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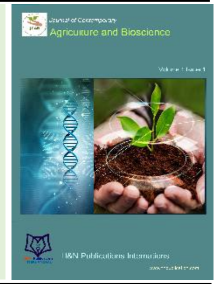

Research Article **Open Access**

The Effect of Rice Husk Compost Tea on the Nutrient Uptake, Plant Growth, and Yield of Kailan (*Brassica oleraceae* var. *Alboglabra*) in Lebak Swamp Soil

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A b s t r a c t

Kailan, (*Brassica oleraceae* var. *Alboglabra*) a widely consumed vegetable known for its health benefits, relies on several essential nutrients, including nitrogen (N), phosphorus (P), and potassium (K), for its growth. When growing kailan on nutrient-poor soil, such as lebak swamp soil, it is necessary to provide different inputs to supplement the lack of nutrients. The use of husks to make compost tea can increase soil fertility and reduce waste. Hence, this study aimed to examine the impact of varying doses of rice husk compost tea and NPK fertilizer on the enhancement of nutrient availability, growth, and yield of kailan plants in lebak swamp soil. Two-factor factorial randomized block design (FRBD) was used to organize in this study its dose of compost tea and NPK fertilizer. The results showed that rice husk compost tea and NPK fertilizer significantly interacted with several plant variables. Fertilizer application had a significant effect on soil C-organic and NPK content. The 60 mL plant^{-1} dose of husk compost tea combined with a 100% dose of NPK fertilizer effectively maximized the availability of nutrients and increased the growth, production, and uptake of N, P, and K by kailan plants. However, the treatment did not reduce the use of NPK fertilizer in the Lebak swamp land. Based on the results, soil NPK content had a positively strong correlation with plant uptake.

Keywords : Compost tea, lebak swamp soil, NPK fertilizer and rice husk.

Introduction

Agricultural waste is one of the main problems in the industry and environment due to the potential ability to disrupt the existing ecosystem when ignored. An agricultural waste derived from rice production waste is husk often found piled up in milling factories (Omar *et al.,* 2021). The amount produced from 1 hectare of rice fields generally ranges from 1 to 1.5 tonnes. Rice husk contain 50% cellulose, 25-30% lignin, and 15-20% silica (Muthuraj *et al.,* 2019). However, application to the soil without prior processing will have a negative impact on the environment due to the relatively long decomposition time (Asadi *et al., 2021;* Azat *et al.,* 2019). There has been a lot of work done toward finding environmentally friendly ways to use rice husk to support plant growth. One technique entails using oxygen or not to make compost tea from rice husk (El-Shaieny *et al.,* 2022; Mohamadou *et al.,* 2023). Rice husk must be treated in order to make compost tea due to numerous organic materials, such as cellulose, lignin, and fiber (Bisht *et al.,* 2020). These materials provide important nutrients that microorganisms can break down, making it easy for plants to absorb (Karam *et al.,* 2022) and improve organic matter, water availability, and soil pH (Demir & Gülser 2021).

The popular vegetable kailan (Brassica oleraceae var. alboglabra) is a prime example of a meal that the public is demanding as a nutritious option. Due to the high level of vitamins, minerals, fiber, protein, and calcium, all of which are good for the body, this green vegetable plant plays a crucial role in meeting nutritional needs (Chen *et al.,* 2020; He *et al.,* 2021). The nutritional content is relatively high, with 100 grams containing vitamin A 3500 IU, vitamin B1 0.11 mg, water 90 grams, fat 3.6 grams, niacin 1.6 mg, calcium 78.0 mg, iron 1.0 mg, magnesium 38.0 mg and phosphorus 74.0 mg (Gabriel & Shafri, 2022; *He et al.,* 2020). However, this horticultural plant is not widely cultivated by people in South Sumatra.

A crucial factor that significantly affects plant growth and production is the nature of cultivated land. Generally, lebak swamp is one of the many suboptimal lands found in South Sumatra with an area of 1.35 million ha, and can be used for plant cultivation (Wildayana & Armanto, 2018). The specific type that has greater potential to be used is a shallow lebak swamp (Wildayana et al., 2016). The plants cultivated are usually flood-resistant varieties such as rice, but shallow waters usually recede in dry conditions and can be used for cultivating vegetable crops (Marlina et al., 2014). Lebak swamp land has a low pH, moderate N content, as well as P, Na, Ca, and Mg at low to very low levels (Ali et al., 2014). According to Mulyawan et al. (2023), the characteristics of shallow swamps include a pH of around 5 with acidic criteria, very low total N content, high P_2O_5, as well as low organic C and K_2O content.

One way to increase the availability of soil nutrients, growth, and plant production is by applying fertilizer. In this context, compost tea is a fertilizer that can support plant growth and production (Curadelli *et al.,* 2023). Previous research has proven that compost tea contains NO_2, K_2O, humic acid, and microorganisms including aerobic, N_2-fixing, and actinobacteria associated with improving soil and plant quality (González-Hernández *et al.,* 2021). *Pant et al.* (2022) showed that giving various types of compost tea with a compost and water ratio of 1:10 (w:v) had a significant effect on the growth of pak choy because the extract contained relatively high levels of N and gibberellins. Compost tea can also act as a biostimulant, making plants more resistant to disease and increasing growth. In addition, González-Hernández *et al.* (2022) proved that compost tea enriched with Trichoderma suppressed Rhizoctonia solani disease and increased potato quality as well as production.

Efforts to increase plant growth and production by using organic fertilizer alone are not enough to meet nutritional needs. One type of fertilizer capable of providing nutrients quickly (fast release) and containing numerous components is NPK (Budiono *et al.,* 2019; Id *et al.,* 2022). It contains the nutrients nitrogen, phosphate, and potassium in greater quantities than organic fertilizer (Gusta & Same, 2022; Kang *et al.,* 2022). According to Fall *et al.* (2023), the combination of NPK and mycorrhizal fungi reduced NPK use by up to 50%. The treatment also increased soil N, P, alongside K and had a significant effect on growth and production in corn cultivation compared to the application of NPK fertilizer or mycorrhizal fungi only. The application of various doses of NPK combined with organic fertilizer had a significant effect on increasing the growth, yield, and quality of broccoli compared to controls (Walling *et al.,* 2022).

The application of compost tea and NPK fertilizer to soil and plants has been proven to improve soil quality, plant growth, and yield. Therefore, this study was undertaken to test the best dose of rice husk compost tea that can reduce the use of NPK fertilizer, and increase nutrient availability, growth, as well as production of kailan cultivation in lebak swamp soil.

Materials and Methods

Place and time

The lebak swamp soil samples used in this research were analyzed at the Soil Department Laboratory, Faculty of Agriculture, Sriwijaya University. Analysis of soil after planting and plant tissue was carried out at BPSIP Bengkulu. Kailan cultivation trials were conducted in the Greenhouse of the Faculty of Agriculture, Sriwijaya University from January to May 2024.

Research design

The experiment was structured using a factorial randomized block design (RAKF) with two factors. The first factor was the dose of rice husk compost tea consisting of 20 mL plant^{-1} (P1), 40 mL plant^{-1} (P2), 60 mL plant^{-1} (P3), 80 mL plant^{-1} (P4), and 100 mL plant^{-1} (P5). The second factor was the NPK fertilizer dose consisting of 0% (N0), 50% (N1), 75% (N2), and 100% (N3). The recommended dose of NPK fertilizer (NPK 16:16:16) for kailan plants was 450 kg ha-^{1}.

Procedures

Preparation of planting media

Preparation of planting media was carried out by taking shallow-type soil from the Lebak swamp. The soil taken was then air-dried in the greenhouse, sieved using a 2 mm sieve, and then given a basic liming treatment with dolomite at a dose of 8.5 tons ha^{-1} (BD = 0.88 g cm^{3}). Soil given basic treatment was then put into polybags measuring 30 x 30 cm, 4kg per polybag, and incubated for 2 weeks.

Preparation and sowing of seeds

Red arrow seeds of kailan nita cap were soaked in water for 1 hour to break the dormancy period, then sown in a tray containing a planting medium of soil and cocopeat in a ratio of 1:1 (v/v).

Planting/transplanting

Kailan seedlings 21 days old and have met the criteria, namely having 3-4 leaves, were transferred into polybags measuring 30 x 30 cm which already contain planting media in the form of Lebak swamp soil.

Preparatiom of rice husk compost tea

Composting of rice husk with a mixture of rice husk and cow dung manure in a ratio of 2:1. Composting is done aerobically for 3 months until the compost is mature. Extraction was carried out using a compost and water ratio of 1:5 (w/v) by wrapping 1 kg of compost in a filter cloth, then putting in a bucket and adding water. This compost tea was made aerobically using an aerator and soaked for 3 days (72 hours) in a bucket.

Application of rice husk compost tea

The application of rice husk compost tea was carried out in accordance with the experimental treatment. Application of rice husk compost tea started 7 days until 35 days after planting with an application interval of once a week. The process entailed watering the compost tea into the soil.

Application of NPK and urea fertilizer

NPK fertilization according to the treatment dose was carried out 10 days after planting. NPK fertilizer was applied by dissolving in water and applying around the plant roots. The recommended doses for kailan plants are 450 kg ha^{-1} (5.4 g plant^{-1}), 4.05 g plant^{-1} (75% recommended dose = 337.5 kg ha^{-1}), and 2.7 g plant $^{-1}$ (50%). recommended dose = 225 kg ha^{-1}). Urea fertilizer was applied twice as a basic treatment, reaching 3 g plant^{-1}. The application was carried out at 7 and 14 days after planting by sprinkling around the plants and then covering with soil.

Maintenance

Plant maintenance was carried out by watering every day and pest control was performed naturally, mechanically, and chemically. Weeds were controlled by pulling out and throwing away from the plant to avoid interference with growth. Furadan was applied when sowing seeds around trays to control ants, while pests found on plants were controlled with the chemical pesticide Curacron.

Harvesting

Harvesting was carried out by removing the entire plant down to the roots, which were then cleaned from the remaining soil. Kailan harvesting was carried out 42 days after transplanting with the criteria of having wide leaves with strong stems.

Data analysis

The variables observed were initial soil analysis in the form of determining the pH value, CEC (cmol kg^{-1}), Al-dd (cmol kg^{-1}), C-organic (%), total N content (%), P-available (mg kg^{-1}) and K-dd (cmol kg^{-1}). Soil analysis after planting included soil pH, organic C (%), total N content (%), available P (mg kg^{-1}), and K-dd (cmol kg^{-}

1). Plant variables observed included plant height (cm), number of leaves (pieces), leaf area (cm^2), greenness level, fresh weight of shoots and roots (g), dry weight of shoots and roots (g), root length (cm), root shoot ratio, as well as N, P, and K uptake (g $plant^{-1}$). The data obtained were analyzed using the method of variance (ANOVA) by comparing the calculated F value with the F table at a confidence level of 95%. When the calculated F value>F table at an F probability of 5%, then the treatment effect was considered significant. Further test procedures to determine differences between treatments used the Duncan multiple range test (DMRT) with a level of 5%. Correlation and regression tests were carried out to examine the relationship and influence between total soil N and plant tissue N, available and plant tissue P, as well as soil K-dd and plant tissue K.

Results and Discussions

Initial Soil Analysis

Initial analysis was carried out to determine the characteristics of the soil from the Lebak swamp which was used as a planting medium. The unprocessed soil type was used, and sampling was carried out compositely. Lebak swamp originated from suboptimal land flooded with water at certain periods and in this study, the soil was initially air-dried and sieved. Based on the analysis results, lebak swamp soil has a pH of 3.52 in the very acidic category, and an organic C content of 3.48% in the high category. Total N (0.32%) was classified as moderate and the available P content (13.17 mg kg^{-1}) was relatively high, while K-dd (0.12 cmol kg^{-1}) was relatively low. Furthermore, the cation exchange capacity was 20 cmol kg^{-1} with medium criteria and Al-dd soil was 0.63 cmol kg^{-1} in the low category. This condition was consistent with the research results of Marlina *et al.* (2014) and Mulyawan et al. (2023), stating that soil originating from lebak swamp was less fertile when used as a medium for growing plants. The swamps are waterlogged land and have low topography hence, agricultural production activities are very dependent on climate (Fahmid *et al.,* 2022).

Final Soil Analysis

Soil pH and C-organic values (%)

CT rice husk and NPK fertilizer each had a significant influence on the pH value. The highest soil pH was found at a CT husk dose of 100 mL $plant^{-1}$ and was significantly different from the values of other doses with a lower average. Rice husk CT had no significant influence on soil organic C, while NPK fertilizer had a significant effect. In NPK fertilizer, the highest pH and C-organic values were found at 0% dose and were significantly different from other treatments. The average values of soil pH and organic C due to the main influence of CT husk and NPK fertilizer treatments are presented in **Table 1**.

Based on the analysis results, the pH value was within the acid criteria and the C-organic content was very high, following the Balittanah criteria. However, compared to the initial analysis (**Table 1**), there was an increase in pH and organic C content after the CT husk was applied. The higher the dose of CT husk given, the higher the soil pH. Compost tea contains nutrients such as calcium, magnesium, and alkaline cations which can increase soil pH (Luo *et al.,* 2022). The release of basic cations into the soil solution reduces acidity. CT husk application also increased soil C-organic compared to before application. Furthermore, compost tea contains organic material capable of increasing soil organic C over time (Islam *et al.,* 2019; Pilla *et al.,* 2023).

An opposite condition was observed with NPK fertilizer, the higher the dose given, the lower the pH value and organic C content. The application of urea base fertilizer is also one of the factors that influences the decrease in soil pH and organic C. Due to the acidic reaction, administering doses of urea fertilizer can reduce soil pH because the nitrification process converts ammonium into nitrate, which releases H^+ ions (Qiao *et al.,* 2021). Fertilizing with NPK fertilizer also reduces soil pH due to the sulfur and ammonium component which will hydrolyze to produce H^+ ions (Fauzan *et al.,* 2024; Iqbal *et al.,* 2020).

Table 1. Average soil pH and C-organic values after planting due to the main influence of CT husk and NPK fertilizer treatment

Husk CT dose (P)	Soil pH value	C-organic (%)
CT husk 20 mL $plant^{-1}$	4.58 a	5.772
CT husk 40 mL $plant^{-1}$	4.66 b	5.772
CT husk 60 mL $plant^{-1}$	4.79 c	5.781
CT husk 80 mL $plant^{-1}$	4.81 d	5.778
CT husk 100 mL $plant^{-1}$	4.84 e	5.772

NPK fertilizer dose (N)	Soil pH value	C-organic (%)
Dose 0% NPK	4.78 d	6.08 d
Dose 50% NPK	4.75 c	5.84 c
Dose 75% NPK	4.72 b	5.68 b
Dose 100% NPK	4.69 a	5.49 a

Description: Numbers followed by different letters in the same column indicate significant differences in the 5% DMRT test.

Cultivated plants also play a role in lowering soil pH, for example, Jethva *et al.* (2022) stated that plant metabolism can cause a decrease in soil pH through root respiration. During plant growth, root respiration continues to occur and produces carbon dioxide (CO_2) which is released into the soil. The concentration of CO_2 produced from root respiration is even higher than in the atmosphere, causing an increase in the groundwater level and low soil pH.

Soil N-Total (%), P-available (mg kg^{-1}), and K-dd (cmol kg^{-1}) content

Based on the results, CT of rice husk had no significant effect on total N content, available P, and soil Kdd, while NPK fertilizer had a significant effect. The highest total N content, available P, and soil K-dd were found at 100% NPK fertilizer dose and were significantly different from other treatments as presented in Table 2. According to the criteria for soil analysis results from Balittanah (2023), in the CT husk treatment, the total N content of the soil ranged between 0.088-0.090% with very low criteria, the available P content ranged between 3.314-3.325 mg kg^{-1} with very low criteria, and soil K-dd ranged from 1,526-1,538 cmol kg^{-1} with very high criteria. Compared to the initial soil analysis, total N and available P decreased, while the K-dd content increased. Providing NPK fertilizer can increase the availability of nutrients in the soil which can be immediately absorbed by plants.

The low content of N and P nutrients may be due to various factors, one of which is because the plant has absorbed the nutrients in the soil. Macronutrients including N, P, and K as well as micronutrients needed by plants can be absorbed and used for growth and development (Toor *et al.,* 2021). Low nutrient content can also be caused by the leaching or dissolving of water, which makes nutrients unavailable to plants. Furthermore, immobilization of nutrients might occur, namely the process of changing nutrients in the soil into forms that are not absorbed by plants. Acidic soil pH also makes elements nutrients to be unavailable optimally (Gondal *et al.,* 2021; Hossain *et al.,* 2020; Khan *et al.,* 2023). This is in accordance with research results where the pH of the soil falls within the acid category, thereby inhibiting the availability of nutrients in Lebak swamp soil used as a planting medium. Compost tea can increase the number and activity of soil microbes, help mineralize soil organic matter, dissolve absorbed nutrients, and chelate ions (Nur *et al.,* 2023). Furthermore, it utilizes nutrients that cannot be separated from the immobilization process by organic acids and others requiring quite a long time to become available to plants.

Table 2. Average N-total, P-available, and K-dd content of soil due to the main influence of CT husk and NPK fertilizer treatment

Husk CT dose (P)	N-total (%)	P-available (mg kg^{-1})	K-dd (cmol kg^{-1})
CT husk 20 mL plant^{-1}	0.088	4.314	1.526
CT husk 40 mL plant^{-1}	0.088	4.321	1.531
CT husk 60 mL plant^{-1}	0.089	4.322	1.534
CT husk 80 mL plant^{-1}	0.090	4.325	1.538
CT husk 100mL plant^{-1}	0.090	4.323	1.535
NPK fertilizer dose (N)	**N-total (%)**	**P-available (mg kg^{-1})**	**K-dd (cmol kg^{-1})**
Dose 0% NPK	0.051 a	4.124 a	1.371 a
Dose 50% NPK	0.061 b	4.239 b	1.440 b
Dose 75% NPK	0.091 c	4.365 c	1.579 c
Dose 100% NPK	0.152 d	4.557 d	1.741 d

Description: Numbers followed by different letters in the same column indicate significant differences in the 5% DMRT test.

Based on the analysis results, the total N, available P, and K-dd content of the soil were significantly influenced by NPK fertilizer. Treatment using 100% dose led to a higher total N, available P, and K-dd content, with significantly different results from other doses. The higher the dose, the greater the NPK content of the soil. Conversely, the lower the dose, the lesser the NPK content of the soil. Adekiya *et al.* (2020) showed that NPK fertilizer did not increase soil organic matter, pH, Ca, and Mg content, but increased soil N, P, and K nutrient content compared to controls without fertilization. Applying compost fertilizer alongside NPK is useful for improving soil biochemical properties, with N, P, and K nutrients being more available in Inceptisol soil (Patra *et al.,* 2021).

Plant Growth and Production

Plant height (cm), leaf greenness, and root crown ratio

Both CT husk and NPK fertilizers significantly affected plant height at harvest, leaf greenness, and the root-to-shoot ratio. The tallest plants and greenest leaves were seen in the CT husk 60 mL plant^{-1} treatment, and these results were notably different from other treatments. The highest root-to-shoot ratio was found in the treatment carried out using CT husk 20 mL plant^{-1}. The 100% NPK fertilizer dose treatment also resulted in the tallest plants and greenest leaves, significantly different from other treatments. The root-to-crown ratio was higher in the 0% NPK dose treatment and was significantly different from others. The average plant height at harvest, leaf greenness, and kailan root-to-crown ratio due to the main effects of CT husk and NPK fertilizer treatments are shown in Table 3.

The higher the dose of NPK fertilizer given, the taller the kailan plants and the greener the leaves. Fadila et al. (2021) showed that the application of NPK fertilizer 6 gram plant^{-1} (100% dose) and 4.5 gram plant^{-1} (75% dose) increased the growth and yield of kailan plants, especially in terms of height, number of leaves, and fresh weight. The NPK fertilizer content at a dose of 100% was identified as the optimum dose to increase plant growth, through height and green leaves (Kurnianta *et al.,* 2021). Plant height and the leaves' level of greenness can influence growth and yield because chlorophyll plays a role in the photosynthesis process, the main mechanism by which plants produce food and energy *(Simkin et al.,* 2022). The application of CT at a dose lower than 40 mL plant^{-1} and more than 60 mL plant^{-1} reduced the greenness of kailan leaves. This is because plants have a threshold for utilizing or absorbing nutrients at certain doses or concentrations. Plants require nutrients in large sufficient quantities to support photosynthesis.

Table 3. Average plant height at harvest, level of leaf greenness, and root crown ratio of kailan due to the main influence of CT husk and NPK fertilizer treatment

Husk CT dose (P)	Plant Height (cm)	Leaf Greenness Level	Root Heading Ratio
CT husk 20 mL plant^{-1}	7.85	45.27 a	2.89
CT husk 40 mL plant^{-1}	8.15	50.40 c	2.47
CT husk 60 mL plant^{-1}	8.55	50.44 c	2.11
CT husk 80 mL plant^{-1}	8.45	46.90 b	2.42
CT husk 100 mL plant^{-1}	8.35	46.50 b	1.98
NPK fertilizer dose (N)	**Plant Height (cm)**	**Leaf Greenness Level**	**Root Heading Ratio**
Dose 0% NPK	6.56 a	37.35 a	3.56 c
Dose 50% NPK	7.70 b	43.61 b	2.48 b
Dose 75% NPK	9.02 c	53.39 c	1.76 a
Dose 100% NPK	9.80 d	57.27 d	1.69 a

Description: Numbers followed by different letters in the same column indicate significant differences in the 5% DMRT test.

The root crown ratio is the quotient between the dry weight of the shoot and the dry weight of the plant roots. This ratio is used to measure the balance between root and plant crown growth (Plapito *et al.,* 2021). Based on the results, husk CT treatment did not have a significant effect on the root-crown ratio, while NPK dose had a significant effect. Both CT husk and NPK fertilizers at higher doses produced lower root crown ratios. This was caused by the large length and weight or number of plant roots (Hutomo *et al.,* 2024). The root crown ratio is related to the number of leaves and root length of the plant, where the higher the number of leaves and root length, the smaller the root crown ratio value (Santosa & Priyono, 2023).

Number of Leaves (Strands) and Leaf Area (cm^2)

The combination of CT husk and NPK fertilizer significantly impacted the number and area of leaves. According to the 5% DMRT test, the combination of 60 mL plant^{-1} CT husk and 100% NPK fertilizer resulted in a higher number and area of leaves, significantly different from other combinations. Table 4 shows the average number of leaves and leaf area of kailan plants at harvest for each treatment combination.

The highest number of leaves and leaf area were observed with the combination of 60 mL plant^{-1} CT husk and 100% NPK fertilizer. Using CT husk without NPK fertilizer did not increase the leaf area, highlighting the importance of NPK fertilizer for plant nutrition. Combining 60 mL plant^{-1} CT husk and 100% NPK fertilizer was found to be the optimal dose for enhancing plant growth. Adding more CT husk beyond this amount reduced the leaf area of kailan plants.

Nutrients and microbes found in compost tea can promote plant growth, especially the size of leaves. Compost tea application raised the leaf area index of pak choy plants in earlier studies, particularly when inorganic fertilizer was added (Raharjo et al., 2023). This is because CT husk contributes to the NPK fertilizer's ability to provide plants with nutrients more effectively.

Table 4. Average number and area of kailan leaves at harvest in each treatment combination

Number of Leaves (pieces)				
Treatment	0% NPK	50% NPK	75% NPK	100% NPK
CT husk 20 mL plant^{-1}	3.60 a	4.60 e	4.80 f	4.80 f
CT husk 40 mL plant^{-1}	3.80 b	5.20 h	5.80 i	4.40 d
CT husk 60 mL plant^{-1}	4.20 c	4.80 f	4.80 f	6.40 l
CT husk 80 mL plant^{-1}	4.40 d	5.00 g	4.60 e	6.00 j
CT husk 100 mL plant^{-1}	3.80 b	5.00 g	5.00 g	6.20 k
Leaf area (cm^2)				
Treatment	0% NPK	50% NPK	75% NPK	100% NPK
CT husk 20 mL plant^{-1}	13.81 a	28.51 f	30.28 g	37.34 l
CT husk 40 mL plant^{-1}	13.93 b	30.45 h	49.28 n	56.90 r
CT husk 60 mL plant^{-1}	20.85 e	34.63 k	50.75 o	62.38 s
CT husk 80 mL plant^{-1}	18.55 d	32.93 i	39.87 m	51.11 p
CT husk 100 mL plant^{-1}	15.75 c	33.57 j	39.78 m	52.18 q

Description: Numbers followed by different letters indicate significant differences in the 5% DMRT test.

Plants receive complete nutritional support from the combination of these two substances, which influences the quantity and size of leaves. Because nitrogen (N), phosphorus (P), and potassium (K) are macronutrients essential for plant growth, including leaf development, NPK fertilizer has the ability to increase plant leaf area. Applying 2.5 tons of NPK fertilizer and vermicompost ha^{-1} to Brassica oleracea var. Italica increased the number of leaves, leaf area, and productivity to 204.76 quintals ha^{-1} (Singh *et al.,* 2021).

Wet Weight of Head and Roots (g)

CT husk and NPK fertilizer significantly interacted with the wet weight of kailan shoots and roots. The 5% DMRT follow-up test results showed that CT husk dose of 60 mL plant^{-1} with 100% NPK fertilizer produced the highest wet weight of shoots and roots.

The values obtained were significantly different from those of other lower treatment combinations. The average wet weight of the crown and roots of kailan plants at harvest from each treatment combination is presented in Table 5. The plant canopy is important because it is a place where photosynthesis occurs, producing food and nutrition (De Souza *et al.,* 2023). Plant roots are the main route to obtain water, nutrients, and minerals from the soil. Roots also play a role in supporting plant structures and preventing soil erosion (Lynch *et al.,* 2021). The wet weight of crowns and roots is influenced by plant growth, and the highest wet weight values of shoots and roots were found in the combination of a CT husk dose of 60 mL plant^{-1} and 100% NPK fertilizer.

The combination of compost tea with NPK fertilizer significantly increased the production of kailan plants compared to only CT husk. This is because plants derive better nutrition and optimal growth support through administering NPK fertilizer at adequate doses. Plants that grow with sufficient nutrition tend to have better quality, such as greener leaves and larger sizes (Ortiz & Sansinenea, 2022). Zahiri (2023) reported that administering liquid organic fertilizer from rabbit urine at a dose of 30 L ha-1 combined with 250 kg ha^{-1} NPK fertilizer increased the wet weight of shoots and roots of pak choy plants compared to the control treatment.

Plant N, P, and K Nutrient Uptake

The combination of 60 mL plant^{-1} CT husk dose and 100% NPK fertilizer resulted in larger and significantly different nutrient uptake of N, P, and K than the other treatment combinations, according to the results of the 5% DMRT follow-up test. Table 6 shows how much N, P, and K were typically absorbed by kailan plants for each combination of treatments.

Table 5. Average wet weight of kailan shoots and roots at harvest in each treatment combination

Header wet weight (g)				
Treatment	0% NPK	50% NPK	75% NPK	100% NPK
CT husk 20 mL plant^{-1}	2.20 a	6.36 e	8.60 f	10.14 h
CT husk 40 mL plant^{-1}	2.52 b	6.44 e	14.62 k	15.30 m
CT husk 60 mL plant^{-1}	2.96 d	9.20 g	15.04 l	23.20 q
CT husk 80 mL plant^{-1}	2.84 c	10.46 i	15.50 n	20.00 p
CT husk 100 mL plant^{-1}	2.84 c	9.22 g	13.46 j	19.76 o
Root wet weight (g)				
Treatment	0% NPK	50% NPK	75% NPK	100% NPK
CT husk 20 mL plant^{-1}	0.30 a	0.70 f	1.48 j	1.50 k
CT husk 40 mL plant^{-1}	0.40 d	1.64 l	2.24 o	2.32 q
CT husk 60 mL plant^{-1}	0.42 e	1.48 j	2.22 n	2.76 s
CT husk 80 mL plant^{-1}	0.38 c	1.18 g	1.72 m	2.60 r
CT husk 100 mL plant^{-1}	0.34 b	1.24 h	1.30 i	2.28 p

Description: Numbers followed by different letters indicate significant differences in the 5% DMRT test.

The nutrient uptake of N, P, and K of kailan plants is in line with the growth and yield, where the highest values were found in the combination treatment of CT husk at a dose of 60 mL plant^{-1} and 100% NPK fertilizer. Based on the results, increasing the dose of CT husk to more than 60 mL plant^{-1} combined with 100% NPK fertilizer caused a decrease in NPK nutrient uptake. Kailan is a vegetable that significantly requires the nutrient N in the growth process. The ability of plants to absorb nitrogen from sources such as soil is called N nutrient uptake. The application of CT husk dose at 60 mL plant^{-1} combined with a 100% NPK fertilizer dose effectively maximized N nutrient uptake. NPK fertilizer supplies 15% N nutrient content hence, the absorption process can be assisted by microorganisms found in CT husk. Funr *et al*. (2020) stated that the application of compost tea has many benefits for soil and plants, namely increasing the availability of soil nutrients, helping to enhance fertility, and also assisting nutrient absorption. Nitrogen is an essential macronutrient responsible for the formation of protein, chlorophyll, amino acids, and many other important compounds (Putra *et al.,* 2020).

The application of compost tea can affect the uptake of P nutrients in plants due to the component microorganisms and organic compounds that influence the availability of nutrients in the soil. Plants need phosphorus for several activities, including energy metabolism, as well as the formation of nucleic acids (RNA and DNA), cell membranes, and ATP (adenosine triphosphate) (Khan et al., 2023). Compost tea can influence P nutrient uptake directly through organic compounds containing phosphate which can be absorbed by plants. Using a combination of organic and inorganic fertilizers increases plant production and quality because the nutrients obtained from inorganic fertilizers such as the addition of NPK can be utilized by microorganisms for energy (Ilahi *et al.,* 2021).

Potassium is an essential macronutrient responsible for a variety of functions, including regulating cell osmotic pressure, maintaining water balance, photosynthesis, carbohydrate metabolism, and fruit formation. The combination of NPK fertilizer and compost tea provided additional nutrients for plants, including nutrient K. This can increase the availability of potassium in the soil and the uptake of nutrients by plants. The microbes in compost tea can help plants absorb and utilize the nutrients in fertilizer more effectively (Huang *et al.,* 2022).

Table 6. Average nutrient uptake of N, P, and K (g plant^{-1}) of kailan in each treatment combination.

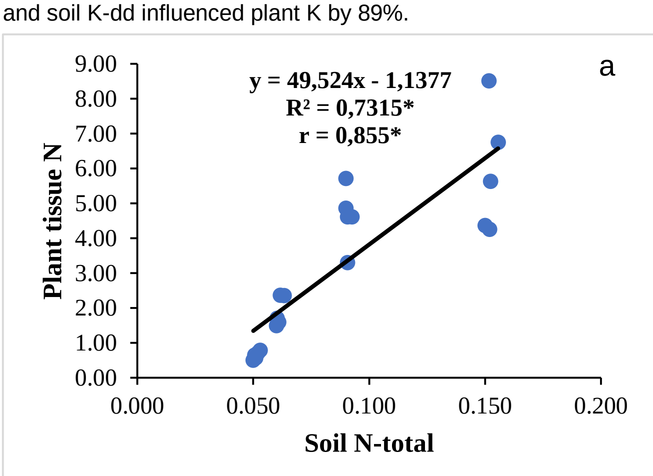
N nutrient uptake (g plant^{-1})				
Treatment	0% NPK	50% NPK	75% NPK	100% NPK
CT husk 20 mL plant^{-1}	0.50 a	1.59 g	3.30 j	4.26 k
CT husk 40 mL plant^{-1}	0.72 d	1.70 h	5.71 p	4.37 l
CT husk 60 mL plant^{-1}	0,78 e	1.49 f	4.61 m	8.51 r
CT husk 80 mL plant^{-1}	0.65 c	2.36 i	4.86 n	6.75 q
CT husk 100 mL plant^{-1}	0.57 b	2.35 i	4.62 m	5.63 o

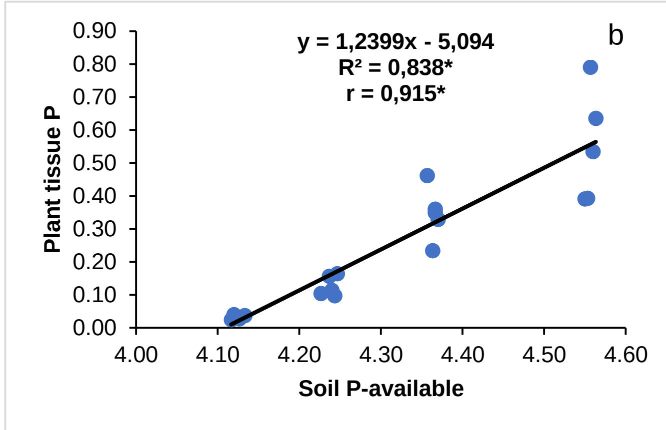
P nutrient uptake (g plant^{-1})				
Treatment	0% NPK	50% NPK	75% NPK	100% NPK
CT husk 20 mL plant^{-1}	0.02 a	0.10 d	0.23 g	0.39 k
CT husk 40 mL plant^{-1}	0.04 c	0.11 e	0.46 l	0.39 l
CT husk 60 mL plant^{-1}	0.04 c	0.10 d	0.35 i	0.79 o
CT husk 80 mL plant^{-1}	0.03 b	0.16 f	0.36 j	0.63 n
CT husk 100 mL plant^{-1}	0.03 b	0.16 f	0.33 h	0.53 m

K nutrient uptake (g plant^{-1})				
Treatment	0% NPK	50% NPK	75% NPK	100% NPK
CT husk 20 mL plant^{-1}	0.44 a	1.23 g	2.27 j	2.71 k
CT husk 40 mL plant^{-1}	0.66 d	1.29 h	3.87 o	2.68 k
CT husk 60 mL plant^{-1}	0.70 e	1.12 f	3.05 l	5.21 q
CT husk 80 mL plant^{-1}	0.58 c	1.75 i	3.20 m	4.20 p
CT husk 100 mL plant^{-1}	0.50 b	1.73 i	3.08 l	3.59 n

Description: Numbers followed by different letters indicate significant differences in the 5% DMRT test.

Relationship between Soil NPK and Plant Tissue NPK
Correlation and regression analysis were carried out to determine whether there was a relationship between soil and plant tissue NPK. Graphs of the relationship between total soil N and plant tissue N, available soil P and plant tissue P, as well as soil K-dd and plant tissue K, are presented in Figure 1. Based on the coefficient of determination (R^2), soil N-total influenced plant N levels by 73.2%, available P influenced plant P content by 83.8%, and soil K-dd influenced plant K by 89%.





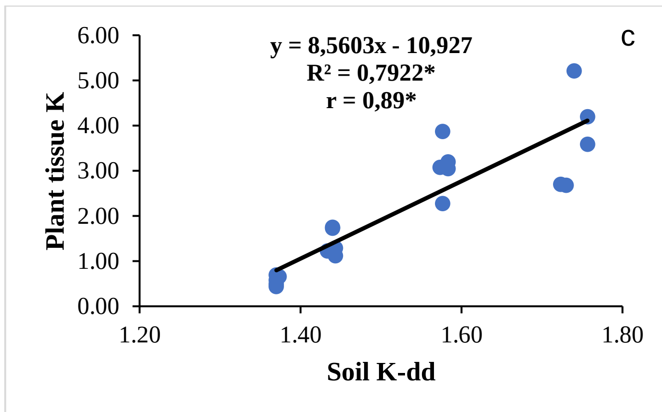


Figure 1. The relationship between total soil N and plant tissue N (a), soil available P and plant tissue P (b), and soil K-dd and plant tissue K (c)

The higher nitrogen content in the soil leads to increased nitrogen uptake by plants. Soil nitrogen and plant tissue nitrogen were strongly positively correlated (r = 0.855). This relationship means that as soil nitrogen increases, plants absorb more nitrogen. In general, nitrogen is crucial for the growth and yield of kailan plants. Soil availability varies due to factors including topography, climate, erosion, leaching, and crop harvesting (Whetton *et al.,* 2022). Nitrogen contributes to plant growth, particularly in leaf development, playing a crucial role in plant greenness through chlorophyll, essential for photosynthesis. Additionally, it promotes plant height, tiller number, and influences leaf size (Anas *et al.,* 2020).

Based on the correlation analysis results, soil phosphorus availability affects plant uptake, as indicated by a strong positive correlation (r = 0.915). This suggests that higher soil phosphorus availability leads to increased phosphorus uptake by plants. Phosphorus is essential for the growth and yield of kailan plants. It serves as a fundamental energy source in biochemical processes within cells and is crucial for the synthesis of compounds including ATP and nucleoproteins, as well as for genetic information systems (Walton *et al.,* 2023). Additionally, phosphorus promotes root growth, especially lateral and hair roots in kailan plants, facilitating nutrient absorption necessary for growth and productivity (Sustr *et al.,* 2019).

The correlation data demonstrated a substantial positive connection (r = 0.890) between soil potassium availability and potassium uptake by kailan plants. This suggests that plants absorb more potassium when the amounts in the soil are higher. Potassium stimulates plant growth points and activates enzymes essential for the synthesis of proteins and carbohydrates (Rawat et *al.,* 2022). Additionally, it facilitates a number of physiological functions, including transpiration, photosynthesis, and general plant growth and development (Imtiaz *et al.,* 2023). Plants that have higher soil potassium availability are more drought-tolerant and resistant to pests and diseases (Rea *et al.,* 2022). During vegetative growth phase, kalan plants mostly use potassium as K+ ions (Sardans & Peñuelas, 2021).

Conclusions

In conclusion, husk compost tea and NPK fertilizer significantly interacted with the number of leaves, leaf area (cm^2), wet weight of shoots and roots (g), as well as plant N, P, and K uptake. The main factor of NPK fertilizer had a significant effect on the C-organic content and soil N, P, and K nutrients. A 60 mL $plant^{-1}$ husk compost tea dose combined with a 100% dose of NPK fertilizer effectively maximized the availability of nutrients and was able to increase the growth, production, as well as uptake of N, P, and K nutrients. However, the treatment was not able to reduce the use of NPK fertilizer in swampy land. Soil NPK content was positively correlated and had a close relationship with the nutrient uptake by kailan plants.

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