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Growth and Yield of Celery (*Apium Graveolens* L.) in Organic Cultivation on Alluvial Soil

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ABSTRACT

Celery (Apium graveolens L.) *is a horticultural crop that is consumable and offers numerous health benefits. The purpose of this study was to ascertain how celery growth and yield cultivated on alluvial soil were affected by the interaction between liquid organic NPK fertilizer and chicken manure. The study utilized a field experiment that was designed completely randomized comprising two factors. The first factor was the dosage of chicken manure with three levels: C_1: 50 g/pot, C_2: 100 g/pot, and C_3: 150 g/pot. The second factor was liquid organic NPK fertilizer with three levels: L_1: 1%, L_2: 2%, and L_3: 3%. All treatment combinations were performed in triplicates. The results indicated that the interaction between chicken manure and liquid organic NPK fertilizer significantly affected the number of tillers and dry weight of celery yield. Chicken manure as a single factor significantly influenced the number of stems and tillers. Liquid organic NPK fertilizer as a single factor significantly influenced the number of tillers, fresh weight, dry weight, and plant height. The combination of chicken manure and liquid organic NPK fertilizer (C_1L_3) produced the highest number of stems per clump (79.44 stems) and the highest number of tillers per clump (9.78 tillers). The combination of C_2L_3 yielded the highest fresh weight (184 g) and dry weight (17.33 g).*

1. INTRODUCTION

Celery (*Apium graveolens* L.) is widely known and used by the community. It contains high levels of vitamins A and C, iron, and other nutrients. In Japan, China, and Korea, the petioles and leaves of celery are commonly used as food ingredients (Rachmawati, 2019). In Indonesia, celery is often used as a flavor enhancer in soups or as a salad ingredient. Celery also offers numerous health benefits, including blood purification, reduction of uric acid, anti-rheumatic properties, reduction of blood sugar levels, lowering high blood pressure, and addressing hair loss (Hasanah, 2018; Sari, 2016; Syam *et al*., 2017). Research by Saputra & Fitria (2016) showed that celery leaves contain compounds including apiin and mannitol that can lower blood pressure by acting as diuretics, helping the kidneys to remove excess fluids and salt from the body, thus reducing blood pressure.

The cultivation of celery (*Apium graveolens* L.) in Indonesia has not been commercially managed. Among the 23 types of important vegetables no celery was reported during the period of 2021-2023 (BPS, 2024). Celery has not been prioritized as a main commodity or research priority (Maunte *et al*., 2018). Celery has good prospects in both domestic and international markets as an export commodity with relatively high and stable prices. The increasing population annually leads to a higher demand for vegetables.

Celery cultivation is very suitable for highland areas at an altitude of 1000-1200 meters above sea level. However, it is still tolerant of lowland cultivation (Elidar, 2018). This opens opportunities for intensive celery cultivation in lowland areas, including West Kalimantan, using technologies such as organic fertilizers. To meet the increasing demand, yield enhancement is necessary through both extensification and intensification. One way to improve yield through intensification is by selecting the right growing media and fertilizers. The growing media is crucial because majority of the nutrients required by plants are provided through the media, drawn by roots, and used by plants for growth (Jenira *et al*., 2018; Pane *et al*., 2014).

One type of soil suitable for celery cultivation is alluvial soil. According to Statistic Agency of West Kalimantan (BPS, 2018), the area of alluvial soil in West Kalimantan is 1,793,771 ha. Thus, alluvial soil holds significant potential for celery cultivation to boost production in West Kalimantan. Alluvial soil has several limiting factors in terms of physical, chemical, and biological properties that pose challenges for its use as a growing medium for celery. These limitations include high acidity, poor structure, and variable C/N ratios. Additionally, alluvial soil has low organic matter content and relatively low N, P, and K availability (Surya *et al*., 2022). These issues can be addressed by fertilization.

Excessive use of chemical fertilizers, however, is not advisable as it can worsen the physical condition of the soil if not balanced with organic fertilizers. To increase celery production on alluvial soil, the use of organic fertilizers is the best solution. Considering its health benefits, celery should ideally be cultivated organically using organic fertilizers like chicken manure and avoiding chemical pesticides (Jenira *et al*., 2018; Pane *et al*., 2014). Celery cultivation requires nutrient-rich growing media. Organic fertilizers can improve the structure of alluvial soil and serve as a nutrient source for plants. The nutrient content in chicken manure is significantly lower than chemical fertilizers. Therefore, adding organic NPK fertilizer, whether solid or liquid, is necessary to meet nutrient needed by plants.

Based on the above explanation, research about the growth and yield of celery cultivated organically on alluvial soil is necessary. Organic fertilizers derived from organic materials contain all types of nutrients, both macro and micro, although usually in small amounts. Organic fertilizers or soil organic matter are the main sources of soil nitrogen. Improvement the physical, chemical, and biological characteristics of the soil is largely accomplished by organic matters.

The use of organic fertilizers can improve land quality in a sustainable manner, lower environmental pollution, and increase both the amount and quality of agricultural output. The long-term application of organic fertilizers can stop land degradation and boost land productivity. Compared to chemical fertilizers, however, organic fertilizers contain less nutrient with poor solubility, and supply nutrients to plants more slowly. Since organic fertilizers are thought to be insufficient in meeting plant nutrient needs, they are not commonly applied (Syam *et al*., 2017). Organic fertilizers applied to the soil will be decomposed by soil microorganisms in several steps until they become humus that is readily available to plants. The purpose of this study is to ascertain how celery growth and yield cultivated on alluvial soil are affected by the interaction of liquid organic NPK fertilizer and chicken manure. This research is expected to serve as a reference for increasing celery production and providing information for future researchers.

2. RESEARCH MATERIALS AND METHODS

This research was conducted in Pontianak, at an altitude of 1 meter above sea level, from December 2022 to March 2023. The materials used in this research were amigo variety celery seeds, black polybags measuring 40 x 50 cm, alluvial soil, dolomite lime, chicken manure, and liquid organic NPK fertilizer. The chicken manure used was obtained from chicken farmers in the Ambawang area. Chicken manure has a high content of N, P, K, and Ca and is readily available to plants (Hartatik & Widowati, 2006; Nurjanah *et al*., 2020). The liquid organic NPK fertilizer was homemade from gamal leaves, banana stems, and banana peels. The tools used in this research included digital scales, analytical balances, measuring tape, writing tools, documentation tools, pH meters, thermometers, hygrometers, measuring cups, and buckets. This research employed a Completely Randomized Design (CRD) with a factorial pattern. The treatments consisted of two factors. The first factor was chicken manure with the code C, comprising three treatment levels, namely C_1 : dose 50 g/pot (10 kg soil); C_2 : dose 100 g/pot (10 kg soil) and C_3 : dose 150 g/pot (10 kg soil). The second factor was liquid organic NPK fertilizer with the code L, comprising three treatment levels, namely L_1 : concentration 1%; L_2 : concentration 2%; and L_3 : concentration 3%. There were nine treatment combinations, each treatment was repeated three times, and each repetition consisted of three plants, resulting in 3×3×3×3 = 81 plants. The treatment combinations were as follows: C_1L_1, C_1L_2, C_1L_3, C_2L_1, C_2L_2, C_2L_3, C_3L_1, C_3L_2, and C_3F_3.

2.1. Soil Preparation

The soil used in this research was alluvial soil. The soil was sieved with a 100 mesh sieve and placed into 40 x 50 cm polybags, each weighing 10 kg. Dolomite lime with an absorption rate of 104% was used. Liming was done 2 weeks before planting at a dose of 9 g/polybag. Liming aimed to raise the soil pH. Chicken manure was applied 1 week before planting, at doses corresponding to the treatments. The manure was thoroughly mixed with the soil in the polybags.

2.2. Planting

Seed selection was done by soaking the seeds in water at room temperature. The celery seeds that sank in water were used. Before sowing, celery seeds were soaked in room temperature water for 1 hour to stimulate germination. Sowing was done using a nursery tray with a 1:1 mixture of soil and chicken manure (5 kg soil + 5 kg manure). Watering with 1 liter of water was performed twice daily, in the morning and evening. After 2 weeks, the seedlings were transplanted into small polybags. Planting was done after the seedlings were 1 month old by transferring them from small polybags to larger ones.

2.3. Liquid Organic NPK Fertilizer Application

Liquid organic NPK fertilizer was applied every 2 weeks, starting 1 week after planting until 1 week before harvest, at concentrations according to the treatment levels. The fertilizer was sprayed on the plants and poured into the soil around the root area, with 150 ml per plant.

2.4. Maintenance

Watering was done twice daily, in the morning and evening, with 1 liter of water per polybag, except on heavy rainy days. Weed control was manually performed by removing weeds growing in and around the polybags.

2.5. Research Observation

Plant height was measured every 2 weeks from 2 weeks after planting (WAP) to 10 WAP. Height was measured from the base of the stem to the highest leaf tip of each plant clump. The number of stems per clump was counted every 2 weeks from 2 WAP to 10 WAP. The number of tillers per clump was counted after harvesting, at 10 WAP. The fresh weight of plants was measured by weighing each plant per polybag, including roots, using digital scales. The dry weight of plants was measured by taking one plant sample (the entire plant per polybag) from each treatment and replication, then placing it in an oven at 70°C for 24 hours, and weighing it until the weight was constant.

2.6. Data Analysis

F-tests at 5% and 1% significance levels were conducted to determine the effects of treatments. If significant effects were found on the observed parameters, treatments were compared according the Tukey test at an alpha level of 5%.

3. RESULTS AND DISCUSSION

3.1. Plant Height

Based on the results of statistical inferences, there was no significant impact of chicken manure as a single factor as well as its interaction with liquid organic NPK fertilizer on the plant height of celery. But, the treatment of liquid organic NPK fertilizer as a single factor significantly impacted plant height at 2, 4, and 10 weeks after planting (WAP). A Tukey test at a 95% confidence level was conducted, and the results are shown in Table 1.

Table 1. Tukey test of the effect of liquid organic NPK fertilizer on plant height (cm) of celery at 2, 4, and 10 WAP.

Treatment	Mean plant height (cm)		
	2 WAP	4 WAP	10 WAP
L_3	7.31 a	13.21 a	32.94 a
L_2	6.51 ab	11.89 b	30.33 ab
L_1	6.07 b	11.64 b	29.13 b
Tukey 5%	0.98	1.21	3.73

Note: same letters following the mean values at the same column indicate not significantly different according to the Tukey test at α = 5%.

The result of Tukey test infers that at 2 WAP, the L_3 treatment created the uppermost plant height of celery (average 7.31 cm) and was statistically different with that of L_1, but not statistically different with that of L_2. Our plant is significantly higher than the findings of Ansari *et al*. (2017), where the highest plant height of celery at 2 WAP was 5.9 cm. At 4 WAP, the L_3 treatment produced the highest average plant height (13.21 cm) and was different significantly from those of L_1 and L_2 treatments. At 10 WAP, the L_3 treatment kept leading the plant height (average 32.94 cm) and even though was not statistically different from that of L_2 treatment. According to the plant description, the height of the Amigo variety of celery can reach 30 - 35 cm. The average plant height in our study resulted from the L_2 and L_3 treatment obviously reached this description. This likely because the liquid organic NPK fertilizer provided sufficient macro and micronutrients for plant growth.

The higher the concentration of liquid organic NPK fertilizer, the greater the plant height. Plant height continued to increase with the application of liquid organic NPK at a 3% concentration (L_3 treatment). Thus, the concentration of the liquid organic fertilizer could be increased further. According to Arlingga *et al*. (2014), optimal fertilization can be achieved when fertilizers are applied according to plant needs. Exceeding the optimum volume can cause plant toxicity. Plants grow well when nutrients are provided in balanced amounts according to their needs. Plant height growth results from the elongation of meristem cells, determined by nutrient availability. Nutrient application to the growing medium affects plant growth, as shown by plant height. Nutrient availability is crucial for plant metabolic processes. Plant growth is significantly impacted by some factors including environmental, physiological, and genetic factors (Hendrika *et al*., 2017). Adequate nutrient availability can increase the plant height and the number of leaves.

Leaves are essential organs for photosynthesis because they contain pigments that absorb sunlight. The number of leaves is closely related to plant height; as plant height increases, the number of nodes increases, resulting in more leaves because leaves form at the nodes (Ansari *et al*., 2017). Yunindanova *et al*. (2018) stated that availability of nitrogen helps plants form protoplasm, and increased protoplasm results in higher fresh plant weight. Calcium affects the meristem or growth point at the root tip, increasing root length and subsequently influencing celery root growth.

The vegetative growth of celery, especially in height, requires Nitrogen (N) and Phosphorus (P) nutrients (Sari, 2020; Syahri, 2020). Macronutrients significantly affect plant growth, especially N. Plant height is related to the number of leaves, as leaves are located at the plant's stem nodes. Therefore, the greater the plant height and leaf number, the higher the chlorophyll content. Increased chlorophyll content enhances the plant's photosynthetic ability, increasing fresh plant and root weight. Rosnina *et al*. (2022) stated that the higher the nutrient availability, the higher the potential plant production, provided environmental factors also support it.

3.2. Number of Stems per Clump

The interaction of chicken manure and liquid organic NPK fertilizer had no significant impact on the number of stems per clump of celery. Chicken manure treatment had no significant impact on the number of stems per clump at 2, 4, 6, and 8 WAP, but exhibited a significant impact at 10 WAP. Liquid organic NPK fertilizer treatment significantly affected the number of stems per clump at 4 and 6 WAP but not at 2, 8, and 10 WAP. The Tukey test results for the differences in the average number of stems produced at various levels of liquid organic NPK fertilizer treatment at 10 WAP are shown in Table 2. The Tukey test results in Table 2 show that at 10 WAP, the C_1 treatment produced the highest number of stems per clump (73.89 stems) and was different significantly from the C_2 and C_3 treatments. The highest number of stems was in the treatment with the lowest dose of chicken manure (50 grams per polybag). Visual observations indicated that the stems produced in the C_1 treatment were small, even though they were numerous. In the C_1 treatment with the lowest dose of chicken manure, the growing medium was less friable. This caused poor root development, prompting more stem growth but with smaller sizes. The Tukey test results for the differences in the average number of stems produced at various levels of liquid organic NPK fertilizer treatment at 4 and 6 WAP are shown in Table 3.

Table 2. Tukey test of the effect of chicken manure on the number of stems per clump at 10 WAP.

Treatment	Mean number of stems per clump (stem)
C_1	73.89 a
C_2	62.56 b
C_3	60.74 b
Tukey 5%	10.08

Note: same letters following the mean values indicate not significantly different according to the Tukey test at α = 5%.

Table 3. Tukey test of the effect of liquid organic NPK fertilizer on the number of stems per clump (stems) at 4 and 6 WAP.

Treatment	Mean number of stems per clump (stem)	
	4 WAP	6 WAP
L_3	5.56 a	22.78 a
L_2	5.11 b	19.19 ab
L_1	4.67 c	18.04 b
Tukey 5%	0.41	3.86

Note: same letters following the mean values at the same column indicate not significantly different according to the Tukey test at α = 5%.

The Tukey test results in Table 3 show that at 4 WAP, the L_3 treatment produced the highest number of stems per clump (5.56 stems) and was different statistically from those of L_2 and L_1 treatments. The L_2 and L_1 treatments were also different statistically. At 6 WAP, the L_3 treatment produced the highest number of stems per clump (22.78 stems) and was significantly different from the L_1 treatment but not different significantly from the L_2 treatment. The L_2 and L_1 treatments were not statistically different. The higher the concentration of liquid organic NPK fertilizer, the greater the number of stems. The number of stems continued to increase with the application of liquid organic NPK at a 3% concentration (L_3 treatment). Thus, the concentration of liquid organic fertilizer could still be increased further.

The growth in the number of stems is part of vegetative growth. Nitrogen (N), Phosphorus (P), and Potassium (K) are essential elements for plants. However, P and K elements significantly influence the processes of differentiation, cell division, and cell enlargement in plants (Paiman, 2022). According to Paiman (2022), plant development is a process of functional changes in body organs that become more complex due to cell differentiation. Cell differentiation is a mechanism that causes cells with the same structure and function to become different, forming mature tissues. The cell differentiation process in celery plants will result in new stems, which then form complete plants. The number of leaf sheaths is significantly influenced by the nutrients produced by the roots during vegetative growth, impacting the number of leaf sheaths formed (Jedeng, 2011).

Stem formation is influenced by the availability of nitrogen (N), phosphor (P), and potassium (K). Nitrogen helps plants producing more chlorophyll. With abundant chlorophyll, plants perform photosynthesis more easily, thereby accelerating growth (height, tiller number, branches, etc.) (Hairuddin & Edial, 2019). Phosphor is involved in cell division and formation of albumin, flower, fruit, and seed. Additionally, P accelerates fruit ripening, strengthens stems, aids root development, and improves plant quality. Potassium plays a vital role in photosynthesis and translocation of photosynthesis products, which are utilized to form stem and increase tiller number (Syam *et al*., 2017). Lingga & Marsono (2013) added that optimal growth and yield occur when nutrient availability is sufficient and balanced.

3.3. Number of Tillers per Clump

The analysis of variance revealed that the interaction of chicken manure and liquid organic NPK fertilizer had a significant impact on the number of tillers per clump at 10 WAP. Chicken manure as a single factor significantly affected the number of tillers per clump. Liquid organic NPK fertilizer as a single factor had a highly significant impact on the number of tillers per clump. The Tukey test results for the differences in the average number of tillers per clump produced at various levels of liquid organic NPK fertilizer treatment at 10 WAP are shown in Table 4. It shows that the highest number of tillers per clump was in the C_1L_3 treatment, with 9.78 tillers, which was different significantly from that of C_2L_3 treatment but not different significantly from those of C_1L_1, C_1L_2, and C_3L_3 treatments. In the C_1 and C_2 treatments, the higher the concentration of liquid organic NPK fertilizer, the greater the number of tillers per clump. In the C_3 treatment, the number of tillers per clump decreased in the L_3 treatment, but it was not significantly different from those of L_1 and L_2 treatments.

Table 4. Tukey test of the effect of chicken manure and liquid organic NPK fertilizer on the number of tillers per clump at 10 WAP.

Treatment	L_1	L_2	L_3
C_1	8.33 a A	8.67 a A	9.78 a A
C_2	6.56 a A	7.22 ab A	9.44 b A
C_3	7.11 a A	9.00 a A	8.11 a A

Note: Numbers followed by the same letter are not different significantly according to Tukey test at $\alpha = 5\%$. Capital letters are read vertically, while lowercase letters are read horizontally.

The highest number of tillers per clump was in the C_1L_3 treatment (the lowest dose of chicken manure and the highest concentration of liquid organic NPK fertilizer). The number of tillers per clump was high, but their size was small. This was due to the dense medium, which hindered root growth and promoted stem growth, affecting the number of clumps formed. Macronutrients are essential for plant growth, particularly for vegetative parts such as roots, stems, and leaves. Insufficient macro and micronutrient availability can hinder plant growth and development because these nutrients enhance lateral bud development, forming new tillers.

3.4. Fresh Weight of Plants

Based on the results of variance analysis, the application of liquid organic NPK fertilizer as a single factor had a very significant effect on the fresh weight of the plants. The results of the Tukey test to determine the differences in the average fresh weight of plants produced at various levels of liquid organic NPK fertilizer treatment can be seen in Table 5. The highest fresh weight of plants (165.52 grams) was found in treatment L_3, which was different significantly from treatment L_1, but not different significantly from treatment L_2. The higher the concentration of fertilizer given, the higher the fresh weight of the plants. The fresh weight of the plants continued to increase at the highest concentration treatment (L_3), indicating that the concentration of liquid organic NPK fertilizer could still be increased further. The fresh weight of the plants produced in this study was higher compared to the study by Arlingga *et al*. (2014), where the highest fresh weight produced was 66.37 grams under different shading percentages and liquid organic fertilizer doses. The water content in plant tissues can affect the fresh weight of plants because water in the cells is used for cell activities in the process of photosynthesis and the circulation of photosynthesis results to all parts of the plant. The fresh weight value is influenced by tissue water content, nutrients, and metabolism. High water content in plant tissues will promote cell elongation, especially in meristem tissues, thus increasing the fresh weight of the plants due to enhanced vegetative growth and development. This underlines that an increase in the number of leaves impacts the fresh weight increase; however, if water availability is low, it will affect the fresh weight of the plants due to suboptimal photosynthesis (Halawa *et al*., 2022).

Table 5. Tukey test of the effect of liquid organic NPK fertilizer on fresh weight of plants (gram)

Treatment	Average fresh weight of plants (gram)
L_3	165.52 a
L_2	143.80 ab
L_1	122.74 b
Tukey 5%	22.7

Note: same letters following the mean values indicate not significantly different according to the Tukey test at $\alpha = 5\%$.

Fresh weight is related to the vegetative growth of plants and is a common measure used to describe and study plant growth and biomass. Kalasari (2018) stated that the fresh weight of plants is influenced by the water content and nutrient content in the plant tissue cells, thus the availability of water and nutrients is crucial. Minerals also significantly determine the fresh weight of plants.

3.5. Dry Weight of Plants

Based on variance analysis, the interaction of chicken manure and liquid organic NPK fertilizer had a significant effect on the dry weight of the plants. The application of chicken manure as a single factor had no significant effect on the dry weight of the plants. The application of liquid organic NPK fertilizer as a single factor had a very significant effect on the dry weight of the plants. The results of the Tukey test to determine the differences in the average dry weight of plants produced at various levels of liquid organic NPK fertilizer treatment can be seen in Table 6. The results of the Tukey test in Table 6 above show that the highest average dry weight of plants (17.33 grams) was found in treatment C_2L_3, which was significantly different from C_2L_1, C_2L_2, C_1L_3, and C_3L_3. Dry weight can represent the metabolic yield of plants because leaves and other organs contain metabolites. The increase in dry weight is used as an indicator of plant growth because it reflects the accumulation of organic compounds synthesized by the plant from inorganic compounds such as water and CO_2. Plant growth is an increase in fresh weight and the accumulation of dry matter. The better the plant growth, the higher the dry weight (Purnamasari *et al*., 2023).

Table 6. Tukey test of the effect of chicken manure and liquid organic NPK fertilizer on the dry weight of plants (gram)

Treatment	L_1	L_2	L_3
C_1	11.15 a A	12.07 a A	15.54 a A
C_2	11.96 a A	11.66 a A	17.33 b A
C_3	8.52 a A	15.09 b A	13.97 a A

Note: Numbers followed by the same letter are not different significantly according to Tukey test at $\alpha = 5\%$. Capital letters are read vertically, while lowercase letters are read horizontally.

Dry weight is the result of carbon fixation from photosynthesis performed by plants. According to Purnama *et al*. (2021), dry weight yield is a balance between photosynthesis and respiration. Photosynthesis increases plant dry weight due to CO_2 absorption, while respiration decreases dry weight due to CO_2 release. According to Rahmah *et al*. (2013), the dry weight of plants reflects the nutritional status of a plant and is also an indicator of plant growth and development, which is closely related to nutrient availability. Jumin (2010) added that growth is indicated by an increase in size that reflects the addition of protoplasm, marked by an increase in plant dry weight. Therefore, optimal availability of nitrogen, phosphorus, potassium, and magnesium nutrients can increase chlorophyll, which in turn enhances photosynthesis, resulting in more assimilates that support the plant's dry weight.

4. CONCLUSION

The results of the study showed that the interaction of chicken manure and liquid organic NPK fertilizer had a significant impact on the number of tillers per clump and the dry weight of the plants, and had no significant impact on plant height, number of stems per clump, and the fresh weight of celery plants. The application of chicken manure as a single factor had a significant impact on the number of stems per clump and the number of tillers per clump, and had no significant impact on plant height, fresh weight, and dry weight of the plants. The application of liquid organic NPK fertilizer as a single factor had a very significant impact on the number of tillers per clump, fresh weight, and dry weight of the plants, had a significant effect on plant height, and had no significant impact on the number of stems per clump. Treatment C_3L_3 gave the highest result for plant height (33.67 cm). Treatment C_1L_3 gave the highest result for the number of stems per clump (79.44 stems) and the number of tillers per clump (9.78 tillers). Treatment C_2L_3 gave the highest result for the fresh weight of plants (184 grams) and the dry weight of plants (17.33 grams).

CONFLICT OF INTEREST

The authors report no conflicts of interest in this work.

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