Restoration of Mined–out Soil Using Carbonized Rice Hull and Rice Hay Compost

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ABSTRACT

Mining activities contribute significantly to land degradation, resulting in nutrient–deficient and unproductive soils that require effective rehabilitation strategies. This study evaluated the effectiveness of Rice Hay Compost (RHC) and Carbonized Rice Hull (CRH) as organic amendments to restore the productivity of mined–out soil collected from the mining area of Berong Nickel Corporation at Quezon, Palawan. A Completely Randomized Design (CRD) was used consisting of nine treatments with varying proportions of RHC and CRH amendments applied to mined–out soil, each replicated eight times. Growth and yield parameters, including leaf length, leaf width, number of leaves, fresh weight, and biomass, were measured over a 59–day growing period. Data were analyzed using Analysis of Variance (ANOVA), and Duncan's Multiple Range Test (DMRT) Post Hoc analysis at 1% level of significance. Results showed highly significant differences ($P < 0.01$) among treatments for all measured parameters. Treatment 9 (60% mined–out soil + 20% RHC + 20% CRH) consistently produced the highest growth and yield values, while the control (100% mined–out soil) and treatments with low amendment levels (T2–T5) exhibited the poorest performance. The combined application of RHC and CRH at higher proportions significantly enhanced plant growth and biomass production. The study concludes that the combination of 20% RHC and 20% CRH is the most effective treatment for enhancing the growth and yield of Pechay in mined–out soils. These findings highlight a sustainable and cost–effective approach for rehabilitating degraded mining areas using agricultural waste materials.

Keywords: soil rehabilitation, organic soil amendment, degraded soil restoration, agricultural waste utilization, sustainable agriculture

INTRODUCTION

Mining is essential for modern life, supplying raw materials for infrastructure and technology. In the Philippines, there are 59 operating metallic mines and some of them are in Palawan (Mines and Geosciences Bureau 2024), contributing significantly to the economy and local livelihoods. However, mining also causes serious environmental impacts, particularly soil degradation. Mining activities such as stripping, excavation, and dumping disrupt the soil's physical, chemical, and biological properties, reducing its capacity to support ecosystem functions (Feng et al. 2019; Leila et al. 2021). Studies have also shown that mining reduces soil nutrients, disturbs microbial communities, and negatively affects plant growth (Ma et al. 2019).

Soil degradation is a major global issue, characterized by the loss of soil fertility, structure, and biodiversity. Mining contributes to this problem by releasing toxic substances and heavy metals such as copper, zinc, lead, manganese, and iron into the soil, which accumulate and disrupt soil processes (Zheng et al. 2021). Areas near mining sites are particularly vulnerable, posing risks to soil quality, food safety, and human health (Bafghi et al. 2024). These concerns have led to stricter regulations, with the Department of Environment and Natural Resources (DENR) requiring mining companies to implement progressive rehabilitation throughout the mining life cycle (Department of Environment and Natural Resources 2022).

Despite these efforts, natural recovery through succession is often slow and insufficient, especially in severely degraded mined–out areas. Harsh soil conditions such as compaction, nutrient deficiency, and toxicity hinder plant establishment and microbial activity, limiting ecosystem recovery (Feng et al. 2019). Without intervention, erosion persists, biodiversity remains low, and environmental risks continue. Therefore, active restoration strategies are necessary.

Ecological engineering offers a sustainable approach to rehabilitation by utilizing natural processes to restore degraded lands (Mariola et al. 2019). Successful restoration depends on soil quality, appropriate plant selection, and proximity to natural forests that serve as seed sources (Konnig et al. 2023). Since mined–out soils are typically low in organic matter, the addition of organic amendments such as compost can improve soil structure and fertility (Nunez 2013; Liu et al. 2014).

Agricultural wastes, particularly from rice production, present a viable solution. Rice hull and rice straw are often improperly disposed of through dumping or burning, causing environmental issues (Nidoy 2016).

However, these materials can be converted into useful soil amendments such as Carbonized Rice Hull (CRH) and Rice Hay Compost (RHC), which supply essential nutrients and improve soil properties (Dinh et al. 2024). The Department of Agriculture (2005) promotes recycling these residues to enhance soil productivity while reducing waste.

Despite their potential, limited studies have examined the effectiveness of CRH and RHC in rehabilitating mined–out soils. Thus, this study aims to evaluate their effectiveness in improving soil fertility and physicochemical properties using Pechay (*Brassica rapa* L.) as a test plant. Specifically, it seeks to assess the effects of different combinations of Rice Hay Compost (RHC) and Carbonized Rice Hull (CRH) on the vegetative growth of Pechay, using leaf length, leaf width, and number of leaves as growth parameters; determine their effects on yield performance as measured by fresh weight and total biomass; and identify the most effective combination of these amendments that produces optimal growth and yield in mined–out soil. Pechay is a suitable indicator species due to its sensitivity to soil conditions, with its growth and biomass reflecting variations in soil quality (Schloter et al. 2003; Zhang et al. 2023; Zunaidi et al. 2024).

METHODS

Research Design

The study employed a completely randomized design (CRD) to test the effects of different levels and combinations of Rice Hay Compost (RHC) and Carbonized Rice Hull (CRH) on the growth and yield of Pechay (*Brassica rapa L.*). The treatments consisted of pure mined–out soil as a control, along with various levels and combinations of Rice Hay Compost (RHC) and Carbonized Rice Hull (CRH). These treatment combinations allowed for the evaluation of individual effects of RHC and CRH as well as their interaction effects on growth and yield of Pechay. The experimental treatments and replicates were randomly assigned to experimental units (pots) to minimize bias and ensure valid comparisons.

This experimental design was appropriate for determining the combined and individual effects of CRH and RHC on the growth performance of Pechay cultivated in rehabilitated mined–out soil under controlled conditions.

Locale of the Study

The study was conducted within the Western Philippines University Main Campus, located in San Juan, Aborlan, Palawan.

Data Gathering Procedures

Materials used in the Study. The volume of soil and soil amendments used in this study were measured using graduated beakers to ensure accuracy in formulating the different treatments. The mixtures of mined–out soil and amendments were placed in standard–sized plastic pots capable of holding four liters of planting material. A metal spatula was used to transfer Pechay seedlings into the treatment pots. Plant growth parameters, particularly, leaf length and width were measured using a caliper. At the end of the experiment, a calibrated digital weighing scale was used to determine the fresh biomass and dried biomass of the Pechay samples. In addition, Pechay samples were thoroughly dried in a hot air oven at 105^{O}C for 14 hours to obtain the dried biomass.

Collection of Soil Samples and Soil Amendments. The mined–out soil was collected from the Berong Nickel Corporation (BNC) mining sites. The collected soil was air–dried and sieved to remove large particles prior to use. The Rice Hay Compost (RHC) was sourced from a local farm, while the Carbonized Rice Hull (CRH) was bought from a local supplier. All materials were stored in clean, labeled containers before treatment preparation.

Sowing of Seeds and Growing of Pechay Seedlings. Pechay (*Brassica rapa* L.) seeds were sown in seedling trays containing a uniform germination mix composed of garden soil, compost, and sand. The trays were placed under partial shade and watered regularly to maintain adequate moisture. Healthy and uniform seedlings were selected 11 days after sowing, once they reached the two– to three–leaf stage.

Planting of Pechay Seedlings in Pots. The selected Pechay seedlings were transplanted individually into the prepared treatment pots, one seedling per pot. Transplanting was done in the late afternoon to minimize transplant shock. Each seedling was placed in a central hole, lightly pressed into the soil mixture, and watered immediately after transplanting to promote establishment in a new planting material.

Growing, Maintenance, Harvesting, and Weighing. During the growing period, the plants were exposed to natural sunlight and watered regularly to maintain adequate soil moisture. No chemical fertilizers were used to isolate the effects of the organic amendments. Pesticide application was minimized and only applied when pests were present to prevent damage that could affect the data. Plant growth particularly, leaf length and width, number of leaves, and leaf coloration were monitored and recorded weekly.

After 59 days, or upon reaching maturity, the Pechay plants were harvested and fresh weight was recorded immediately to prevent weight loss due to air drying. These measurements were used to evaluate the influence of CRH and RHC on the growth and yield of Pechay in rehabilitated mined–out soil.

The experiment was arranged in a Completely Randomized Design (CRD) with nine treatments consisting of pure Carbonized Rice Hull (CRH), pure Rice Hay Compost (RHC), and their combinations at different proportions (0%, 10%, and 20% by volume). These treatment combinations were as follows:

Table 1. Treatment combinations and proportions.

Treatment	Mined–Soil	Rice hay compost	Carbonized rice hull
1	100%	—	—
2	90%	10%	—
3	90%	—	10%
4	80%	20%	—
5	80%	—	20%
6	80%	10%	10%
7	70%	10%	20%
8	70%	20%	10%
9	60%	20%	20%

Each treatment with eight replications was thoroughly mixed to achieve uniform composition, with a total planting volume of four liters per pot.

Data Analysis

The data on fresh weight and biomass were subjected to natural logarithmic (LN) transformation to achieve homogeneity of variance and normal distribution, meeting the assumptions required for valid statistical. The transformed data were then analyzed using the Analysis of Variance (ANOVA). Since the mean fresh weight and biomass showed highly significant differences among treatments at the 1% level of significance, the means were further separated using Duncan's Multiple Range Test (DMRT) as a post hoc analysis. The data on average number of leaves, average leaf length and average leaf width were also analyzed using ANOVA, followed by DMRT for mean comparison.

RESULTS

The growth and yield performance of Pechay (*Brassica rapa* L.) grown in mined–out soil amended with different levels and combinations of Carbonized Rice Hull (CRH) and Rice Hay Compost (RHC) showed significant variation among treatments.

Vegetative Growth

Leaf Number. Analysis of variance (ANOVA) revealed a highly significant effect of treatments on leaf number ($F_{8,63} = 7.97$, $P < 0.001$) (Table 1). Treatment 9 recorded the highest mean leaf number (11.63), which was significantly greater than all other treatments. Treatments 6, 7, and 8 produced moderately high leaf numbers, while Treatments 1 to 5 had the lowest values and were statistically comparable to the control.

Table 2. Average Leaf number of Pechay (*Brassica rapa* L.) grown in mined–out soil amended with different levels and combinations of Carbonized Rice Hull (CRH) and Rice Hay Compost (RHC), (Note: Means with the same letter are not significant from each other.

Treatment	Leaf Number
1	6.75^{cd}
2	6.25^{d}
3	7.00^{cd}
4	6.13^{d}
5	5.75^{d}
6	8.13^{bc}
7	8.13^{bc}
8	8.50^{b}
9	11.63^{a}
Grand Total	546
Grand Mean	7.59
ANOVA	($F_{8, 63} = 7.97$, $P < 0.001$)

ANOVA

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F	p–value
Treatment	8	208.42	26.05	7.97**	0.000
Error	63	206.00	3.27		
Total	71	412.42			

**highly significant

Leaf Length. Leaf length was also significantly affected by the treatments ($F_{8,63}$ = 15.91, $P < 0.001$) (Table 2). Treatment 9 produced the longest leaves (56.99 mm), significantly outperforming all other treatments. Treatments 6, 7, and 8 showed intermediate values, whereas Treatments 1 to 5 exhibited shorter leaf lengths.

Table 3. Average leaf and length of Pechay (*Brassica rapa* L.) grown in mined–out soil amended with different levels and combinations of Carbonized Rice Hull (CRH) and Rice Hay Compost (RHC). (Note: Means with the same letter are not significant from each other).

Treatment	**Leaf Length (mm)**
1	38.81^{cd}
2	33.98^{d}
3	39.77^{cd}
4	39.29^{cd}
5	35.15^{d}
6	45.75^{bc}
7	49.48^{b}
8	46.17^{bc}
9	56.99^{a}
Grand Total	3468.44
Grand Mean	42.82
ANOVA	($F_{8, 63}$ = 15.91, $P < 0.001$)

ANOVA

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F	p–value
Treatment	8	5628.12	703.52	15.91**	0.000
Error	63	2785.12	71		
Total	71	8413.24			

** highly significant

Leaf Width. A highly significant effect of treatments on leaf width was observed ($F_{8,63}$ = 16.50, $P <$ 0.001). Treatment 9 had the widest leaves (46.96 mm), followed by Treatments 7, 8, and 6. Treatments 1 to 5 produced significantly narrower leaves (Table 3).

Table 4. Average leaf width of Pechay (*Brassica rapa* L.) grown in mined–out soil amended with different levels and combinations of Carbonized Rice Hull (CRH) and Rice Hay Compost (RHC), (Note: Means with the same letter are not significant from each other).

Treatment	**Leaf Width (mm)**
1	32.14^{d}
2	28.60^{e}
3	32.79^{d}
4	32.51^{d}
5	29.62^{e}
6	35.00^{c}
7	38.07^{b}
8	36.77^{bc}
9	46.96^{a}
Grand Total	2499.62
Grand Mean	34.72
ANOVA	($F_{8, 63}$ = 16.50, $P < 0.001$)

ANOVA

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F	p–value
Treatment	8	5421.47	677.68	16.50**	0.000
Error	63	2588.15	41.08		
Total	71	8009.62			

** highly significant

Yield Performance

Fresh Weight. The ANOVA indicated a highly significant effect of treatments on fresh weight ($F_{8,63} = 13.566$, $P < 0.001$) (Table 4). Treatment 9 recorded the highest mean fresh weight (51.46 g), which was significantly higher than all other treatments. Treatments 6, 7, and 8 produced intermediate fresh weights, while Treatments 1 to 5 showed significantly lower values ranging from 6.79 to 9.70 g (Treatment 4).

Table 5. Mean Fresh weight of Pechay (*Brassica rapa* L.) grown in mined–out soil amended with different levels and combinations of Carbonized Rice Hull (CRH) and Rice Hay Compost (RHC), (Note: Means with the same letter are not significant from each other).

Treatment	Fresh Weight (g)
1	8.53[c]
2	6.79[c]
3	9.19[c]
4	9.70[c]
5	6.97[c]
6	18.11[b]
7	23.31[b]
8	25.50[b]
9	51.46[a]
Grand Total	1276.39
Grand Mean	17.73
ANOVA	$F_{8,63} = 13.566$, $P < 0.001$

ANOVA

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F	p–value
Treatment	8	31.534	3.942	13.566**	0.000
Error	63	18.306	0.291		
Total	71	49.839			

Natural log (LN) was used ** highly significant

Biomass. Biomass data, after natural logarithm transformation, also showed a highly significant treatment effect ($F_{8,63} = 9.661$, $P < 0.001$). In general, treatments receiving higher levels of organic amendments produced greater biomass compared to treatments with lower amendment rates.

Treatment 9 yielded the highest biomass (4.15 g), significantly exceeding all other treatments. Treatments 7 and 8 formed the second group, followed by Treatment 6, while Treatments 1 to 5 recorded the lowest biomass values. These results exhibited a pattern like that observed for fresh weight.

Table 6. Mean biomass of Pechay (*Brassica rapa* L.) grown in mined–out soil amended with different levels and combinations of Carbonized Rice Hull (CRH) and Rice Hay Compost (RHC), (Note: Means with the same letter are not significant from each other).

Treatment	Biomass (g)
1	0.99[d]
2	0.72[d]
3	1.03[cd]
4	1.01[cd]
5	0.71[d]
6	1.57[bc]
7	1.95[b]
8	2.11[b]
9	4.15[a]
Grand Total	113.84

Grand Mean	1.58
ANOVA	$F_{8,63} = 9.661$, $P < 0.001$

ANOVA

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F	p–value
Treatment	8	21.881	2.735	9.661**	0.000
Error	63	17.835	0.283		
Total	71	39.716			

Natural log (LN) was used ** highly significant

DISCUSSION

Growth Parameters

The results clearly demonstrate that the application of Carbonized Rice Hull (CRH) and Rice Hay Compost (RHC) significantly improved the vegetative growth of Pechay (*Brassica rapa* L.) grown in mined–out soil, as reflected in leaf number, leaf length, and leaf width.

Treatment 9 consistently produced the highest values across all growth parameters. This treatment, composed of 60% mined–out soil, 20% RHC, and 20% CRH, provided the most favorable growing conditions. The superior vegetative performance can be attributed to improved soil fertility, enhanced nutrient availability, better moisture retention, improved soil structure, and increased microbial activity (Abdaljabar et al. 2025; Yu et al. 2024). These findings indicate that balanced and higher levels of organic amendments are most effective in enhancing plant growth.

The increase in leaf number, length, and width suggests enhanced vegetative development. Leaves are the primary sites of photosynthesis; thus, increased leaf area likely contributed to improved photosynthetic efficiency. This observation supports the findings of Goyit et al. (2023), who emphasized that leaf growth parameters are reliable indicators of plant productivity.

Treatments 6, 7, and 8 also showed improved growth compared to lower treatments, indicating that moderate to high levels of CRH and RHC positively influence vegetative development. A clear increasing trend was observed as the proportion of organic amendments increased and the percentage of mined–out soil decreased, highlighting the importance of both amendment level and balanced combination.

In contrast, Treatments 1 to 5 exhibited poor vegetative performance. These treatments contained little to no organic amendments and a higher proportion of mined–out soil, which is typically characterized by low organic matter, poor nutrient availability, and unfavorable physical properties. Such conditions limit plant growth and development (Mante et al. 2019), confirming that mined–out soils alone are insufficient for optimal crop production.

These findings demonstrate that mined–out soils can be effectively rehabilitated through the incorporation of appropriate organic amendments. The combined use of RHC and CRH provides a sustainable and cost–effective approach for improving soil fertility and promoting plant establishment in degraded mining areas.

Yield Parameters

The application of CRH and RHC also had a significant effect on the yield performance of Pechay, as reflected in fresh weight and biomass production.

Treatment 9 produced the highest fresh weight and biomass among all treatments, demonstrating a strong positive response to higher combined levels of organic amendments. The marked increase in yield suggests a synergistic effect when both CRH and RHC are applied at 20% each. This combination likely improved soil aeration, water–holding capacity, nutrient retention, and overall soil structure, thereby creating optimal conditions for root development and nutrient uptake.

Treatments 6, 7, and 8 also exhibited significantly higher yield compared to Treatments 1 to 5, indicating that moderate to high levels of organic amendments enhance plant productivity. A consistent increasing trend in fresh weight and biomass was observed as the level of organic amendments increased and the proportion of mined–out soil decreased. This trend highlights the importance of both the amount and balanced combination of CRH and RHC in maximizing crop yield.

In contrast, Treatments 1 to 5 recorded the lowest fresh weight and biomass values. These treatments had minimal or no organic amendments, resulting in poor soil conditions that restricted plant growth. Mined–out soils are generally characterized by low nutrient content, poor structure, and limited biological activity, which negatively affect plant productivity (Mante et al. 2019).

The findings are consistent with previous studies. Herencia and Maqueda (2016) reported that organic amendments improve soil nutrient content, including nitrogen, phosphorus, and magnesium, which are essential for plant growth. Similarly, Zanao et al. (2022) demonstrated that CRH enhances soil physicochemical properties, while Danapriatna et al. (2023) reported that RHC improves soil organic carbon and nutrient levels. These improvements collectively contribute to increased biomass accumulation and overall plant productivity.

Overall, the results confirm that the combined application of RHC and CRH is effective in enhancing the yield performance of Pechay in mined–out soils. Given the poor condition of mined–out soils, characterized by low fertility, poor structure, and limited biological activity (Singh et al. 2024), the use of these organic amendments offers a practical, sustainable and low–cost approach for soil rehabilitation.

From an application standpoint, mining companies and land rehabilitation practitioners may adopt the combination of 60% mined–out soil, 20% RHC, and 20% CRH as an effective soil enhancement strategy for restoring degraded mined–out lands. Government agencies such as the Department of Environment and Natural Resources (DENR), Department of Agriculture (DA), and Local Government Units (LGUs) may also incorporate these organic amendments into land restoration and reforestation programs to improve soil quality and support vegetation establishment.

Furthermore, farmers and local communities in mining–affected areas are encouraged to utilize agricultural wastes such as rice hay and rice hulls as organic soil amendments. Their combined application provides a low–cost and sustainable method for improving soil productivity in nutrient–depleted environments.

Finally, further research is recommended to evaluate the long–term effects of CRH and RHC on soil properties, microbial activity, and plant performance under field conditions. Future studies should also explore their application to other crops and native tree species to support broader land rehabilitation and ecosystem restoration efforts.

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GENERATIVE AI STATEMENT

The author used Chat GPT 4o for this research as a tool to check for grammar mistakes.

ETHICAL CONSIDERATIONS

This study was conducted with careful attention to environmental safety, ethical research standards, and responsible resource management. The mined–out soil used in the experiment was collected only from designated areas with prior permission from local authorities, ensuring that no additional environmental degradation occurs. The soil amendments, including CRH and RHC, were derived from locally available agricultural wastes, promoting sustainable and eco–friendly waste recycling practices.

All plant materials, particularly Pechay (*Brassica rapa* L.), were handled following accepted horticultural practices to ensure that no harm was caused to biodiversity or surrounding ecosystems. The study also adhered to the ethical use of pesticides, applying them in a safe, responsible, and justifiable manner to minimize potential harm to humans, non–target organisms, and the environment while still achieving their intended purpose.

Furthermore, organic wastes generated during the experiment were properly disposed of in a composting facility to support environmentally sound waste management.

DECLARATION OF COMPETING INTEREST

The authors declare that there are no competing interests to any authors.

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