Growth and Yield of Mint (*Mentha spicata* L.) as Affected by Composition of Charcoal Husk and Organic Fertilizer

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ABSTRACT

The high industrial demand for mint products, coupled with low domestic production, has led to a 63% import dependency. Enhancing mint production requires optimizing planting media and fertilization strategies. This study aimed to evaluate the effects of different soil-to-husk charcoal ratios and manure types on the growth and yield of mint (*Mentha spicata* L.). A factorial experiment was conducted from February to April 2022 at the Faculty of Agriculture, UNS, using a randomized complete block design (RCBD) with two factors: The first factor was soil-to-husk charcoal ratios consisting of 1 to 3, 1 to 1, and 3 to 1. The second factor was the manure type, which consisted of cow, goat, and chicken manure. Each treatment was replicated four times. The results showed that the P1 combined with the cow manure significantly increased the number of branches compared to P1 with goat manure. P1 also resulted in the highest number of leaves, leaf area, fresh weight, and dry weight. Cow manure yielded the highest values for leaf number, leaf area, and dry weight among manure treatments. These findings suggest that optimizing planting media composition and manure selection can enhance mint productivity, reducing reliance on imports.

Keywords: Biochar; Herbs; Husk; Manure; Mint

INTRODUCTION

Mint (*Mentha spicata* L.) is a widely cultivated aromatic herb valued for its essential oils, medicinal properties, and applications in the food, pharmaceutical, and cosmetic industries. The genus *Mentha* is known for its high content of bioactive compounds, including menthol, carvone, and flavonoids, which contribute to its antimicrobial, antioxidant, and therapeutic properties (Hutsol et al., 2023) However, mint's chemical composition and nutritional value vary significantly depending on genetic, environmental, and agronomic factors (Lakušić et al., 2012).

The 17 global Sustainable Development Goals directly or indirectly influence soil and factors such as plant productivity, environmental sustainability, and human health (El-Ramady et al., 2022). One of the main goals of sustainable agriculture nowadays is to reduce the usage of chemical fertilizers to maintain sustainable crop productivity (Moradzadeh et al., 2021). Quality and production metrics are positively impacted by using organic and biofertilizers in cultivating crops of high economic value (El-Beltagi et al., 2023). Horticultural crops grown organically are of higher quality and yield a safe product that humans may use (Nada et al., 2022). Mint is a type of medicinal plant, which is a horticultural plant, so it is necessary to use planting media and apply organic fertilizer to support

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growth and yield.

Despite its economic importance, domestic mint production in Indonesia remains insufficient to meet the demand for industrial needs. The country relies heavily on imports, with an average annual import volume of 76.10 tons, accounting for 63% of total industrial demand, and the import value reached 529.5 billion rupiah (Hasanah et al. 2019; BPS, 2016). The high dependency highlights the need for improved practices to enhance local production. Increasing mint productivity can be achieved through agronomic optimization, particularly by improving planting media composition and fertilization strategies, which play a critical role in plant growth and biomass accumulation (Song et al., 2019).

The selection of an optimal planting medium is crucial, as it influences root development, nutrient availability, water retention, and aeration. Previous studies suggest that well-balanced planting media should have high porosity, adequate moisture retention, and sufficient nutrient-holding capacity to support early root establishment, especially in vegetatively propagated plants such as mint (Dharaben Champaklal & Mansungbhai Chaudhari, 2023). Husk charcoal is widely recognized as a soil amendment that improves aeration and drainage while enhancing microbial activity and nutrient availability (Sodiq et al., 2019). Organic fertilizers, particularly animal manure, are essential for sustaining soil fertility and providing a slow-release nutrient source. Goat manure and husk charcoal have been reported to improve soil structure and enhance the supply of N, K, P, Mg, and Ca, which are critical for plant growth and development (Rayne & Aula, 2020). Moreover, organic fertilization is recommended for medicinal plants because it enhances secondary metabolite production, which is crucial for the pharmaceutical and essential oil industries (Kementrian Pertanian, 2013). The recommended application of organic manure for mint cultivation is 30 tons per hectare, yet the most effective combination of manure type and planting media composition remains unclear.

Despite the growing interest in optimizing mint cultivation, studies on the ideal combination of planting media and organic fertilizer to maximize growth and yield remain limited. While previous research has demonstrated the benefits of husk charcoal and manure application, their interaction in different proportions requires further investigation. Therefore, this study aimed to evaluate the effects of different soil-to-husk charcoal ratios and manure types on the growth and yields of *Mentha spicata* L. The findings are expected to contribute to sustained mind cultivation strategies, reducing import dependency while improving productivity and soil health.

MATERIALS AND METHODS

The research was conducted in the greenhouse, Ecology and Crop Production Management, and Soil Chemistry Laboratory of the Faculty of Agriculture, Universitas Sebelas Maret, from February to April 2022. The experiment was arranged in a randomized complete block design. The first factor was the ratio weight of soil and husk charcoal, namely 1:3, 1:1, and 3:1. The second factor was the type of manure, namely cow, goat, and chicken, with a dose of 30 t ha or 577 g per polybag (Kementrian Pertanian, 2013). Polybags were prepared by mixing soil, husk charcoal, and manure according to the treatment. There were 12 polybags for each treatment. The organic fertilizer used was mature fertilizer, which is one of the most important organic fertilizer sources. Soil fertility increases since manure provides nutrients such as nitrogen that soil microbes can take. Manure increases the water-holding capacity or soil structure (Ullah, 2023).

Plant management was carried out in accordance with the procedures for cultivating mint plants, including modifying the surrounding environment, watering, removing weeds, replanting, and controlling pests and diseases. Every afternoon, the plants were watered. Weeding was done to prevent weeds from competing for nutrients so that mint plants can absorb as many nutrients as possible. Disease-affected plant components were removed, and pests were eradicated manually.

The parameters observed included mint growth and yield. The growth parameters include plant height, number of leaves, branches, and leaf area. Plant height observations were carried out once a week. The observation of the number of leaves was done manually by counting the leaves. The calculation of leaf area was carried out using the paper gravimetric method using Formula (1). (Sitompul, 2005).

$$Leaf\ area = \frac{weight\ of\ sampels}{weight\ of\ paper} \times paper\ area \quad (1)$$

The observation of the number of branch shoots was done by manually counting the branch shoots. Meanwhile, the variables of yield parameter include fresh weight and dry weight. The fresh weight of the plant was weighed after harvest by separating all parts of the plant from the roots. Weighing was carried out using digital scales. The dry weight of the plant was calculated after the plant parts separated from the roots were heated in the oven for 1 x 24 hours at a temperature of 60 degrees Celsius and then weighed until reaching constant weight.

The observation data were analyzed using the ANOVA test and SPSS software. The test was continued with Duncan's test with a 5% to determine a significant difference between treatments.

RESULTS AND DISCUSSION

Environment Conditions

Mint was planted in polybags in a greenhouse located at coordinates 7°33'38.54" South Latitude, 110°51'32.18" East Longitude, and an altitude of 106.2 meters above sea level. The air temperature at the research location ranges from 27° to 34°C, the average humidity is 78%, and the light intensity is 2146.3 lux. Higher air temperatures and lower relative humidity are ideal growing conditions for M. arvensis. Because the plants develop better in terms of plant height and leaf area index, which leads to a higher fresh yield, M. arvensis can produce valuable essential oil under these conditions. Syahirah et al. (2019) state that Indonesia's microclimate is suitable for mint plant growth. During the growth stages of plants, changes occur in the atmosphere. Environmental conditions need to be considered to support mint growth. Ideal temperature, humidity, and light intensity factors can increase the quantity and quality of mint. This indicates that the light intensity in the research environment is less than optimal for mint growth. Sunlight primarily affects photosynthetic and photostimulus processes, including pigment creation, chlorophyll synthesis, leaf growth, blooming, and plant bud development.

Table 1. Soil chemical properties before providing treatment with a composition of husk charcoal and organic fertilizer before experiment

Properties	result	unit	VALUE
pH soil (actual method)	6.67	-	Neutral
Total N (Kjeldhal)	0.12	%	Low
Available P (Bray 1)	4.14	mg kg^{-1}	Very low
Total K (Fotometer)	0.37	cmol(+)kg^{-1}	Very low
Total organic C (Walkey & Black)	3.99	%	High
Ratio C/N	33.25	-	Very high

Sources: Results of analysis from the Chemistry and Soil Conservation Laboratory of Faculty of Agriculture UNS (2022) * values were adjusted to Balittan in 2009.

The type of soil used is alfisol soil originating from Karangpandan, Karanganyar Regency. Alfisol soil itself is formed from the weathering of limestone and sedimentary rocks. Alfisol soil has a higher pH than that made from parent material or sandstone. The results of the soil chemical analysis conducted in the laboratory (Table 1) showed that the soil pH was neutral, but the available P and total K content was very low. The total N content and organic C were low, resulting in a very high C/N ratio.

Plant Height

Various compositions of soil, husk charcoal, and various types of manure, as well as the interaction of both, did not affect the height of the mint plants. Based on Figure 1, mint plants treated with the composition of soil and husk charcoal with a ratio of 1:3 and chicken manure showed an average plant height of 56.58 cm. Meanwhile, those treated with a ratio of 1:3 and goat manure had a low average plant height of 40.1 cm. According to Tambunan et al. (2022), increasing the length of mint plants is called sympodial growth. Primary branches will form secondary branches, then tertiary branches continuously. This causes the main stem of the mint plant not to reach its maximum height because the branches grow even faster than the main stem.

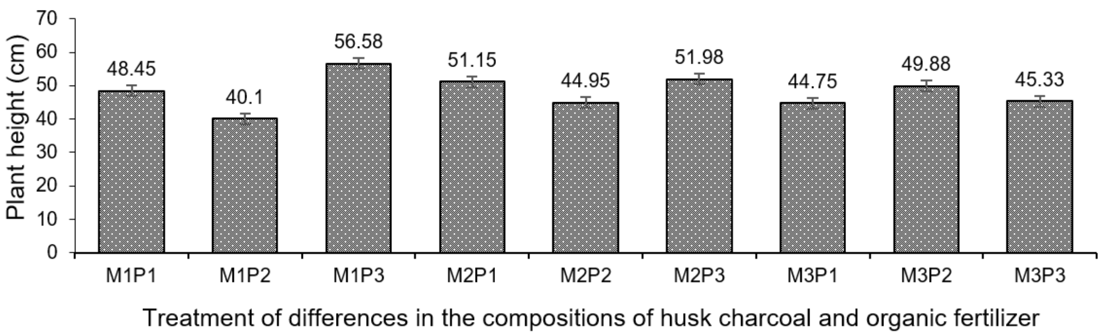

Figure 1. Effects of the composition of husk charcoal and the application of various types of manure on the height of mint plants. M1= soil: husk charcoal (1:3), M2 = soil: husk charcoal (1:1), M3: soil: husk charcoal (3:1), P1 = cow manure, P2= goat manure; P3 = chicken manure

Number of Branches

Applying different kinds of manure and husk charcoal to the soil had an impact on the quantity of mint plant branches. Table 2 shows the number of mint branches with the highest value, which is

Table 2. Average number of branches as affected by differences composition of husk charcoal and organic fertilizer by treatments

Treatment of composition soil and husk charcoal + type of manure	Number of branches (branch)	
(1:3) + cow	47.00±7.37	A
(1:3) + goat	31.50±3.59	C
(1:3) + chicken	42.25±4.00	A
(1:1) + cow	40.25±2.59	Ab
(1:1) + goat	33.75±2.00	bc
(1:1) + chicken	33.00±2.53	bc
(3:1) + cow	32.50±2.89	c
(3:1) + goat	34.00±1.83	bc
(3:1) + chicken	35.00±1.12	bc
Sig.	0.01	
CV%	14.55%	

Remarks: Values followed by the same letters indicate no significant difference based on Duncan's Multiple Range test (DMRT) at 5%.

47, produced by a 1:3 soil and husk charcoal composition with cow manure. The lowest number of branches, 31.5, was produced by a 1:3 soil and husk charcoal composition with goat manure.

The number of mint branches is one of the supporting factors that can influence the number of leaves. The number of branches in a plant will also affect the weight of the plant. According to Harahap et al. (2020), husk charcoal has an organic C content of 18.45% and a total soil N content of 1.07%, with a C: N ratio of 1 of 7.24. Furthermore, a good planting medium allows the roots to absorb water and nutrients optimally, thus influencing the formation of branches. When compared to a treatment without charcoal, applying biochar raises the amount of available soil nutrients, particularly available P and K (Zhang et al. 2024).

The availability of nitrogen in the growing medium affects the number of branches. Rosawanti (2019) states that the nitrogen content of organic fertilizer functions as a constituent of chlorophyll so that it can capture solar energy for photosynthesis. Besides, the amino acid (protein) content can influence growth in ways such as supporting branching, increasing leaf formation, and increasing the size and shape of plants. Furthermore, cow manure increased the yield of plant height, number of branches, fresh weight, and dry weight of mint plants.

Number of Leaves

The soil and husk charcoal composition combined with the application of manure independently showed an effect on the number of mint plant leaves. Table 3 shows that ratio 1:1 produced the lowest number of mint leaves (167.17) compared to 1:3 and 3:1, with the respective values of 219.35 and 210.08. The use of cow manure showed the highest number of mint leaves (222.33) compared to goat manure and chicken manure, with values of 183.67 and 191.00 mint leaves, respectively (Table 4). Based on Table 3, the ratio 1:1 produced the lowest number of mint leaves compared to 1:3 and 3:1, with the respective values of 53 and 43. The use of cow manure showed the highest number of mint leaves compared to goat manure and chicken manure, with values of 39 and 32 mint leaves, respectively (Table 4).

In this research, the best organic fertilizer used was cow manure, resulting in an average number of leaves of 219.75. Providing organic fertilizer affects vegetative growth by increasing the number

Table 3. Average number of leaves, fresh weight of plants, dry weight of plants, and leaf area of the crop as affected by various compositions of soil and husk charcoal

Composition of soil and husk charcoal	Number of leaves	Fresh weight of plant (g crop^{-1})	Dry weight (g crop^{-1})	Leaf area (cm^2 crop^{-1})
1:3	219.75±14.67a	11.77±0.98a	3.24±0.50a	209.50±23.27a
1:1	167.17±22.50b	10.16±0.16ab	2.55±0.01ab	139.87±25.96b
3:1	210.08±7.83a	9.21±0.83b	1.82±0.51b	174.37±1.57b
Sig.	0.13	0.06	0.16	0.38
CV%	17.73%	20.52%	37.78%	27.70%

Remarks: Values followed by the same letters indicate no significant difference based on Duncan's Multiple Range test (DMRT) at 5%.

Table 4. Average number of leaves, fresh weight of plants, dry weight of plants, and leaf area of the crop as affected by various types of manure

Type of manure	Number of leaves	Fresh weight of plant (g crop^{-1})	Dry weight (g crop^{-1})	Leaf area (cm^2 crop^{-1})
Cow manure	222.33±16.50a	11.49±0,78a	2.96±0.30a	211.21±24.48a
Goat manure	183.67±10.84b	8.71±1,18b	1.84±0.49b	149.38±19.24b
Chicken manure	191.00±5.66ab	10.94±0,40a	2.80±0.19a	164.26±8.72ab
Sig.	0.13	0.06	0.16	0.38
CV%	17.73%	20.52%	37.78%	27.70%

Remarks: Values followed by the same letters indicate no significant difference based on Duncan's Multiple Range test (DMRT) at 5%.

of leaves and other plant growth parameters (Qulsum et al., 2021). Cow manure contains a number of nutrients and organic materials that can improve the fertility of the soil. Increases in N and P elements significantly affect plant physiological processes. Nitrogen plays a role in the formation of chlorophyll, so the photosynthesis process increases. Besides, it can stimulate the number of leaves. Meanwhile, phosphorus is a component of ADP and ATP, which are important in photosynthesis and ion absorption. The longer the presence of elements in the media will impact growth, namely the number of leaves that will form.

The highest average number of mint leaves was produced by a 1:3 soil and husk charcoal composition (M1). According to research by Gaso et al. (2022), applying a husk charcoal composition with a ratio of 4/5 produced the highest number of kale leaves compared to smaller ratios, namely 3/5, 2/5, and 1/5. This is also supported by research by Ahmad et al. (2021), which shows that using 300g of husk charcoal per plant, namely the highest dose, produces the highest average number of celery leaves. The aeration of organic planting media is comparable to that of rockwool planting media, and its high porosity can help plant nutrient solutions store more (Rahayu & Mulyani, 2022). The advantage of husk charcoal is that it can improve the physicochemical properties of the soil, namely porosity, root respiration, and soil moisture. Besides, husk charcoal can bind water, then release it into the micropores to be absorbed by plant roots, and can encourage the growth of microorganisms that are good for soil and plants.

Fresh Weight of the Plant

Using various compositions of soil and husk charcoal and applying different types of manure independently showed an effect on the fresh weight of mint plants. Table 3 shows that the composition of soil and husk charcoal in a ratio of 3:1 resulted in the lowest fresh weight compared to a composition of soil and husk charcoal in a ratio of 1:3 and 1:1. The application of goat manure showed the lowest fresh weight compared to cow manure and chicken manure, each with a difference of 2.78 g and 2.23 g in fresh weight (Table 4).

Cow manure has several benefits, such as balancing low substrate parameters, pH, C/N ratio, and nutrient content in the soil (Tallou et al., 2020). According to Musdalifah et al. (2021), widely distributed organic fertilizers are cow manure, which has not been used optimally. Cow manure has a high nutrient content of C, N, P, Ca, and Mg. By increasing the photosynthetic rate, chemical fertilizers particularly N and P can improve the growth characteristics and output of plants (Iqbal et al., 2019). It was claimed that when 50% chemical fertilizer and nano-chelated fertilizer were applied, the proportion of menthol increased and the percentage of benzofuran decreased, which was correlated with the quality of peppermint essential oil (Ostadi et al., 2020). The research results of Biswas et al. (2022) show that applying cow manure to mint plants can increase plant height, main branches, and secondary branches. Carbohydrates will be synthesized into protein by nitrogen so that the cell division process increases, which impacts the formation of stems and branches and is followed by an increase in the fresh weight of mint.

Dry Weight

Various compositions of soil and husk charcoal and various types of manure independently affected the dry weight of mint plants. The composition of soil and husk charcoal with a ratio of 3:1 produced the lowest dry weight of mint plants compared to other treatments (Table 3). Meanwhile, goat manure was applied to the type of manure, which resulted in the lowest dry weight of mint plants compared to cow manure and chicken manure. In addition to its high nutrient content, organic manure has a lot of vitamins, plant development hormones, and beneficial microorganisms. Applying organic fertilizer has a positive impact on the biomass production of mint (Olumide, 2022). By enhancing soil quality and structure, plant nutrient availability, and biomass C input through improved crop development, manure application can sustain high levels of crop yield. A sustainable increase in soil productivity is probably the cause of higher crop productivity when manure is applied (Du et al., 2020).

Dry weight shows the biomass plants produce from the photosynthesis process while the plant is growing. According to Amani et al. (2019), Enhancing biomass yield and the quality of essential oils in aromatic and medicinal plants depends on nutrient availability. The use of husk charcoal in the planting medium increased the dry-weight yield of mint (Table 3). Rice husk charcoal can improve soil structure so that it becomes loose. Pratama et al. (2020) state that husk charcoal functions to bind and release water and is a source of N, P, and K. The result of research by Biswas et al. (2022) showed that the application of organic manure had a significant effect on dry weight and fresh weight of mint.

Different mint species have different physical traits and chemical compositions depending on their surroundings (Koutsoukis et al., 2019). Genetic variables from distinct species influence the growth, synthesis, and accumulation of secondary metabolisms in medicinal and aromatic plants (Li et al., 2020). The research showed that the application of cow manure could increase the dry weight of mint. Organic fertilizers can influence plant growth through improving soil physical properties, C, N, P, and K status, and microbial biomass. The availability of macro-nutrients like N, P, and K is very important for the growth of mint plants because if a deficiency occurs, it will have an impact on plant production, such as reducing shoot root ratio, leaf area, and dry weight (Janpen et al., 2019).

Leaf Area

Various compositions of soil, husk charcoal, and various types of manure independently showed an effect on the leaf area of mint plants. Based on Table 3, the composition of soil and husk charcoal with a ratio of 1:3 produced the largest plant leaf area compared to the ratios of 1:1 and 3:1, each with a difference of 0.35 cm^2 and 0.37 cm^2. The application of cow manure showed the largest plant leaf area compared to goat manure and chicken manure, each with a difference of 0.41 cm^2 and 0.27 cm^2 (Table 4).

The production of dry matter and photosynthesis are strongly correlated with leaf area, therefore a larger leaf area boosts the plant's ability for photosynthesis. As a result, a significant portion of photosynthetic energy is used by plants to make leaves. Because they are involved in a variety of physiological processes (Shanmugabhavatharani et al. 2021). This research shows that husk charcoal and manure affect the leaf area of mint. Husk charcoal and manure contain a lot of organic material, which is beneficial for plant growth, including leaf area. Amri's research results show that using organic fertilizer can increase the growth of mint because the presence of microorganisms in the soil changes the ability to mobilize unavailable elements into available elements that are efficiently utilized directly by plants.

Using husk charcoal as a mint planting medium provides the highest mint plant leaf area yield. Adding husk charcoal affects increasing plant growth. Applying materials such as rice husk, wood ash, sawdust, and charcoal results in a higher dry matter yield in mint, presumably because they provide essential plant nutrients. It appears that the increased biomass is caused by the addition of certain essential nutrients to the soil after the decomposition of waste materials (Haque & Sakimin, 2022). Following the research by Syahda (2019) on kailan plants, which showed that the use of husk charcoal increased the yield of leaf area, leaf color, fresh weight of the crown, and dry weight of the roots, Wijaya et al. (2020) state that husk charcoal as a planting medium is very good at increasing leaf area because it contains good macro- and micronutrients. Macronutrients and micronutrients are crucial for the growth and development of plants. The availability of nutrients in manure has been proven to improve plant growth. Kaho et al. (2020) mention that cow manure contains balanced nutrients to supply the nutrients needed for plant growth. The nutrients contained in cow manure undergo complete decomposition, and they can release the nutrients needed to increase leaf area. The leaf area will be higher if the nutrient content in the planting medium is sufficiently available because most of the assimilated allocated is used for leaf formation, thereby increasing leaf area. According to (Olumide, 2022), such a promoting effect is optimal when applying organic fertilizer concerning the number of leaves, number of tendrils, fresh and dry weight compared with Inorganic fertilizer. Thus, using organic fertilizer positively impacted the biomass production of *Mentha piperita*.

CONCLUSION

The interaction of a 1:3 soil and husk charcoal composition with cow manure could increase the number of mint plant branches to a total of 47 branches. The composition of soil and husk charcoal in a ratio of 1:3 showed the highest number of leaves (219.75), leaf area (209.50cm^2), fresh weight (11.77g), and dry weight (3.24g) compared to all treatments. The application of cow manure resulted in the highest number of leaves, leaf area, and dry weight compared to all treatments, with their respective values of 223.33, 211.21cm^2, and 2.96.

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AUTHORS CONTRIBUTIONS

PDN coordinated research activities such as preparing outputs and activity reports. AIN coordinated research activities in the field to collect research data. PH provided guidance in preparing reports and research outputs. The experiment was conducted by MMFN. All authors provided critical feedback and contributed to the development of the research, analysis, and manuscript.

COMPETING INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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