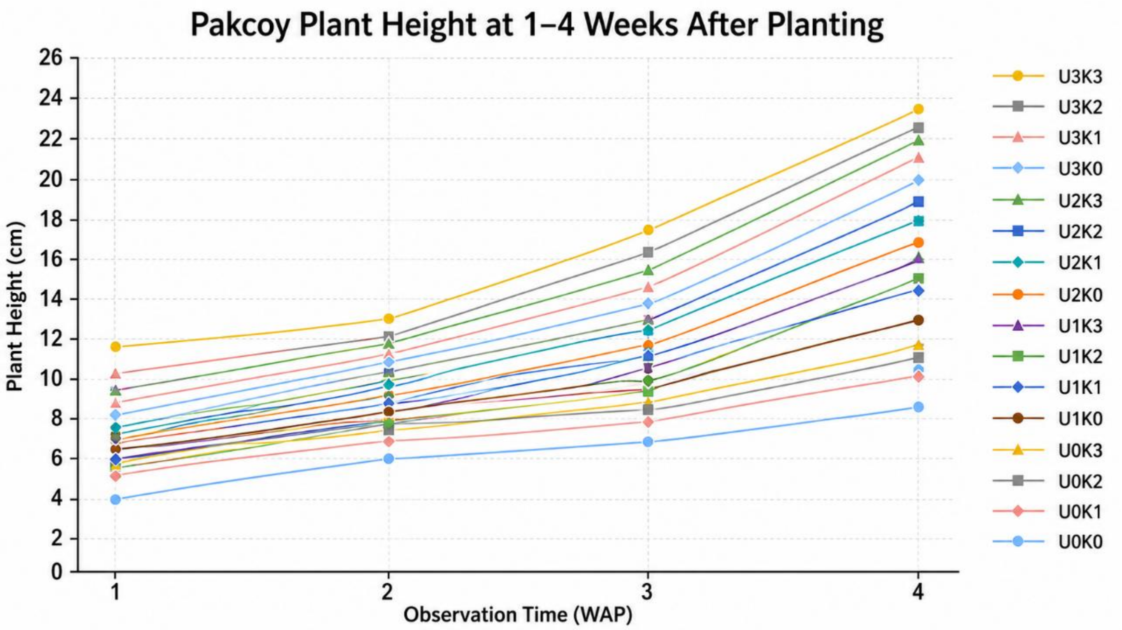

Figure 1. Comparison of pakcoy mustard growth

Based on Table 1, urea fertilizer consistently increased pakcoy plant height across all observation periods. At 1 WAP, the highest mean plant height was observed in U3, which differed significantly from U0, U1, and U2. The lowest mean value was recorded in U0. A similar trend was observed at 2, 3, and 4 WAP, where U3 consistently produced the highest plant height, while U0 produced the lowest value. These results indicate that the application of 1.6 g urea effectively increased nitrogen availability in the soil, thereby stimulating vegetative growth in pakcoy plants.

The increased nitrogen availability likely enhanced chlorophyll formation, cell division, and cell elongation, which subsequently increased plant height compared with the control treatment. Klorofil et al. (2026) stated that plants supplied with sufficient nitrogen exhibit more optimal cell division and elongation. Nitrogen also plays an important role in protein and enzyme synthesis, which supports plant metabolism and accelerates stem growth. Similarly, Harahap et al. (2021) reported that nitrogen stimulates vegetative growth, including plant height.

Chitosan fertilizer also improved plant height, particularly at higher concentrations. At 1 WAP, the highest mean plant height was obtained in K3, which differed significantly from K0, K1, and K2. At 4 WAP, K3 also produced the highest mean value, although it did not differ significantly from K2. These findings indicate that the application of 40 ml chitosan provided the most favorable response for increasing pakcoy plant height. This result is consistent with Griselda et al. (2024), who reported that chitosan enhances plant height by stimulating physiological activity, improving nutrient uptake, and promoting cell division and elongation.

The interaction between urea and chitosan showed that U3K3 produced the highest plant height at all observation periods. However, a significant interaction effect was observed only at 1 WAP. This suggests that the combination of high-dose urea and high-concentration chitosan produced the best early growth response. Nitrogen from urea supported cell division and elongation, while chitosan acted as a biostimulant that improved nutrient uptake efficiency and plant physiological activity. Gea Havizsya Pz et al. (2023) stated that combining urea with chitosan, particularly through coating or encapsulation, can produce an effective slow-release fertilizer by reducing nitrogen volatilization, prolonging nutrient release for 3–6 months, and improving nutrient uptake efficiency.

Number of Leaves

The observation results and analysis of variance showed that urea fertilizer significantly affected the number of pakcoy leaves at 1, 2, 3, and 4 WAP. Chitosan fertilizer significantly affected the number of leaves at 1, 3, and 4 WAP.

Table 2. Mean number of pakcoy leaves as affected by organic chitosan fertilizer and inorganic urea fertilizer

WAP	Urea Treatment	K0 (0 ml)	K1 (20 ml)	K2 (30 ml)	K3 (40 ml)	Mean
1	U0 (0 g)	4.67	4.83	5.50	5.33	5.08 c
1	U1 (0.8 g)	5.00	5.50	5.67	5.50	5.42 bc
1	U2 (1.2 g)	5.33	5.33	5.67	6.50	5.71 b
1	U3 (1.6 g)	5.83	6.50	5.83	6.50	6.17 a
1	**Mean**	**5.21 c**	**5.54 bc**	**5.67 ab**	**5.96 a**	
2	U0 (0 g)	6.33	6.50	6.33	6.67	6.46 d
2	U1 (0.8 g)	7.00	6.67	6.83	7.33	6.96 c
2	U2 (1.2 g)	7.67	7.50	7.17	7.50	7.46 b
2	U3 (1.6 g)	7.67	7.83	8.00	8.50	8.00 a
2	**Mean**	**7.17**	**7.13**	**7.08**	**7.50**	
3	U0 (0 g)	10.50	10.33	10.33	10.67	10.46 c
3	U1 (0.8 g)	10.67	11.00	11.50	11.67	11.21 b
3	U2 (1.2 g)	11.50	11.67	12.33	12.50	12.00 a
3	U3 (1.6 g)	11.67	12.17	13.33	12.83	12.50 a
3	**Mean**	**11.08 c**	**11.29 bc**	**11.88 ab**	**11.92 a**	

WAP	Urea Treatment	K0 (0 ml)	K1 (20 ml)	K2 (30 ml)	K3 (40 ml)	Mean
4	U0 (0 g)	13.17	13.50	12.83	13.00	13.13 c
4	U1 (0.8 g)	12.83	12.50	13.50	13.67	13.13 c
4	U2 (1.2 g)	14.33	13.83	15.50	15.67	14.83 b
4	U3 (1.6 g)	15.50	16.50	16.17	17.17	16.33 a
4	**Mean**	**13.96 b**	**14.08 b**	**14.50 ab**	**14.88 a**	

Note: Values followed by different letters in the same row or column are significantly different according to DMRT at the 5% level.

Based on Table 2, urea fertilizer increased the number of pakcoy leaves throughout the observation period. At 1 and 2 WAP, U3 produced the highest mean number of leaves and differed significantly from the lower urea treatments. At 3 WAP, U3 produced the highest value but did not differ significantly from U2. At 4 WAP, U3 again produced the highest mean number of leaves, while U0 and U1 showed the lowest values. These results indicate that urea application, particularly at 1.2–1.6 g, effectively supported leaf formation.

The increase in leaf number was associated with the role of nitrogen in promoting vegetative growth. Nitrogen supports protein synthesis, chlorophyll formation, and photosynthetic activity, thereby increasing cell division and leaf development. Basit (2022) stated that sufficient nitrogen availability increases protein synthesis, enhances photosynthesis, promotes leaf expansion, and increases cell number, ultimately increasing the number of leaves.

Chitosan fertilizer also tended to increase the number of leaves. The highest mean values were generally observed in K3, particularly at 1, 3, and 4 WAP. This indicates that chitosan may stimulate physiological processes that support leaf formation. Chitosan can enhance photosynthesis, regulate stomatal activity, and increase antioxidant enzyme activity. According to Shabah et al. (2025), chitosan can act as a photosynthetic stimulant and influence stomatal closure through interaction with abscisic acid (ABA). Because stomatal activity is essential for photosynthesis, improved stomatal regulation may contribute to better leaf development.

The interaction between urea and chitosan did not significantly affect the number of leaves, although several treatment combinations showed higher mean values. At 4 WAP, the highest number of leaves was obtained in U3K3, while the lowest value was observed in U1K1. This suggests that the combined application of urea and chitosan may improve leaf formation, although the effect was not statistically significant. This result is in line with Letahiit et al. (2022), who reported that the interaction between NPK fertilizer and chitosan did not significantly affect the number of leaves in green mustard plants.

Stem Base Diameter

The observation results and analysis of variance showed that urea fertilizer, chitosan fertilizer, and their interaction significantly affected the stem base diameter of pakcoy plants.

Table 3. Mean stem base diameter of pakcoy mustard as affected by inorganic urea fertilizer and organic chitosan fertilizer

Urea Treatment	K0 (0 ml)	K1 (20 ml)	K2 (30 ml)	K3 (40 ml)	Mean
U0 (0 g)	14.67 e	14.33 e	15.33 e	17.33 d	15.42 d
U1 (0.8 g)	17.67 d	18.33 c	17.67 d	17.33 d	17.75 c

Urea Treatment	K0 (0 ml)	K1 (20 ml)	K2 (30 ml)	K3 (40 ml)	Mean
U2 (1.2 g)	19.33 c	20.67 b	20.67 b	21.33 ab	20.50 b
U3 (1.6 g)	22.00 ab	21.33 ab	21.67 ab	22.33 a	21.83 a
Mean	**18.42 b**	**18.67 b**	**18.83 b**	**19.58 a**	

Note: Values followed by different letters in the same row or column are significantly different according to DMRT at the 5% level.

Table 3 shows that the highest mean stem base diameter under urea fertilizer treatment was recorded in U3, with a value of 21.83 cm, and differed significantly from U0, U1, and U2. The lowest mean value was observed in U0. These results indicate that the application of 1.6 g urea was sufficient to support stem base enlargement in pakcoy plants. Adequate and balanced nutrient availability is essential for supporting plant physiological processes. According to Prakoso et al. (2022), optimal and complete nutrient supply according to plant requirements can support plant growth and development. Therefore, the control treatment produced the lowest value because nutrient availability was insufficient to support optimal growth.

For chitosan fertilizer, the highest mean stem base diameter was observed in K3, with a value of 19.58 cm, and differed significantly from K0, K1, and K2. The lowest mean value was recorded in K0, although it did not differ significantly from K1 and K2. This result indicates that increasing the chitosan concentration to K3 produced a better response in stem base enlargement. Kadir & J (2023) stated that chitosan can induce plant growth by influencing nutrient absorption, cell division, cell elongation, enzymatic activation, and protein synthesis, which ultimately contribute to increased yield.

The interaction between urea and chitosan produced the highest stem base diameter in U3K3 (22.33 cm), although it was not significantly different from U3K0, U3K1, and U3K2. The lowest value occurred in U0K1 and was comparable to U0K0 and U0K2. These results indicate that stem base diameter was more strongly affected by urea than by chitosan, as nitrogen supports cell division, cell enlargement, chlorophyll formation, and tissue development. Chitosan likely functioned mainly as a biostimulant, with a less direct effect on stem enlargement. This finding agrees with Afrianti et al. (2024), who reported that adequate and balanced nutrient availability accelerates cell division, enlargement, and elongation, thereby promoting organ development.

Fresh Weight (g)

The observation results and analysis of variance showed that urea fertilizer, chitosan fertilizer, and their interaction significantly affected the fresh weight of pakcoy plants.

Table 4. Mean fresh weight of pakcoy mustard as affected by organic chitosan fertilizer and inorganic urea fertilizer

Urea Treatment	K0 (0 ml)	K1 (20 ml)	K2 (30 ml)	K3 (40 ml)	Mean
U0 (0 g)	19.58 e	35.11 de	52.87 bcde	61.46 bcde	42.26 b
U1 (0.8 g)	93.49 abc	84.69 abcd	55.73 bcde	85.52 abcd	79.65 a
U2 (1.2 g)	102.50 ab	72.80 abcd	91.81 abc	102.30 ab	92.35 a
U3 (1.6 g)	43.86 cde	84.15 abcd	117.63 a	117.71 a	90.84 a
Mean	**64.86 b**	**69.19 b**	**79.51 ab**	**91.75 a**	

Note: Values followed by different letters in the same row or column are significantly different according to DMRT at the 5% level.

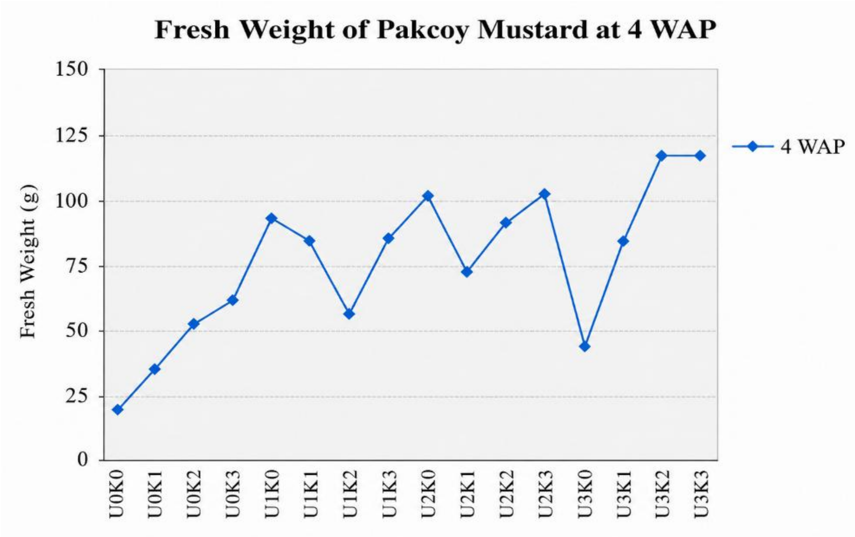

Figure 2. Fresh weight of pakcoy mustard at 4 Weeks After Planting (WAP)

The highest mean fresh weight under urea fertilizer treatment was observed in U2, with a value of 92.35 g, although it did not differ significantly from U3 and U1. The lowest mean value was recorded in U0, with a value of 42.26 g, and differed significantly from U1, U2, and U3. This result indicates that urea fertilizer increased pakcoy fresh weight by improving nitrogen availability, which supported vegetative growth. Havizsya Pz (2023) stated that urea contains approximately 46% nitrogen, making it suitable for supporting pakcoy growth.

Fresh weight is also closely related to water absorption. According to Gunawan & Sudalmi (2020), plants with good growth may contain up to 90% water in their tissues. Water uptake supports nutrient absorption and vegetative development, which directly affects plant fresh weight. Thus, fresh weight is influenced by tissue water content, nutrient availability, and metabolic products.

For chitosan fertilizer, the highest mean fresh weight was recorded in K3, with a value of 91.75 g, although it did not differ significantly from K2. The lowest mean value was observed in K0, with a value of 64.86 g, and did not differ significantly from K1. This result indicates that higher chitosan application improved soil fertility and supported nutrient availability. Conversely, lower chitosan concentrations provided fewer nutrients and weaker stimulation. According to Sulakhudin (2024), nutrient availability plays an important role as an energy source, and nutrient sufficiency strongly influences plant biomass accumulation.

The interaction between urea and chitosan showed that the highest fresh weight was obtained in U3K3, with a value of 117.71 g, although it did not differ significantly from U3K2. The lowest value was recorded in U0K0, with a value of 19.58 g. These findings indicate that combined urea and chitosan application increased fresh weight compared with the unfertilized control. Fertilization increased plant height and leaf number, which contributed to higher fresh weight. Samini & Fatah (2020) stated that increases in plant height and leaf number can increase the fresh weight of mustard plants. Because leaves are the main organs for photosynthesis, a greater number of leaves can produce more photosynthates. High fresh weight in mustard plants indicates good and optimal vegetative growth (Prana et al., 2024).

Dry Weight (g)

The observation results and analysis of variance showed that urea fertilizer, chitosan fertilizer, and their interaction did not significantly affect pakcoy dry weight.

Table 5. Mean dry weight of pakcoy mustard as affected by organic chitosan fertilizer and inorganic urea fertilizer

Urea Treatment	K0 (0%)	K1 (20%)	K2 (30%)	K3 (40%)	Mean
U0 (0 g)	2.56	4.04	5.48	6.20	4.57
U1 (0.8 g)	8.42	7.03	5.68	5.97	6.77
U2 (1.2 g)	6.45	7.24	7.30	8.21	7.30
U3 (1.6 g)	27.10	8.50	9.35	10.28	13.81
Mean	**11.13**	**6.70**	**6.95**	**7.66**	

Note: Based on the analysis of variance (ANOVA), urea fertilizer, chitosan fertilizer, and their interaction did not significantly affect dry weight at the 5% level; therefore, no further DMRT test was performed.

Based on Table 5, the highest mean dry weight under urea fertilizer treatment was observed in U3, with a value of 13.81 g, while the lowest value was recorded in U0, with a value of 4.57 g. Although the effect was not statistically significant, this result indicates a tendency for higher urea doses to increase pakcoy dry weight compared with no urea application. This tendency may be related to the increased availability of nutrients that support plant growth. Afrianti et al. (2024) stated that the level of total plant dry weight depends on the amount of nutrient uptake.

For chitosan fertilizer, the highest mean dry weight was recorded in K0, with a value of 11.13 g, while the lowest was found in K1, with a value of 6.70 g. However, chitosan fertilizer did not significantly affect dry weight. This indicates that the differences among treatment means were not sufficiently consistent to produce a statistically significant effect. This condition may have been influenced by the low physiological response of the plants to chitosan, suboptimal application dose, or environmental conditions during the experiment. According to Rafiqi et al. (2024), plant dry weight represents the net accumulation of photosynthates during growth and development. Higher dry biomass reflects more effective metabolic activity.

The interaction between urea and chitosan showed that the highest mean dry weight was obtained in U3K0, with a value of 27.10 g, while the lowest value was recorded in U0K0, with a value of 2.56 g. Nevertheless, the interaction was not statistically significant. The high value in U3K0 indicates a tendency for high nitrogen supply from urea to support biomass formation, but this response was not consistent across treatment combinations. Dry weight accumulation is also influenced by light intensity, water availability, and plant photosynthetic capacity. Rachman et al. (2024) stated that sunlight and water are essential components of plant growth and are closely related to biomass production. Therefore, the differences observed in this study should be interpreted as treatment tendencies rather than significant increases (Letahiit et al., 2022).

Chlorophyll Content (mg/cm²)

The observation results and analysis of variance showed that urea fertilizer, chitosan fertilizer, and their interaction did not significantly affect the chlorophyll content of pakcoy plants.

Table 6. Mean chlorophyll content of pakcoy mustard as affected by organic chitosan fertilizer and inorganic urea fertilizer

Urea Treatment	K0	K1	K2	K3	Mean
U0	12.13	12.73	16.85	11.11	13.21
U1	17.35	12.08	17.80	14.45	15.42

Urea Treatment	K0	K1	K2	K3	Mean
U2	14.43	15.55	16.39	17.34	15.93
U3	15.53	18.67	12.72	13.85	15.19
Mean	**14.86**	**14.76**	**15.94**	**14.19**	

Note: Based on the analysis of variance (ANOVA), urea fertilizer, chitosan fertilizer, and their interaction did not significantly affect chlorophyll content at the 5% level; therefore, no further DMRT test was performed.

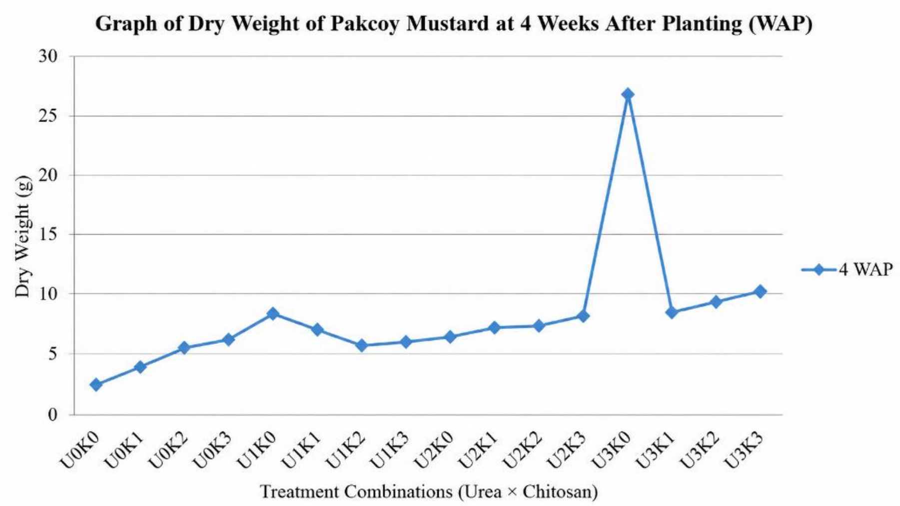

Figure 3. Dry weight of pakcoy mustard at 4 Weeks After Planting (WAP)

Table 6 shows that the highest mean chlorophyll content under urea fertilizer treatment was recorded in U2, while the lowest value was observed in U0. However, urea fertilizer did not significantly affect chlorophyll content. This indicates that although differences in mean values were observed among treatments, the plant response was not strong enough to produce a significant effect. This condition may have been influenced by plant age at the time of observation, measurement time, light intensity during the experiment, and fertilizer doses that were not yet optimal (Basit, 2022). Nitrogen is known as a major component of chlorophyll and plays an important role in leaf formation; therefore, sufficient nitrogen availability can theoretically increase chlorophyll content (Martopani et al., 2022).

For chitosan fertilizer, the highest mean chlorophyll content was observed in K2, with a value of 15.94 mg/cm², while the lowest was recorded in K3, with a value of 14.19 mg/cm². However, chitosan fertilizer also did not significantly affect chlorophyll content. The relatively small differences among treatment means indicate that the plant response to chitosan application was low or not yet optimal. This finding is consistent with Rizi (2022), who reported that chitosan treatment did not significantly affect plant photosynthetic pigments. In addition, the effectiveness of chitosan may be influenced by environmental conditions, application dose, and the ability of plants to absorb the compound (Letahiit et al., 2022).

The interaction between urea and chitosan showed that the highest mean chlorophyll content was recorded in U1K2, with a value of 17.80 mg/cm², while the lowest value was observed in U0K3, with a value of 11.11 mg/cm². Nevertheless, the interaction between the two treatments did not significantly affect chlorophyll content. This indicates that the combined application of urea and chitosan did not produce a consistent response in chlorophyll formation. The non-significant effect may have been influenced by environmental factors such as sunlight intensity, temperature, humidity, and individual plant variation during the experiment. According to Iham & I (2025), leaf chlorophyll index is influenced not only by plant metabolism but also by climatic conditions that support photosynthesis (Prana et al., 2024).

CONCLUSION

Based on the findings of this study, the application of inorganic urea fertilizer had a significant effect on the growth of pak choi mustard (*Brassica rapa* L.), particularly on plant height, number of leaves, stem base diameter, and fresh weight. The best treatment for plant height, number of leaves, and fresh weight was obtained at a concentration of 1.6 g per plant, whereas the greatest stem base diameter was achieved at a concentration of 1.2 g per plant. The application of chitosan organic fertilizer also had a significant effect on several growth parameters, especially plant height, number of leaves, stem base diameter, and fresh weight, with the best treatment level observed at a concentration of 40%. The interaction between urea and chitosan fertilizers was shown to enhance the growth of pak choi mustard, particularly in terms of plant height, stem base diameter, and fresh weight. Therefore, the combined application of inorganic urea fertilizer and chitosan organic fertilizer may serve as an effective cultivation technology to improve the growth and productivity of pak choi mustard.

RECOMMENDATION

Based on the results of this study on pak choi mustard (*Brassica rapa* L.), farmers and cultivation practitioners are advised to combine inorganic urea fertilizer with chitosan organic fertilizer to improve plant growth and yield. The application of urea fertilizer at a concentration of 1.6 g per plant produced the best response in plant height, number of leaves, and fresh weight, whereas a concentration of 1.2 g per plant was more optimal for stem base diameter. In addition, concentrations of 0.8–1.2 g per plant were effective in increasing chlorophyll content. Meanwhile, the application of chitosan fertilizer at a concentration of 40% is recommended because it produced significant and consistent effects on nearly all observed growth and yield parameters.

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