Improving Chinese kale (*Brassica oleracea* var. alboglabra) Productivity and Profitability in Low-Fertility Soils through Organic Amendments and Planting Distance Management

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Abstract
Chinese Kale cultivation in Dadaprejo, Bumiaji, which is a vegetable production center in Batu City and its surrounding areas is still not optimal due to low soil conditions in C-organic and nitrogen content. The soil texture tends has a low water holding capacity. The purpose of this study was to observe the quantity and quality of Chinese Kale through organic approach and planting spacing on low-fertile soil. The factorial experiment designed used Randomized Block Design with 2 factors and 3 replications. The first factor consists of 4 levels of chicken manure dosage: 0 tons ha^{-1} (M0); 5 tons ha^{-1} (M1); 10 tons ha^{-1} (M1) and M3: 15 tons ha^{-1}. Second factors were 3 levels of planting spacing of 20 cm x 20 cm (S1); 25 cm x 25 cm (S2) and 30 cm x 30 cm (S3). The results showed that there was no interaction between chicken manure dosage application and the space planting distance on the growth and yield of Chinese Kale. Chicken manure dosage treatments did not show any significant effect on the growth and yield of Chinese Kale. Applying 30 cm x 30 cm space showed the best results in CGR and yield variables (the total plant fresh weight of 9.55 t ha^{-1} and the edible fresh weight of 9.20 t ha^{-1}). Although it is still unable to meet the potential of the variety description, the results of the harvest quality analysis and the farming feasibility analysis indicate the potential for Chinese Kale cultivation with organic inputs and the application of planting distance compared to the control.

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Keywords: Go Organic System, Plant Density, Sustainable Agriculture

Introduction

Chinese Kale (*Brassica oleracea* var. alboglabra) is one of the horticultural commodities with a fairly high economic value (IDR 10,000/kg cultivated conventionaly and IDR 15,000/kg cultivated organicaly). Chinese Kale is also rich in minerals, vitamin B, vitamin C, antioxidants, fiber, Ca, and Fe (Srikanth *et al*., 2016) [22]. Chinese kale is a leafy vegetable harvested for its foliage, making it particularly sensitive to environmental disturbances during its development. Dadaprejo is an area in Batu City considered as a center for horticultural commodity production by the surrounding community. The cultivation practices in the area has a fairly high dependence on inorganic inputs to meet the nutritional needs of cultivated crops. Based on the results of the initial soil chemical analysis, it is known that the C-organic and N (nitrogen) content is quite low, which is 1.19% and 0.07% respectively. The type of soil in the Dadaprejo area is also categorized into class S3 (rather coarse) with a fairly low clay content so that it has a low water holding capacity (Aditiyas *et al.*, 2014) [2]. Therefore, one potential approach to mitigate this issue is the application of organic fertilizers, such as chicken manure, to improve soil quality and support plant growth. Soil organic matter is an important indicator of soil fertility. Soil organic matter comes from complex organic compounds that undergo a decomposition process. Organic matter can improve soil structure both physically, chemically and biologically, improve soil quality, and increase nutrients in the soil, both micro and macro (Nurhidayati *et al*., 2012) [18].

The use of organic fertilizer in the form of chicken manure, in addition to being able to meet the nutrient needs of plants, can also minimize the use of inorganic fertilizers that can become residues for the soil. According to Sari *et al.* (2016) [20], the nutrient content of chicken manure is 2.44% N; 0.67% P_2O_5; 1.24% K_2O; and 16.10% C-organic. The nutrient content contained in chicken manure has the potential to support the growth of Chinese Kale, especially until the end of the vegetative phase (harvest period). The cultivation of Chinese Kale primarily targets leaf development, as the leaves are the edible organs of the plant.

Chinese Kale productivity related to plant population can be increased by adjusting the planting distance. According to Afandi (2019) [3], the best planting distance for Chinese Kale cultivation is 30 cm x 30 cm. Setting the planting distance is very important to optimize the land use efficiency, competition between plants can also be regulated during the growth phase. This focus directly influences the quality of the harvested product and determines the overall economic benefits of cultivation. This is in accordance with research conducted by Dantri *et al.* (2015) [6] setting the planting distance can increase Chinese Kale production per unit area. Setting the appropriate planting distance is also able to prevent excessive evaporation that the available water can be utilized optimally by the plants. The application of fertilizers combined with optimal planting spacing can reduce inter-plant competition for nutrients, thereby promoting optimal growth and development of the crop.

The experiment aims to determine the effect of chicken manure doses and planting distance on the growth and yield of Chinese Kale. The hypothesis proposed in this experiment is 1) there is an interaction between the dose of chicken manure and planting distance on the growth and yield of Chinese Kale and 2) Low doses of chicken manure require closer planting distances, while high doses of chicken manure require wider planting distances. Furthermore, analysis of harvest quality and farming feasibility is essential to validate both the cultivation outcomes and the economic viability of the enterprise. These assessments can guide future research by incorporating agronomic and financial considerations. The findings of this study are expected to offer valuable insights for Chinese kale cultivation in Dadaprejo, particularly through the adoption of more environmentally sustainable organic farming practices.

Materials and Methods

Study area

The experiment was conducted from February to April 2023 in Dadaprejo Village, Junrejo District, Batu City, East Java. The experimental area is located in 739 m above sea level which has average temperature of 28-32 ºC. The location of the experimental area is part of the conventional horticultural cultivation land unit of the local community with relatively low N and C-Organic content (Table 1). Initial soil quality tests were conducted at the Integrated Laboratory UPT of the National Development University "Veteran" East Java. Laboratory analysis for plant growth observation was carried out at the Land and Environmental Resources Laboratory, Department of Agronomy, Faculty of Agriculture, Brawijaya University, Malang.

Experimental design

The experiment was designed using a Randomized Block Design (RBD) consisting of 2 factors and repeated 3 times to obtain 36 experimental units. The first factor is chicken manure dose that consists of 4 levels which are M0: 0 t ha^{-1} (without chicken manure), M1: 5 t ha^{-1}; M2: 10 t ha^{-1} and M3: 15 t ha^{-1}. The space planting distance factor consists of 3 levels which are S1: 20 cm x 20 cm, S2: 25 cm x 25 cm and S3: 30 cm x 30 cm. Each plot measures 4.5 m^2 and a total of 2,808 plants were obtained. The number of plants obtained at a planting distance of 20 cm x 20 cm per plot is 112 plants, a planting distance of 25 cm x 25 cm consisted of 72 plants and a planting distance of 30 cm x 30 cm consisted of 50 plants. The variety used as a representation of Chinese Kale in this experiment is NITA which is produced by PT East West Seed Indonesia with Ministerial Decree of Indonesia's Ministry of Agriculture No. 257/Kpts/TP.240/5/2000.

Data collection methods

a. Plant growth

Plant growth observations were carried out through several variables consisting of stem diameter, number of leaves, leaf area index, and crop growth rate (CGR). Stem diameter data collection was done by a measurement using a digital sigmat caliper (caliper 150 mm). Data collection on the number of leaves was carried out by counting leaves that had opened completely and were not damaged up to above 70%. Leaf area observations used a Leaf Area Meter (LAM) LI-31000C. Leaf Area Index (LAI) shows the ratio between leaf area and shaded land area (Equation 1) (Susanti and Safrina, 2018). CGR calculations were carried out at plant age 28-35 DAP by drying the sample at a temperature of 85°C for 3 x 24 hours using a DHG-9920A drying oven which was then weighed with an analytical scale explore pro 22000 grams. The equation for calculating the CGR value is presented in Equation 2. Observations of stem diameter, number of leaves, and leaf area index were carried out at plant ages of 21, 28, and 35 DAP.

$$\mathrm{LAI} = \frac{\mathrm{LA}}{\mathrm{GA}} \qquad \text{Equation 1}$$

Note:
LA = Leaf area (cm^{-2} plant^{-1})
GA = Sampling plot area (0.9 m x 0.3 m)

$$\mathrm{CGR} = \frac{1}{\text{sampling plot area } (\mathrm{m}^2)} \times \frac{(\mathrm{W2}-\mathrm{W1})}{(\mathrm{T2}-\mathrm{T1})} \qquad \text{Equation 2}$$

Note:
W1 = Dry weight sample on 28 DAP (g plot^{-1})
W2 = Dry weight sample on 35 DAP (g plot^{-1})
T1 = Age of plant sample (28 DAP)
T2 = Age of plant sample (35 DAP)

b. Plant yield

1. Total Fresh Weight (t ha^{-1})

The observation was conducted at harvest by weighing the entire sample plant parts within a 0.54 m^2 sample plot directly after being uprooted and washed clean of soil. The total plant weight was measured using an analytical scale. The fresh weight per plot (g plot^{-1}) was then converted into tons per hectare (t ha^{-1}).

2. Edible Fresh Weight (t ha^{-1})

The observation was conducted at harvest by weighing all edible parts of the sample plants within a 0.54 m^2 sample plot, excluding the roots of the Chinese Kale. The result of marketable edible fresh weight per plot (g plot^{-1}) was then converted into tons per hectare (t ha^{-1}).

c. Yield Quality Assessment

The yield quality assessment consisted of postharvest shelf life of plants and organoleptic tests. Postharvest shelf life observation was conducted to evaluate the postharvest durability of Chinese kale. The postharverst shelf life was assessed under room temperature and refrigerated conditions for a duration of 7 days. After 7 days, the wilting level of the plants was observed. Obeservations considered factors such as temperature, storage duration, and room humidity. The organoleptic test was used to evaluate the harvest quality using the hedonic test method, where scoring was performed by 20 panelists to assess the crispness of Chinese kale (Lestari and Pepi, 2015) [14]. The organoleptic evaluation included sweet taste (agree, disagree, strongly disagree) and texture (crispiness) (strongly agree, agree, disagree). The assessment was conducted after harvest.

d. Feasibility analysis of farming business

The feasibility analysis of farming is done by calculating the R/C Ratio. Farming can be considered its feasiblility by looking at the efficiency of cost use and the magnitude of the comparison between total income and total costs. The economic analysis used includes the calculation of the Return Cost Ratio (R/C ratio) (Juanda and Cahyono, 2000) which is presented in Equation 3. The criteria in the R/C ratio are R/C ratio > 1 means its efficient and profitable, R/C ratio = 1 means its BEP and R/C ratio < 1 means inefficient or detrimental.

$$R/C = \frac{P_Q \times Q}{(TFC + TVC)} \qquad \text{Equation 3}$$

Note:

R = Return (profit)

C = Total Cost

P_Q = Output cost

Q = Total output

TFC = Total fixed cost

TVC = Total variable cost

Data analysis

The data obtained were tested using analysis of variance or F test at the 5% level. The further test of group data comparison is continued using the Honest Significant Difference (HSD) at the 5% level when indicated a significant different. The product quality test is presented in the form of a histogram graph to determine the tendency of the experimental results. The results of the farming business analysis are presented in a table to compare the feasibility index between treatments.

Table 1: Soil chemical properties

No	Variables	Value	Unit	Methods
1	Moisture content	5.92	%	Gravimetry
2	pH H_2O	6.68±0.02	-	LPT.A.05.12.06.05-7.4 (pH meter)
3	pH KCl	5.60±0.02	-	LPT.A.05.12.06.05-7.4 (pH meter)
4	C-Organic	1.19±0.13	%	LPT.A.05.12.06.02.7-4(Spectophotometer)
5	N-Total	0.07±0.01	%	LPT.A.05.12.06.03.7-4 (Spektofotometer)
6	P-Available	60.55±7.58	ppm	LPT.A.05.12.06.04.7-4 (Spektofotometer)
7	K-dd	0.7	Cmol/kg	Atomic Absorption Spectrophotometry

Result and Discussion

Plant Growth

The results of the analysis of variance (ANOVA) showed no interaction between the application of chicken manure doses and the application of planting distance on Chinese Kale plants on all plant growth variables at the observation ages of 21, 28, and 35 DAP. The independence of the treatment factor can be caused by its low sensitivity. The complex content of chicken manure has not been able to improve soil quality within the experimental period and has no impact on Chinese Kale growth observation variables. Chicken manure (poultry) has slow-release properties and has the potential to have a positive impact on the soil/planting media in the long term period of time (Hoover *et al*., 2019) [7]. The benefit obtained from the application of poultry can be in the form of improving soil physical properties (texture, drainage, porosity, and water holding capacity), soil chemistry (pH and nutrient input), and soil biology (microbial abundance and activities). The absence of interaction between the two treatment factors is also potentially caused by the irresponsive plant cultivars towards the treatment. Experiment conducted by Akbar *et al*. (2018) [4] showed no interaction between vermicompost dose treatments and planting distance on the height, number of leaves, and stem diameter of *Brassica oleracea* var. Alboglabra on the same variety.

The application of chicken manure input treatment did not have a significant impact on stem diameter (Figure 1a), number of leaves (Figure 1c), and leaf area index (Figure 1e) at observation ages of 21, 28, and 35 DAP. The same result also happened to the treatment factor of application of planting distance variation which did not affect the diameter of the plant stem (Figure 1b) and number of leaves (Figure 1d) at all observation ages. The average maximum kale stem diameter obtained from both treatment factors was only able to reach approximately 48.4% compared to the potential of the variety described (Ministerial Decree of Indonesia's Ministry of Agriculture, 2000). Based on this, it can be used as an indicator that cultivation with organic approach and arrangement of planting distances on degraded land are still unable to meet the optimum nutritional needs of plants. The same results were also obtained by Akbar *et al.* (2018) [4] on the application of organic fertilizer as well as optimizing the planting distance that were still unable to increase kale growth compared to controls on the same variety. The absence of significant differences in the observation variables of the treatment study with the control can also indicate on the inability of the organic fertilizer input treatment to meet plant nutritional needs and inhibit photosynthesis activity. In a different scenario (assumed to be done in a better soil fertility), the provision of organic and inorganic fertilizer can increase Chinese Kale growth such as plant height, number of leaves, leaf area, root length, and fresh weight (Nahar *et al*., 2021) [17].

The application of planting distance treatment has a significant impact on the leaf area index (Figure 1f). The leaf area index resulted by the 30 cm x 30 cm planting distance treatment is lower compared to the 20 cm x 20 cm planting distance treatment. This indicates that with the increase in growing space and the decreasing potential for competition, plants are still unable to increase their leaf area that caused the leaf area index value to be decreases. The inability of plants to increase leaf area is assumed to be due to nutrient deficiencies, especially macronutrients (N, P, and K) which have an important role in supporting the growth of Chinese Kale specifically the cell devision process (Chen *et al*., 2013; Tayebi-Meigooni *et al*., 2014; Hu *et al*., 2020) [5, 25, 8]. The decrease in the leaf area index value of plants in a certain cultivated land unit indicates that the application of cultivation planting distance is too high causing the area of land shaded by the plant canopy is increasingly wide. The decrease in the leaf area index value can also indicate on the inefficient use of land as a natural resource, potential nutrient leaching/run off, and increasing potential for soil evaporation (Jiang *et al*., 2013; Liu *et al*., 2022) [18, 15]. Daily crop growth rate of Chinese kale did not show significant differences by variations in chicken manure input, but was significantly influenced by planting distance settings. A wider planting distance (30 cm x 30 cm) was able to increase plant biomass accumulation compared to a planting distance of 20 cm x 20 cm. The reduced potential for competition can increase the rate of plant photosynthesis compared to area with higher population density (Hu *et al*., 2020) [8].

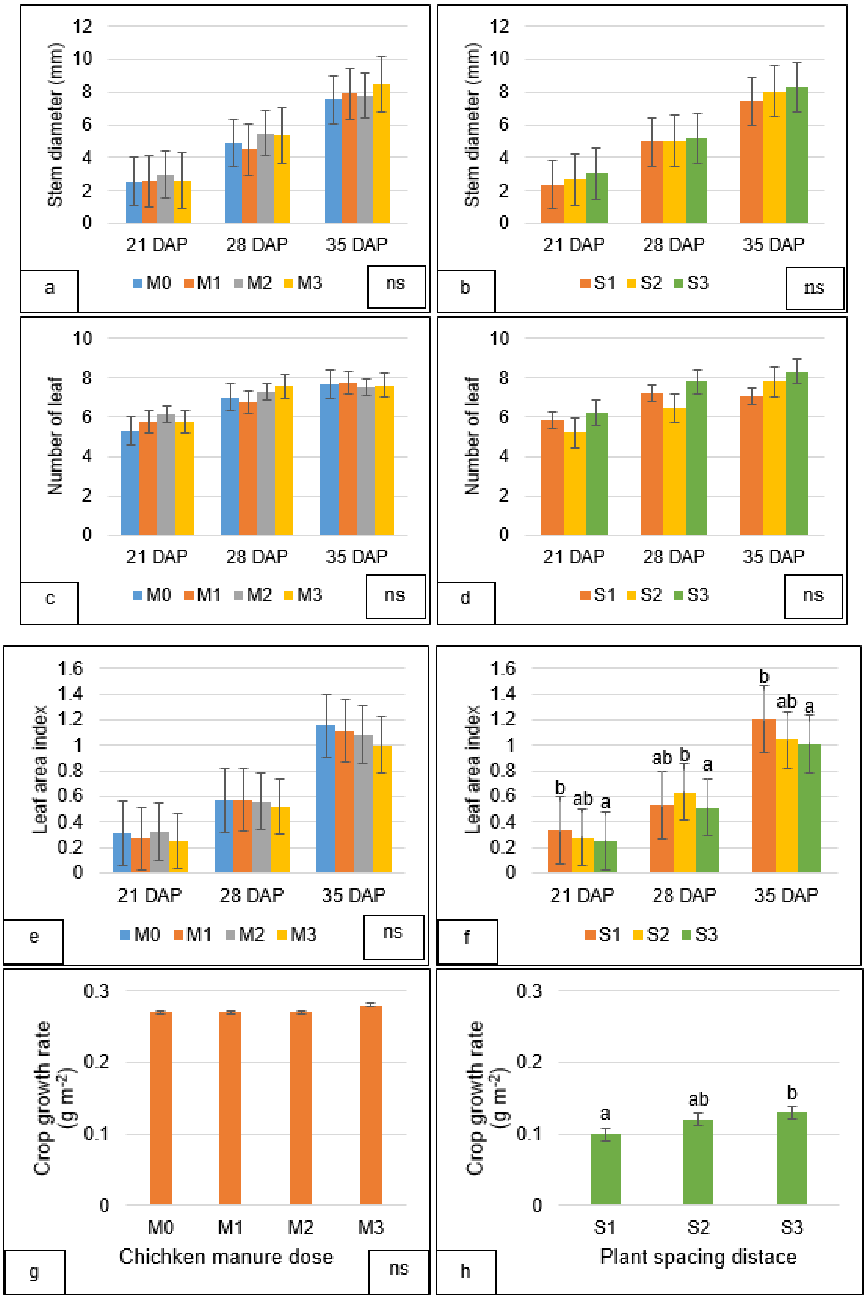

Fig 1: Plant growth effects of treatment; a. stem diameter by chicken manure dose, b. stem diameter by plant spacing, c. number of leaf by chicken manure dose, d. number of leaf by plant spacing, e. leaf area index by chicken manure dose, f. leaf area index by plant spacing, g. daily crop growth rate by chicken manure dose, h. daily crop growth rate by plant spacing Histogram followed by the same alphabet indicate results that are not significantly different from the Turkey's HSD test (5%). M0 = control, M1 = Chicken Manure 5 tons ha^{-1}, M2 = Chicken Manure 10 tons ha^{-1}, M3 = Chicken Manure 15 tons ha^{-1}, S1 = 20 cm x 20 cm spacing, S2 = 25 cm x 25 cm spacing, and S3 = 30 cm x 30 cm spacing. DAP = days after planting, ns = non-significant

Plant Yield

The results of the analysis of variance showed no interaction between the treatment factors of chicken manure application doses and the application of variations in planting distance on the variables of total fresh weight and edible fresh weight. The treatment factor of chicken manure dose did not have a significant impact on the results of fresh harvest weight and fresh consumption weight. According to Supriono (2013) [23], the fresh weight of Brassica plants can be influenced by the number of branches, and the wider the planting distance applied, the higher the fresh weight due to the greater space for growth. Similarly, Abed *et al*. (2015) [1] reported that a wider planting distance provides more growing space and reduces interplant competition, thereby increasing the fresh weight of the plants.

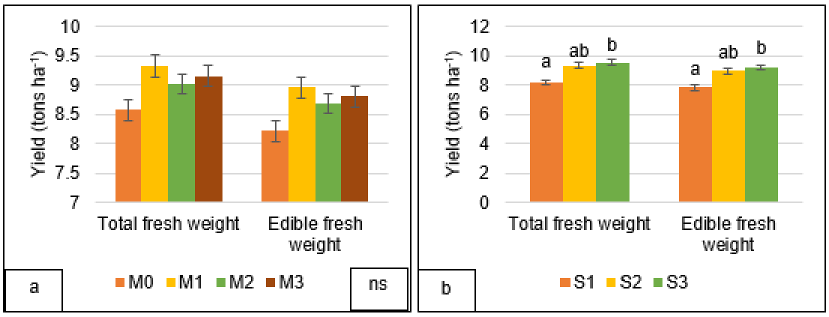

Fig 2: Total fresh weight and edible fresh weight of Chinese Kale resulted from; a. Dose of chicken manure application, b. Plant spacing. Histogram followed by the same alphabet indicate results that are not significantly different from the Turkey's HSD test (5%). M0 = control, M1 = Chicken Manure 5 tons.ha^{-1}, M2 = Chicken Manure 10 tons.ha^{-1}, M3 = Chicken Manure 15 tons.ha^{-1}, S1 = 20 cm x 20 cm spacing, S2 = 25 cm x 25 cm spacing, and S3 = 30 cm x 30 cm spacing. ns = non-significant

The best planting distance treatment, 30 cm x 30 cm, had a significant effect on edible fresh weight, resulting in 9.20 tons ha^{-1}. The fresh weight of edible yield can be influenced by the accumulation of photosyntetic carbon in the leaf. According to Kaur *et al*. (2021) [12], the use of appropriate planting distance allows plants to grow optimally, as the available light can be efficiently utilized for photosynthesis.

Yield quality assessment

Based on observations, the storage quality of kailan over a 7-day period under two temperature conditions room temperature (average 26.7°C; minimum 26°C; maximum 26.7°C) and cold storage (8°C) showed the emergence of deterioration symptoms in the Chinese Kale. At room temperature, the highest rate of spoilage was recorded in the treatment without chicken manure (0 tons ha^{-1}), with 65% of samples showing signs of rot and being watery (Figure 3a). Conversely, under cold storage, all treatments showed uniform results, with 65% of the kailan samples exhibiting yellowing (Figure 3b). According to Wu Ya *et al*. (2016), storage at 0°C maintained the best visual quality and extended shelf life to more than 21 days, while storage at 5°C retained marketable quality for 7–14 days. In contrast, storage at 10°C reduced shelf life to just 3–4 days. Furthermore, research by Ying-Sanga and Maturut (2018) [27] reported that yellowing in Chinese Kale stored at room temperature (30 ± 2°C) with relative humidity of 60%–70% occurred more rapidly in the outer leaves (fourth leaf) compared to inner leaves. This discoloration significantly affected consumer appeal, with only 1 day of storage considered commercially acceptable, although the product remained edible up to 3 days.

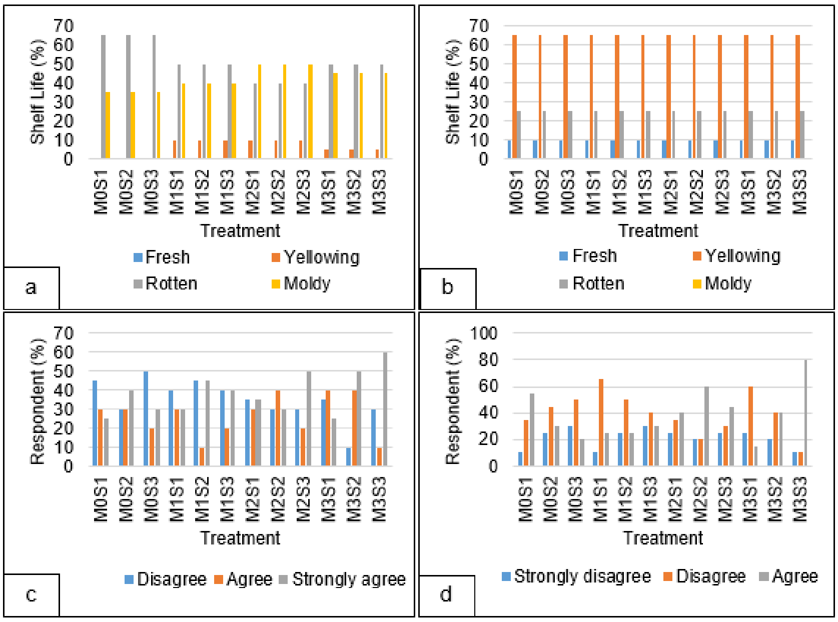

Fig 3: Analysis results; a. Shelf life of 7 days at room temperature, b. Shelf life of 7 days at refrigerator temperature, c. Organoleptic texture based on the level of crispiness, d. Organoleptic taste based on the level of sweetness. M0 = control, M1 = Chicken Manure 5 tons.ha^{-1}, M2 = Chicken Manure 10 tons.ha^{-1}, M3 = Chicken Manure 15 tons.ha^{-1}, S1 = 20 cm x 20 cm spacing, S2 = 25 cm x 25 cm spacing, and S3 = 30 cm x 30 cm spacing

Based on the organoleptic assessment, the application of chicken manure significantly influenced the crispness and taste of Chinese Kale (Figures 3c and 3d). The M3S3 treatment produced the highest levels of crispness and flavor. Approximately 60% of respondents rated the leaf texture in this treatment as very crisp, while 80% stated that the taste of the Chinese Kale leaves was moderately sweet. Supplied plants with chicken manure rich in nutrients and planted at an optimal spacing, positively affects the sensory quality. Chicken manure contributes to improving soil structure and increasing the availability of nutrients gradually (Rahayu and Islahiyati, 2024) [19], resulting in crispier leaves and a fresher and more natural taste compared to plants without organic fertilizer treatment (Kurniawan *et al.*, 2021) [13]. The crispness and color also tend to improved, as chlorophyll forms more effectively in the presence of high nitrogen content. As a result, the leaves are fresher and more palatable, leading to higher consumer acceptance. According to Sopyan (2022) [21], the combination of appropriate plant spacing and organic fertilizer dosage can enhance plant growth and yield, as optimal spacing allows plants to access sufficient space, which in turn improves sensory attributes such as leaf texture and taste. The resulting product of organic practice tends to be safer and healthier for consumption and more desirable for consumers (Kurniawan *et al.*, 2021; Insaniy *et al.*, 2024) [13, 9].

Feasibility analysis of farming business

Table 2: Analysis of the feasibility of chinese kale under several doses of chicken manure and plant spacing distances

Treatments	Total Cost	Revenue	Profit	R/C Ratio
M0S1	39.250.000	235.407.400	196.157.400	5,99
M0S2	38.275.000	232.851.900	194.576.900	6,08
M0S3	37.780.000	271.963.000	234.183.000	7,19
M1S1	44.410.000	349.027.800	304.617.800	7,86
M1S2	43.435.000	397.972.200	354.537.200	9,16
M1S3	42.940.000	462.277.800	419.337.800	10,77
M2S1	49.650.000	392.527.800	342.877.800	7,91
M2S2	48.675.000	426.555.600	377.880.600	8,76
M2S3	48.180.000	352.388.850	304.208.850	7,31
M3S1	54.890.000	315.472.200	260.582.200	5,75
M3S2	53.915.000	439.083.300	385.168.300	8,14
M3S3	53.420.000	432.972.150	379.852.150	8,11

Note: M0 = control, M1 = Chicken Manure 5 tons.ha^{-1}, M2 = Chicken Manure 10 tons.ha^{-1}, M3 = Chicken Manure 15 tons.ha^{-1}, S1 = 20 cm x 20 cm spacing, S2 = 25 cm x 25 cm spacing, and S3 = 30 cm x 30 cm spacing

Based on Table 2, observations of the feasibility analysis of your plant farming business at the dose of chicken manure without chicken manure, 5 tons ha^{-1}, 10 tons ha^{-1}, and 15 tons ha^{-1} and the application of plant spacing distances of 20 cm x 20 cm, 25 cm x 25 cm, and 30 cm x 30 cm show that the farming business is feasible to continue, because the R/C ratio of each treatment shows an R/C ratio> 1, meaning that the business is feasible to continue and is profitable. Among the treatments of planting distances of 30 cm x 30 cm, the highest R/C ratio is in the treatment of chicken manure dose of 5 tons ha^{-1} which is 10.77. Strategically, the use of organic fertilizers such as chicken manure also provides added value in terms of product branding. Today's consumers increasingly prioritize healthy and environmentally friendly agricultural products, so that organically cultivated products have a positive image in the eyes of the market (Kurniawan *et al.*, 2021; Insaniy *et al.*, 2024) [13, 9]. This makes organic products more competitive and have a higher selling value. The added value strategy based on the use of organic fertilizers has been proven to be significant in influencing consumer purchasing interest and increasing product competitiveness in the market (Insaniy *et al.*, 2024) [9]. In the context of marketing, the opportunity to apply a green marketing approach is very relevant, by highlighting aspects of sustainability, health, and food safety. The positive image of this organic brand has even been empirically proven to increase consumer purchase intention (Insaniy *et al.*, 2024) [9]. Therefore, this advantage can be utilized as the main selling point by emphasizing that the product is produced without chemical fertilizers, is healthier, and contributes to a sustainable agricultural system, through various communication media such as packaging labels, digital promotions, and direct education to consumers (Kurniawan *et al.*, 2021; Insaniy *et al.*, 2024) [13].

Conclusion

The results of the experiment showed that there was no interaction between the input of chicken manure and planting distance on the variables of observation of growth and yield of Chinese Kale. The input of chicken manure did not show a significant effect on all variables of growth and yield of Chinese Kale. Based on the growth and yield of the plant, the application of a planting distance of 30 cm x 30 cm showed the best results in CGR and total fresh weight of plants of 9.55 tons ha^{-1} and edible yield weight of 9.20 tons ha^{-1}. Overall, soil amendment through organic fertilizer input using chicken manure combined with the application of planting distance has not been able to support the quantity of Chinese Kale harvest compared to the variety potential and evidence of conventional cultivation. However, the quality produced in terms of life shelf life, sensory, and farming business analysis is able to show superiority and has more potential to be developed further.

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