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Boosting and attaining high yield of lettuce using coffee grounds as organic foliar fertilizer under nursery management

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ABSTRACT

Coffee consumption worldwide generates large amounts of spent coffee grounds (SCG), which are often discarded despite their nutrient content. It contains nitrogen (2.28%), phosphorus (0.06%), and potassium (0.6%), making them a potential organic fertilizer source. The study was conducted to evaluate the efficacy of coffee ground (CG) as foliar fertilizer in lettuce (*Lactuca sativa* L.) production under nursery management. Specifically, it aimed to determine the effects of different coffee ground concentrations on growth parameters, yield per hectare, and Return On Investment (ROI). The experiment was carried out from February to March, 2024 at the CSU Lal-lo Nursery using Completely Randomized Design (CRD) with six treatments and three replications: T_1 – Department of Agriculture Package of Technology; T_2– 11.34 g CG per 3 L water; T_3 – 25.44 g; T_4 – 39.0 g; T_5– 50.88 g; and T_6 – commercial foliar fertilizer. Growth parameters measured included plant height, number of leaves, leaf area, root length, stem diameter, and fresh weight at harvest. Results revealed that CG application significantly influenced lettuce growth and development. T_3 (25.44 g) produced the tallest plants and longest leaves, while T_2 (11.34 g) achieved the highest leaf area, root length, stem diameter, and overall yield. Importantly, T_2 also delivered the greatest economic return, with an ROI of 1680.06%. The findings suggest that low concentrations of CG are most effective for enhancing lettuce growth and profitability. CG thus represents a sustainable alternative to commercial fertilizers. Further studies are recommended to validate these results across different environments and cropping systems.

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INTRODUCTION

Coffee consumption worldwide generates large amounts of defective or spent coffee grounds (SCG), which are often discarded as waste. These residues contain both beneficial nutrients and potentially phytotoxic compounds. Chemically, SCG are rich in nitrogen (2.28%), phosphorus (0.06%), and potassium (0.6%), making them a promising organic fertilizer source (Masarirambi *et al.*, 2012). However, they also contain caffeine, tannins, and polyphenols, which in excessive amounts may negatively affect plant growth (Cruz and Cordovil, 2022). The environmental challenge of managing coffee waste has therefore prompted researchers to explore its agricultural applications. For instance, Gomes *et al.* (2013) demonstrated that moderate doses of fresh and composted SCG enhanced lettuce root development, while higher concentrations inhibited growth due to phytotoxic effects.

Beyond growth parameters, SCG use aligns with sustainable agriculture goals. Hernandez *et al.* (2010) emphasized the environmental risks of excessive inorganic fertilizer use, including soil acidification and groundwater pollution. Transitioning to organic inputs such as SCG supports Good Agricultural Practices (GAP) and reduces dependency on costly synthetic fertilizers. Recent work by Kim *et al.* (2024) further showed that dehydrated food waste and SCG improved yield and nutritional composition of leafy vegetables, underscoring their potential as eco-friendly bio-inputs.

Moreover, nitrogen management is central to crop productivity. Liquid fertilizers are widely used to increase nitrogen availability in the soil. Nitrogen is the main constituent of proteins in plants, yet most nitrogen in nature exists in inert forms that cannot be directly absorbed by crops (Havlin *et al.*, 2014). Adequate nitrogen supply plays a crucial role in encouraging rapid plant growth, improving crop yields, and enhancing overall quality (Fageria, 2016). A study conducted in Bekasi, Indonesia demonstrated that liquid organic fertilizer derived from fermented oil palm fruit fiber increased nitrogen absorption in mustard plants by up to 24%, while also improving soil chemical properties such as pH, organic carbon, and total nitrogen (Suryanto *et al.*, 2019). Similarly, recent research has shown that organic liquid fertilizers from agro-industrial residues, including coffee grounds, can enhance nutrient uptake efficiency and promote sustainable soil fertility management (Kim *et al.*, 2024; Basílio *et al.*, 2026).

On the other hand, Lettuce (*Lactuca sativa L.*), a high-value commercial crop harvested within 30–45 days, is particularly responsive to nutrient management. Its short growth cycle and high market demand make it an ideal candidate for testing organic foliar fertilizers. Farmers traditionally rely on inorganic fertilizers to optimize yield, but excessive use has led to soil pollution, pH imbalance, and long-term fertility decline. Because of these disadvantages, several studies have focused on shifting toward organic fertilization practices to reduce input costs and restore soil health. Coffee grounds, in particular, have been found to contain more nitrogen, phosphorus, and potassium than many animal manures, including those of cows, pigs, and chickens (Butay, 2018 and Masarirambi *et al.,* 2012).

Hence, biofertilizers or organic foliar fertilizers are considered vital solutions in revitalizing soil fertility and productivity. This study was therefore designed to generate scientific information on lettuce production using different rates of coffee grounds as organic foliar fertilizer. Specifically, it aimed to identify the optimum dosage that maximizes lettuce growth, yield, and Return On Investment, while minimizing potential phytotoxic effects.

MATERIALS AND METHODS

Research design

The study was conducted in a single factor experiment in Completely Randomized Design (CRD) with six (6) treatments and three (3) replications. Laying-out the Experimental Area and Experimental Design. A total land area of 50.5 m^2 including alleys were used for the experiment. Each plot measures 1m × 1.5 m.

Experimental treatments

The experimental treatments used were the following: T_1- Lettuce POT; T_2- 11.34 grams (0.15 cup) of coffee ground per 3 liter of water, T_3- 25.44 g (0.3 cup) of coffee ground per 3 liter of water, T_4- 39.0 grams of coffee ground per 3 liter of water, T_5- 50.88 grams (0.6 cup) of coffee ground per 3 liter of water and T_6- Commercial foliar fertilizer.

Soil sampling and analysis

Before land preparation, soil samples were collected in different locations within the experimental area at a depth and width of 6 inches. These soil samples were submitted to Cagayan Valley Integrated Agricultural Laboratory (CVIAL), Tuguegarao City for soil chemical and physical analysis.

Construction of greenhouse

The greenhouse was made out of steel tubular and net with a height of 7 ft. A total area of 90.5 square meters was covered and was used as the experimental area.

Land preparation

The experimental area was thoroughly prepared to have a uniform seedling emergence and good root emergence. The area was prepared by plowing two times and harrowing one week after plowing. Pick Mattock and grab hoe was used to cultivate the area to break the soil clods for effective weed control after the second plowing and are ready for transplanting.

Seedlings management

Seedlings were raised on seedling tray consisting of one part compost, one part carbonized rice hull (CRH), and one part garden soil with 3-5mm depth. And was sprinkled with water daily until the seedlings have emerged. Once the seedling appears, the watering routine may be lessened.

Transplanting

Transplanting was done two to three weeks after sowing or when they reach the height of 5cm to 8cm, and it was ensured that some soil is still attached to the roots. It was transplanted with a spacing of 25x30cm. Immediately water the seedling after transplanting. Water the seedlings daily. In cases of mortality, plants were re-planted 5-7 days after transplanting.

Coffee ground preparation and application

The defective coffee bean was roasted and blended which was become a coffee ground, then this was weighed using an analytical weighing scale and measure based on a standard ratio of one (1) cup is equal to 80. 44 grams, where the standard mixture is two (2) cups for a five (5) gallons of water.

The coffee ground was applied as foliar fertilizer based on the imposed treatments, and this was done every after seven days started at seven(7) days after transplanting and administered in the morning between 6:00 and 7:00 under fair weather conditions, coinciding with stomatal opening for optimal nutrient absorption.

Fertilizer application

Soil analysis showed that the experimental area had a pH of 5.3, which is below the optimal range for lettuce growth (6.0–6.5). To improve soil condition, vermicompost was applied at a rate of 12 bags per hectare. For the plots, 9.075 kg (half of the recommended rate) was incorporated into the soil through cultivation and leveling with a hand cultivator and rake, one month before transplanting to allow proper soil adjustment.

Nutrient requirements identified in the soil analysis included 1.13 kg of 16-20-0 and 1.76 kg of 0-18-0 fertilizer. Since superphosphate (0-18-0) was unavailable, the nutrient balance was achieved by substituting with 1.36 kg of ammonium sulfate (16-20-0) and 120 g of urea (46-0-0) for basal application. To sustain crop growth, 4 g of urea was applied during the first side-dress and another 4 g during the second. Only half of the recommended fertilizer rate was used to avoid excessive application and maintain balance fertilization while ensuring adequate supplementation from coffee grounds.

Weeding and water management

Weeding was done at 14 days after transplanting and was repeated depending on the weed population.

Plants were watered early in the morning to allow the foliage to dry quickly and minimize the risk of disease, with irrigation carried out only as necessary.

Cultivation and care management

Lettuce has shallow roots. As such it should be hoed and cultivated carefully to ensure rapid development and high-quality product.

Harvesting

The lettuce was harvested at 35 days from transplanting. This was done by carefully dug the surroundings of the plants and to get the whole roots of the plants for the measurement of the root length.

Data gathered

To evaluate growth and yield parameters, ten representative sample plants from each treatment were randomly selected (excluding border rows) and measured at 7, 14, 21, 28, and 35 Days After Transplanting. Plant height was recorded from the base to the highest leaf using a ruler, while the number of leaves was manually counted and averaged per plot. Leaf area was determined by tracing the largest and smallest leaves on graphing paper, calculating their areas, and averaging the values. Root length was measured from three destructive samples per plot using a ruler, and stem diameter was assessed from three destructive samples with a vernier caliper. Yield was determined at harvest (35 days after transplanting) by weighing ten sample plants per plot, converting the values to tons per hectare. Finally, cost and return analysis was computed based on actual expenditures and gross income, with net income calculated as gross income minus total expenses, and return on investment (ROI) derived by dividing net income by total expenses multiplied by 100.

Statistical analysis

All the data gathered and were analyzed following the Analysis of Variance for the Completely Randomized Design. Duncan's Multiple Range Test (DMRT) was used for the comparison of means with significant results.

RESULTS AND DISCUSSION

Average plant height (cm)

The average plant height of lettuce for five weeks of production as applied by the different rates of coffee ground as foliar fertilizer is presented in Table 1. T_3 (25.44g coffee ground) produced the tallest lettuce plants, significantly outperforming all other treatments with a mean value of 61.15 cm. T_2 (11.34g) also showed strong growth with a mean value of 58.22 cm, suggesting that moderate coffee ground application enhances plant height. T_5 (50.88g) with a mean value of 51.64 cm resulted in the shortest plants, indicating that excessive coffee ground concentration may inhibit growth. Commercial fertilizer (T_6) with a mean value of 53.67 cm did not outperform organic treatments, highlighting the potential of coffee grounds as a sustainable alternative.

Table 1. Average plant height (cm) of lettuce as selected HVCC crop for five weeks of production applied with different rate of coffee ground as organic foliar fertilizer under nursery management

Treatment	Average plant height
T_1- DA POT	54.05c
T_2- 11.34 grams (0.15 cup) of coffee ground per 3 liter of water	58.22b
T_3- 25.44 g (0.3 cup) of coffee ground per 3 liter of water	61.15a
T_4- 39.00 grams of coffee ground per 3 liter of water	55.02c
T_5- 50.88 grams (0.6 cup) of coffee ground per 3 liter of water	51.64d
T_6- Commercial foliar fertilizer	53.67c
Statistical Inference -Significant at *5%	*

On the other hand, the *5% significance level* confirms that differences in plant height among treatments are statistically meaningful. Treatments with different letters (a, b, c) are significantly different from each other. The significant results of the study is conforms to the findings of Gomes *et al.,* 2013 where in low concentrations of fresh coffee grounds (2.5–5%) stimulated lettuce growth. Higher concentrations led to nutrient imbalances, reducing foliar nitrogen and potassium. This mirrors the current study where T_3 (moderate dose) yielded optimal growth, while T_5 (high dose) suppressed it.

According to (https://veggieknowledge.com), Coffee grounds are rich in nitrogen, phosphorus, and potassium, which are essential for leafy vegetables like lettuce. Moderate use improves soil structure and moisture retention, promoting root and shoot development. Excessive use can lead to acidic soil conditions and nutrient lockout, explaining the reduced height in T_5. Hence, coffee ground as foliar application especially at moderate rates, can enhance lettuce growth in Cagayan's vegetable sector.

Promotes eco-friendly practices and reduces dependence on commercial fertilizers.With proper training and dosage control, this method could be adopted by local farmers to improve productivity and profitability.

Average number of leaves

Table 2 presents the average number of leaves produced by lettuce over five weeks under different foliar treatments using coffee grounds (CG) as organic foliar fertilizer, package of technology and a commercial fertilizer.

The results are statistically significant at the 5% level, indicating meaningful differences among treatments. T_2 (11.34 g CG) produced the highest number of leaves with a mean value of 47.09, significantly outperforming all other treatments. T_3 and T_1 showed similar results, with a mean value of 43.56 and 42.91 suggesting that moderate CG application (T_3) is comparable to the package of technology of lettuce (T_1). T_4, T_5, and T_6 formed the lowest statistical group with a mean of 39.48, 39.45 and 39.66, respectively, indicating that higher CG concentrations and commercial fertilizer were less effective in promoting leaf development.

Thus, low CG concentration (T_2) likely provided optimal nutrient levels without introducing toxicity, enhancing leaf proliferation. Higher concentrations (T_4–T_5) may have led to nutrient imbalance or inhibited leaf development due to allelopathic effects. Commercial fertilizer (T_6) performed similarly to high CG doses, suggesting that CG at optimal levels may be more effective than synthetic alternatives.

Table 2. Average number of leaves of lettuce for 5 weeks of production using coffee ground as organic foliar fertilizer under nursery management

Treatment	Average number of leaves
T_1- DA POT	42.91b
T_2- 11.34 grams (0.15 cup) of coffee ground per 3 liter of water	47.09a
T_3- 25.44 g (0.3 cup) of coffee ground per 3 liter of water	43.56b
T_4- 39.00 grams of coffee ground per 3 liter of water	39.48c
T_5- 50.88 grams (0.6 cup) of coffee ground per 3 liter of water	39.45c
T_6- Commercial foliar fertilizer	39.66c
Statistical Inference	*

On the other hand, Spent coffee grounds contain essential nutrients like nitrogen, potassium, and phosphorus, which can stimulate vegetative growth. However, they also contain phenolic compounds, caffeine, and tannins, which may become phytotoxic at higher concentrations. Moreover, the results of this study is conform to the study of Fan *et al.* (2020) where in the composted SCG enhanced leaf development in leafy vegetables, but raw or excessive application led to reduced growth due to nitrogen immobilization.

Furthermore, this study confirms that moderate application of spent coffee grounds as a foliar fertilizer can significantly enhance leaf production in lettuce. However, excessive use may hinder growth due to phytotoxic effects. These findings are consistent with other research emphasizing the importance of dosage and preparation when using organic waste in agriculture.

Average length of leaves (cm)

Table 3 presents the average leaf length of lettuce after five weeks of foliar application using different rates of coffee grounds (CG) and other fertilizer treatments under nursery management. The results are statistically significant at the 5% level, indicating that the differences in leaf length are meaningful. T_2 and T_3 (low to moderate CG concentrations) produced the longest leaves with a mean value of 63.39 cm and 62.26 cm, significantly outperforming all other treatments. T_6 and T_4 showed comparable results with a mean value of 57.95 cm and 57.78 cm, suggesting that moderate CG application is as effective or slightly better than commercial foliar fertilizer. T_1 (DA Package) and T_5 (highest CG concentration) had the shortest leaves with a mean value of 55.89 cm and 51.82 cm, indicating that excessive CG may hinder leaf elongation.

Table 3. Average length of leaves (cm) of lettuce for 5 weeks of production applied different rates of coffee ground as organic foliar fertilizer under nursery management

Treatment	Average length of leaves (cm)
T_1- DA POT	55.89c
T_2- 11.34 grams (0.15 cup) of coffee ground per 3 liter of water	63.39a
T_3- 25.44 g (0.3 cup) of coffee ground per 3 liter of water	62.26a
T_4- 39.00 grams of coffee ground per 3 liter of water	57.78b
T_5- 50.88 grams (0.6 cup) of coffee ground per 3 liter of water	51.82d
T_6- Commercial foliar fertilizer	57.95b
Statistical Inference -Significant at *5%	*

Table 4. Average leaf area of lettuce plants applied with different rates of coffee ground used as organic foliar fertilizer under nursery management

Treatments	Average leaf area (cm^2)
T_1- DA POT	2519.66c
T_2- 11.34 grams (0.15 cup) of coffee ground per 3 liter of water	3,066.00a
T_3- 25.44 g (0.3 cup) of coffee ground per 3 liter of water	2890.00b
T_4- 39.00 grams of coffee ground per 3 liter of water	2,269.00d
T_5- 50.88 grams (0.6 cup) of coffee ground per 3 liter of water	2308.33d
T_6- Commercial foliar fertilizer	2537.00c
Statistical Infierence	*

Thus, low CG doses (T_2 and T_3) likely provided optimal nutrient levels without introducing toxicity, promoting cell expansion and leaf elongation. High CG dose (T_5) may have introduced excessive organic compounds, leading to nutrient imbalance or inhibited leaf growth. Commercial fertilizer (T_6) performed well but was slightly less effective than optimal CG treatments, suggesting that CG can be a viable organic alternative.

Moreover, the significant findings of this study is in support to the study of Santos *et al.* (2018) and it was highlighted that caffeine in coffee waste can inhibit leaf expansion and cell division at high concentrations, supporting the decline seen in T_5.

Nevertheless, this study confirms that moderate application of spent coffee grounds as foliar fertilizer can significantly enhance leaf length in lettuce, outperforming both commercial fertilizers and traditional methods. However, excessive application may hinder growth due to phytotoxic effects. These findings align with other research emphasizing the importance of dosage and preparation when using organic waste in agriculture.

Average leaf area (cm²)

Table 4 presents the average leaf area (cm^2) of lettuce after five weeks of foliar application using different rates of coffee grounds (CG) and other fertilizer treatments under field management. The differences are statistically significant at the 5% level. T_2 (11.34 g CG) resulted in the largest leaf area with a mean value of 3,066 cm^2, significantly outperforming all other treatments. T_3 (moderate CG) with a mean value of 2890 cm^2 also showed strong performance, though slightly less than T_2. T_6 (commercial fertilizer) and T_1 (control) with a mean value of 2537 cm^2 and 2519 cm^2 were statistically similar, suggesting limited impact from conventional methods. T_4 and T_5 (high CG concentrations) with a mean value of 2269.00 cm^2 and 2308.33 cm^2 showed the smallest leaf areas, indicating potential negative effects at excessive doses.

Thus, low CG concentrations (T_2 and T_3) provided optimal nutrient availability especially nitrogen and potassium without introducing toxicity, promoting cell expansion and leaf development. High CG concentrations (T_4 and T_5) may have introduced excessive caffeine, tannins, and phenolic compounds, which can inhibit cell division and leaf expansion. Commercial fertilizer (T_6) was less effective than optimal CG treatments, highlighting the potential of CG as a sustainable alternative when applied correctly.

On the other hand, this study confirms that moderate application of spent coffee grounds as foliar fertilizer significantly enhances leaf area in lettuce, outperforming both commercial fertilizers and traditional methods. However, excessive application may hinder growth due to phytotoxic effects.

Average root length (cm)

Table 5 presents the average root length of lettuce plants applied with different rate of coffee ground used as organic foliar fertilizer. Significant result was obtained in this parameter where in T_2- 11.34 grams (0.15 cup) of coffee ground per 3 liter of water got the longest root length with a mean of 22.92 cm, but the latter is comparable to T_5- 50.88 grams (0.6 cup) of coffee ground per 3 liter of water with a mean of 22.44. Next in rank is T_1- Lettuce POT and T_6- Commercial foliar fertilizer with a mean of both 21.36 cm, however, these treatments are comparable to T_3- 25.44 g (0.3 cup) of coffee ground per 3 liter of water with a mean of 21.33 cm. The least was obtained in T_4- 39 grams of coffee ground per 3 liter of water with a mean of 19.98 cm, respectively.

Table 5. Average root length of lettuce applied with different rate of coffee ground used as foliar fertilizer

Treatments	Average root length (cm)
T_1- DA POT	21.36$_b$
T_2- 11.34 grams (0.15 cup) of coffee ground per 3 liter of water	22.92$_a$
T_3- 25.44 g (0.3 cup) of coffee ground per 3 liter of water	21.33$_b$
T_4- 39.00 grams of coffee ground per 3 liter of water	19.98$_c$
T_5- 50.88 grams (0.6 cup) of coffee ground per 3 liter of water	22.44$_a$
T_6- Commercial foliar fertilizer	21.36$_b$
Statistical inference	*

The study is in support to the study of the research study titled"Effect of fresh and composted spent coffee grounds on lettuce growth, photosynthetic pigments and mineral composition" by Teresa Gomes *et al.,* 2013. This study found that different rates and forms of spent coffee grounds (fresh and composted) affected root development in lettuce. Moderate application rates of coffee grounds enhanced root length, while higher concentrations could inhibit root growth due to phytotoxic effects from compounds in coffee grounds like caffeine.

Another supporting study reported that low to moderate levels of spent coffee grounds increased root growth and antioxidant properties in lettuce, but excessive amounts caused reduced root development and overall growth suppression.

These findings align with your results where the lowest and highest root lengths corresponded to moderate (11.34 g) and higher (50.88 g) rates, respectively, showing that moderate coffee ground foliar fertilizer application can optimally support root growth in lettuce, whereas some rates may be less effective or inhibitory.

Furthermore, the moderate application of coffee grounds likely provided nutrients and bioactive compounds that stimulate root growth, while higher or inappropriate doses may cause chemical stress, thus reducing root length. This balance is crucial for maximizing growth benefits.

Average stem diameter

Table 6 presents the stem diameter of lettuce plants applied with the different rates of coffee ground used as organic foliar fertilizer. Significant result was garnered on the stem diameter of lettuce plants applied with coffee ground as foliar fertilizer wherein T_5- 50.88 grams (0.6 cup) of coffee ground per 3 liter of water obtained the widest diameter with a mean of 3.12 mm. This was followed by T_2- 11.34 grams (0.15 cup) of coffee ground per 3 liter of water with a mean of 2.93mm but T_2 is comparable to T_1- Lettuce POT or control with a mean of 2.90. Next in rank was a plants under T_4- 39 grams of coffee ground per 3 liter of water with a mean of 2.89 but this treatment is also comparable to T_3- 25.44 g (0.3 cup) of coffee ground per 3 liter of water with a mean of 2.88 mm, and the least was obtained in T_6- Commercial foliar fertilizer with a mean of 2.78 mm, respectively.

Table 6. Average stem diameter (mm) of lettuce applied with different rates of coffee ground used as foliar fertilizer

Treatments	Average stem diameter (mm)
T_1- DA POT	2.90b
T_2- 11.34 grams (0.15 cup) of coffee ground per 3 liter of water	2.93b
T_3- 25.44 g (0.3 cup) of coffee ground per 3 liter of water	2.88c
T_4- 39.00 grams of coffee ground per 3 liter of water	2.89c
T_5- 50.88 grams (0.6 cup) of coffee ground per 3 liter of water	3.12a
T_6- Commercial foliar fertilizer	2.78d
Statistical Inference	*

The significant result on the stem diameter of lettuce plants is conforms to the study of Ragauskait˙e, 2022. This study demonstrated that both fresh and composted spent coffee grounds (SCG) significantly influenced lettuce growth parameters, including stem thickness or diameter.

The effect was dependent on coffee ground concentration, with moderate amounts promoting better growth and stem development compared to controls or excessive SCG concentrations that could induce stress and inhibit growth.

The finding that 50.88 grams (0.6 cup) of coffee ground per 3 liters of water (T_5) produced the widest stem diameter aligns with this study's observation that optimal SCG doses enhance plant structural development due to improved nutrient availability and growth stimulation. Lower or excessive doses typically showed less effect or adverse outcomes, consistent with the results where some lower doses (T_2) were comparable to controls and commercial fertilizer produced the smallest stem diameter.

In summary, the study supports that moderate application of coffee grounds as foliar fertilizer can significantly enhance stem diameter and overall plant robustness in lettuce by supplying essential nutrients and improving physiological growth conditions.

Yield of lettuce at harvest (tons/ha)

The yield of lettuce for one hectare of production as applied by the different rates of coffee ground as organic foliar fertilizer is presented in Table 7. The data show that the application of spent coffee ground as foliar fertilizer at the lowest dosage (11.34 g/3L) significantly increased lettuce yield of 14.46 tons/ha compared to DA POT and commercial fertilizer of 12.46 tons.ha and 13.20 tons/ha, indicating a growth-promoting effect. Moderate dose (25.44 g) with a mean of 13.33 tons/ha also enhanced yield but to a lesser extent. Higher doses (39 g and 50.88 g) resulted in reduced yields with a mean value of 12.80 tons.ha and 10.30 tons/ha, with the highest dose causing significant yield decline, likely due to phytotoxicity or nutrient imbalance.

This optimal low dosage effect suggests that SCG provides beneficial nutrients such as nitrogen, potassium, phosphorus, and bioactive compounds that stimulate lettuce growth, but high concentrations may introduce stress to plants.

The significant results of this study is conforms to the study of Cervera-Mata *et al.* (2019) demonstrated that SCG increased lettuce nutritional value and biomass when applied adequately, reinforcing SCG's capacity to improve lettuce yield and quality.

Table 7. Average yield (t/ha) of freshly harvested lettuce applied with the different rates of spent coffee ground used as organic foliar fertilizer under nursery management.

Treatments	Yield at harvest (t/ha)
T_1- DA POT	12.46c
T_2- 11.34 grams (0.15 cup) of coffee ground per 3 liter of water	14.46a
T_3- 25.44 g (0.3 cup) of coffee ground per 3 liter of water	13.33b
T_4- 39.00 grams of coffee ground per 3 liter of water	12.80c
T_5- 50.88 grams (0.6 cup) of coffee ground per 3 liter of water	10.30d
T_6- Commercial foliar fertilizer	13.20b
Statistical inference	*

Table 8. Cost and return analysis of lettuce plants in a one hectare of production applied with the different rate of coffee ground used as organic foliar fertilizer

Treatments	Cost of production	Gross income	Net income	ROI (%)
T_1- DA POT	121,500	1,869,000	1,747,500	1438.27
T_2- 11.34 grams (0.15 cup) of coffee ground per 3 liter of water	121,850	2,169,000	2,047,150	1680.06
T_3- 25.44 g (0.3 cup) of coffee ground per 3 liter of water	122,259	1,999,500	1,877,241	1535.46
T_4- 39.00 grams of coffee ground per 3 liter of water	122,558	1,920,000	1,797,442	1466.60
T_5- 50.88 grams (0.6 cup) of coffee ground per 3 liter of water	122,880	1,545,000	1,422,120	1157.32
T_6- Commercial foliar fertilizer	122,500	1,980,000	1,857,500	1516.33

Cost and return analysis

The cost and return analysis of one hectare lettuce production applied with the different rates of coffee ground as organic foliar fertilizer is shown in Table 8. The return on investment obtained in the different treatments is arranged in descending order. Treatment 2 had 1680.06%, Treatment 3 had 1535.46%, Treatment 6 had a 1516.33%, Treatment 4 had a 1466.60%, Treatment 1 had 1438.27% and the lowest was obtained by Treatment 5 with 1157.32%.

T_5- 50.88 grams (0.6 cup) of coffee ground per 3 liter of water had the highest total production cost at Php 122,800, followed by T_4- 39 grams of coffee ground per 3 liter of water with a total cost of Php 122,558.00, T_6- Commercial foliar fertilizer with a total production cost of Php. 122,500.00, also followed by T_3- 25.44 g (0.3 cup) of coffee ground per 3 liter of water with a total production cost of Php 122,259.00, T_2- 11.34 grams (0.15 cup) of coffee ground per 3 liter of water with a total cost of production of Php121,850.00, and T_1- DA POT as the lowest total cost of production of Php. 121,500.00. Net income of T_2 gave the highest at Php. 2,047,150.00, followed by T_3 had a net income of Php 1,877,241.00, T_1 gave Php. 1,869,000.00, T_6 with a net income of Php. 1,857,500.00 , T_4 with a net income of Php 1,797,442.00 and the lowest was found in T_5 with a net income of Php 1,422,120.00. This only means that plants treated with coffee ground can increase the fresh leaves yield of lettuce. The lowest rate of coffee ground as liquid foliar fertilizer, the highest yield could obtain on the lettuce plants.

Cagayan's vegetable and root crop production declined by 9.78% in 2024, with lettuce being part of this category. Nationally, lettuce production is forecasted to grow modestly by 1.72% in 2025, indicating potential but requiring innovation. The ROI from T_2 suggests that integrating coffee ground foliar fertilizer could significantly boost profitability per hectare, potentially reversing regional declines.

Coffee grounds are a low-cost, eco-friendly alternative to commercial fertilizers, aligning with sustainable agriculture goals in Cagayan.If adopted province-wide, even a modest increase in lettuce yield per hectare could contribute to reversing the 2024 downturn in vegetable production.

Moreover, based on the results of the study, it is suggested that farmers in Cagayan should Use 12.06g of coffee ground per 3L water as foliar spray for optimal ROI. Local government units (LGUs) and DA regional offices could support trials to validate results under Cagayan's climate. Educate farmers on proper application techniques and benefits of organic foliar fertilizers.

CONCLUSION

The study evaluated the effectiveness of coffee grounds as foliar fertilizer in lettuce (*Lactuca sativa* L.) production under nursery management. Six treatments were tested using a Completely Randomized Design, including varying rates of coffee grounds and a commercial foliar fertilizer. Results showed that moderate application (25.44 g per 3 L water, T_3) produced the tallest plants and longest leaves, while the lowest rate (11.34 g per 3 L water, T_2) yielded the highest leaf area, root length, stem diameter, and overall harvest weight. Importantly, T_2 also delivered the greatest economic return, with an ROI of 1680.06%. These findings confirm that low concentrations of coffee grounds are most effective for enhancing lettuce growth and profitability, offering a sustainable alternative to commercial fertilizers.

RECOMMENDATIONS

Based on the findings of this study, the application of 11.34 grams (0.15 cup) of coffee grounds per 3 liters of water (T_2) is recommended as the most effective foliar fertilizer treatment for lettuce production. This rate consistently produced the heaviest harvest weight and achieved the highest Return on Investment (ROI), making it both agronomically and economically advantageous.

To strengthen these results, follow-up studies should be conducted under varying environmental conditions and across multiple growing seasons to validate the consistency of outcomes. Future research may also explore on the following: Leaf nutrient analysis to evaluate the nutrient and phytotoxicity of the lettuce leaf, long-term soil effects to assess how repeated application of coffee grounds influences soil fertility, pH balance, and microbial activity, Crop diversification to test the efficacy of coffee grounds on other high-value crops beyond lettuce, Economic feasibility to evaluating cost-benefit analysis at larger farm scales to determine commercial viability and preparation methods to compare raw versus composted or biochar-converted coffee grounds to identify the most effective form for foliar application. Thus, by pursuing these directions, coffee grounds can be further established as a sustainable, low-cost alternative to commercial fertilizers, contributing to eco-friendly agricultural practices and improved farmer profitability.

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