



Utilization of Fruit Waste Compost to Enhance Growth and Yield of Malabar Spinach (*Basella alba*)

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Authors' contributions

This work was carried out in collaboration among all authors. Author FF developed the research concept, conducted the field work, collection and analyzed the data and wrote the original manuscript.

Authors SMB and BCS supervised, assisted with the research concept, reviewed and edited the manuscript. Author SSI prepared the Graph, assisted with analysis and edited the manuscript. Author PP assisted with the field work, data collection and writing the original manuscript. All authors read and approved the final manuscript.

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ABSTRACT

The present study was designed to investigate the effect of different decomposed fruit wastes with rates on the growth and yield of Malabar spinach (*Basella alba*). Recycling organic wastes into nutrient-rich compost can assist organic farming and maintain soil health, fertility, and productivity, as well as reduce pollution in the face of rising waste, especially in urban areas. So, the conversion

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of fruit peels into compost will be beneficial both for soil nutrition and environmental pollution from the sense of solid waste management. In this regard, an experiment was carried out to investigate the growth and yield of Malabar spinach at different composts with their rates of application. Jackfruit, banana, and mango peel compost and four different rates of application (0, 1000, 1500, and 2000 kg ha⁻¹) were undertaken as the experimental treatments. The factorial experiment was arranged in a completely randomized design with three replications. From the experiment, it was investigated that mango peel compost resulted in the highest growth and yield attributes, followed by banana and jackfruit peel compost, respectively. On the other hand, compost application at 2000 kg ha⁻¹ showed significantly higher results in growth and yield than 1500 kg ha⁻¹, 1000 kg ha⁻¹, and control, respectively. The study showed a strongly positive correlation for leaf number, shoot and root length, and plant fresh weight, but a negative or no correlation was investigated in plant dry weight for jackfruit peel compost. From the findings of this study, it can be suggested that, among the formulations, mango and banana fruit peel compost at a rate of 2000 kg ha⁻¹ is beneficial for the growth and productivity of crops. The use of seasonal fruit peels for compost preparation may reduce the waste load from the environment and ultimately minimize environmental pollution. These results, however, are limited to a single-pot trial and cannot be applied to other situations. Field tests will be the main focus of future research to support this suggestion.

Keywords: *Basella alba*; fruit peels; crop biomass; rate of compost.

1. INTRODUCTION

With the rapid growth of the population, agricultural output, byproducts, and industrialization ultimately have increased the production of organic waste significantly. These waste can be used for compost preparation, which can be applied for the improvement of soil health, promote the nutrient uptake by plant and thus improve the growth, yield and quality of crops (Ramli et al., 2023). These wastes are threatening organisms, ecosystems, and the environment by releasing toxins and harmful gasses into the atmosphere (Mgeni et al. 2024). However, the biggest concern of the global environment nowadays is the pace of waste generation and management, as the development of population and consumption results in an increase in the production of waste (Abdel-Shafy and Mansour 2018). But composting agricultural solid waste by using different living organisms such as bacteria, fungi, worms, insects, and other organisms offers an environmentally friendly, sustainable solution in this regard (Pajura 2024; Adebayo and Obiekezie 2018). Organic composts are useful for the availability of primary and secondary micronutrients for plants, soil structure, soil aeration, and the water-holding capacity of soil, as well as increasing microorganisms in the fertilized soil (Ho et al. 2022). Fruit peel compost is a good source of micro- and macronutrients, acting as a soil conditioner and a source of plant nutrition. Jackfruit, mango, and banana production and intake remain some of the major fruits worldwide people (Tsan et al. 2018; Biswas

et al. 2021; Kaur et al. 2024). Thus, the management of this peel compost will be beneficial from the sense of solid waste management (Afrin and Billah 2020). Malabar spinach (*Basella alba* L.) is a widely cultivated leafy vegetable valued for its high nutritional content and adaptability to various growing conditions. As consumer demand for nutritious and sustainably grown produce increases, there is a growing interest in enhancing agricultural practices to improve both the yield and quality of crops. Among the various agronomic practices, the use of biochar and compost has emerged as a promising approach to enhance soil fertility, improve plant growth, and contribute to sustainable agriculture (Quddus et al., 2024; Sharmin et al., 2025).

In Bangladesh, the yearly yield of jackfruit was 1,031,316 MT by 2016, with roughly 70–80% of jackfruit containing waste and by-products (BBS, 2016). Subburamu et al. (1992) reported that approximately 55–60% of the jackfruit comprises peel. Cellulose, pectin, protein, and starch make up about 27.75%, 7.52%, 6.27%, and 4% of jackfruit peel, respectively (Sundarraj and Ranganathan, 2017). Similar to this, Subburamu et al. (1992) made a meal out of the central core of jackfruit and found that the primary proximate compositions were crude fiber (15.9%), crude protein (10.6%), and carbohydrates (20.5%).

One ton of banana waste contained 15 kg N, 7 kg P, and 23 kg K, according to Doran and Kaya (2005). Furthermore, Teshome (2022) found that banana leaves before composting contained organic carbon (14%), nitrogen (1.49%),

hydrogen (5.2%), phosphorus (4.65 mg kg⁻¹), and potassium (34 mg kg⁻¹). Total N (0.95%), organic C (15.34%), P (0.23%), K (0.72%), Mg (0.10%), Ca (1.04%), Fe (28.91 mg l⁻¹), and Mn (1.13 mg l⁻¹) were all examined for mango peel compost by Tsan et al. (2018). Mango, banana, and jackfruit peel wastes therefore improve soil fertility and health, boost agricultural output, boost soil biodiversity, and lower environmental hazards (Wanapat et al., 2024). Composting these peel wastes has many advantages, including increasing organic matter, boosting soil microbial activity, improving water-holding capacity, increasing crop yields, and being an affordable source of nutrients. Considering the above facts, this study was designed to investigate the effect of different decomposed fruit wastes with rates on the growth and yield of Malabar spinach (*Basella alba*).

2. MATERIALS AND METHODS

2.1 Soil Collection and Analysis

The experiment was carried out from September 2021 to April 2022 in the net house of the Soil, Water, and Environment Discipline at Khulna University, Bangladesh (GPS coordinates 22°48'07.4"N and 89°31'58.1"E). Soil samples were collected from the university campus, and samples were air-dried, ground, and sieved using a 2 mm sieve. Soil properties, including texture (Gee and Bauder, 1986), pH (Jackson, 1973), EC (Allison and Richards, 1954), soil organic carbon (Walkley and Black, 1965), and cation exchange capacity (Jackson, 1962), of the soil were determined in the laboratory of Khulna University, Bangladesh. The initial soil (used for pot filling) properties have been analyzed and presented in Table 1.

Table 1. Physicochemical properties of the initial soil used for pot filling

Properties of soil	Parameters
Sand (%)	6.69
Silt (%)	30.27
Clay (%)	63.04
pH	6.70
EC (dS m ⁻¹)	1.09
CEC (meq/100g)	933.30
OM (%)	1.80

2.2 Experimental Design

A completely randomized design with three replications for each treatment was applied to investigate the growth and yield attributes of different peel compost and doses. Malabar

spinach (*Basella alba*) was selected to be tested in the experiment. Three types of fruits peel include jackfruit, bananas, and mangos were selected for composting. Three different composts (jackfruit, banana, and mango) with three different doses (1000, 1500, and 2000 kg ha⁻¹) were undertaken, with a control pot receiving no compost for conducting this experiment.

2.3 Compost Preparation

Peels from jackfruit, bananas, and mangos were collected from restaurants, households, and fruit market areas. The collected fruit peels were properly cleaned with tap water to get rid of any impurities and then allowed to dry under shed at room temperature for three weeks, reaching a 60% drying rate. After that, the peels were chopped into tiny pieces (1-5 cm) and placed in different bags in the ground for a period of four months. The bags were covered to prevent excessive evaporation, and watering was done on a regular basis to avoid dehydration. Every 21 days (three weeks), the undecomposed materials were mixed by hand to ensure consistent distribution. The composting process was monitored and assessed until the compost was ready to use. The compost's color and odor were used to determine its decomposition.

2.4 Tested Plant

Malabar spinach (*Basella alba*) is a perennial vegetable with a quick growth rate that is frequently grown in tropical and subtropical areas (Ramli et al., 2023). Depending on the type, its heart-shaped, succulent, thick leaves and stems can be either green or reddish-purple. Small, meaty, white or purple flowers and dark purple berries are produced by the shrub. In ideal circumstances, it produces 4–6 t ha⁻¹ (Chaurasiya et al., 2021). Minerals, including calcium, iron, and potassium, as well as vitamins A, C, and B-complex, are abundant in Malabar spinach. Among its many health advantages are its high levels of protein, dietary fiber, and antioxidants (Adhikari et al., 2012). Because of its moist leaves and bioactive ingredients, it's a great option for boosting health and nutrition.

2.4 Seed sowing and crop management

Seeds of Malabar spinach were sown on 3rd March, 2022, where the plants were harvested on 10 April 2022. Weather data of the plant growth period were collected from Khulna Meteorological Station, the nearest weather station to the experimental site (Fig. 1).

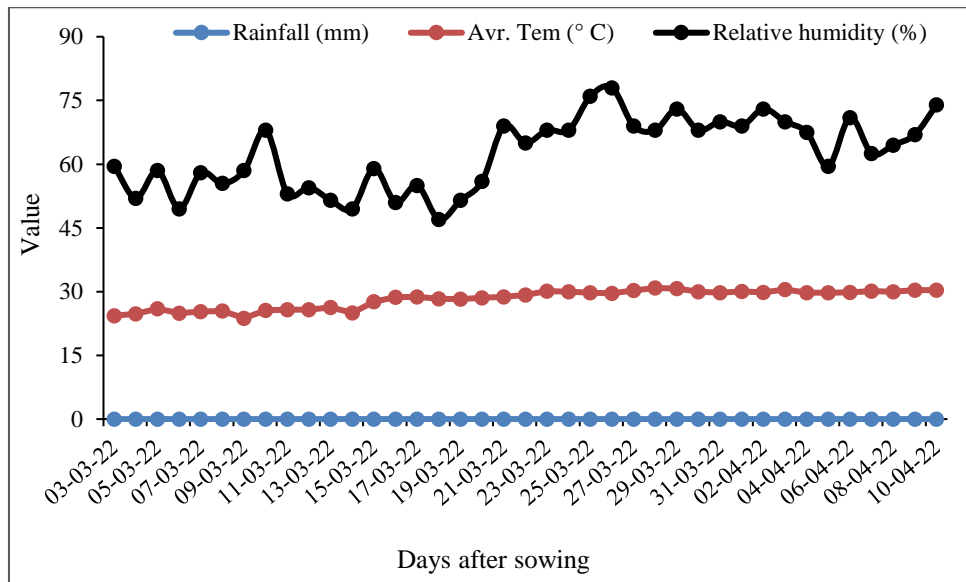


Fig. 1. Daily rainfall, daily average temperature and relative humidity during the period of the experiment (3 March, 2022 to 10 April, 2022 a total growing period of 39 days). Weather data were collected from Khulna Meteorological Station, the nearest weather station from the experimental site

There was no additional fertilizer added in the pots except the treatments. Seeds were evenly distributed in the earthen pot and sown at an appropriate depth, then covered with soil. The seeds began to sprout within 9-12 days after sowing. Five plants were preserved in each pot after germination for the investigation of growth and yield attributes against the composts and different doses. Bermuda grass (*Cynodon dactylon*) was seen in the pot, and weeding and thinning were done as necessary, as well as water was provided to each pot as needed to maintain sufficient moisture for normal crop growth. Plots were routinely monitored for changes in crop development and other characteristics. Pesticides were not applied throughout the experiment, and no pest attacks were seen.

2.5 Statistical Analyses

The collected, calculated and measured data were compiled and analyzed following analysis of variance (ANOVA) techniques (One-way and two-way) using the statistical computer software 'Statastix 10'. The means among the treatments were compared by all pairwise comparisons by least significant difference (LSD) at 95% confidence level. The figures have been constructed using MS Excel (Microsoft Office 2016).

3. RESULTS

3.1 Effect of Compost Types and their Rates on Growth and Yield Attributes of Malabar Spinach

Growth and yield Attributes were found to be statistically significant in the case of different doses of fruit peel composts as well as types of peel composts. The study showed a positive correlation with leaf number (LN), shoot length (SL), root length (RL), and plant fresh weight (PFW) against different types of compost and different doses, whereas a negative correlation was found for plant dry weight (PDW) in this experiment (Figs 2, 3, and 4).

3.2 Effect of Compost Types and Their Rates on Yield and Dry Matter Accumulation of Malabar Spinach

In the case of yield properties, mango peel compost @ 2000 kg ha⁻¹ showed the highest PFW (30.78 g pot⁻¹), and PDW (1.77 g pot⁻¹), which were statistically significant compared with the other compost doses, where the lowest result was found at 6.59 g pot⁻¹ for PFW (Table 3). Likewise, the growth and yield attributes within different doses of the same compost were also ranked highest at 2000 kg ha⁻¹, followed by 1500 kg ha⁻¹ and 1000 kg ha⁻¹.

Table 2. Interaction effect of compost types and their rates on growth parameters of Malabar spinach

		Leaf number \pm SD	Shoot length \pm SD	Root length \pm SD
Control (No compost)		3.16 \pm 0.10 f	8.08 \pm 1.00 f	6.92 \pm 0.98 de
Jackfruit peel compost	1000 kg ha ⁻¹	4.78 \pm 0.38 e	8.30 \pm 0.46 ef	8.76 \pm 0.47 de
	1500 kg ha ⁻¹	5.78 \pm 0.51 d	9.59 \pm 1.01 de	9.46 \pm 0.35 cd
	2000 kg ha ⁻¹	7.11 \pm 0.69 b	12.26 \pm 1.17 bc	10.89 \pm 1.11 ab
Mango peel compost	1000 kg ha ⁻¹	5.89 \pm 0.19 cd	10.56 \pm 0.77 cde	9.61 \pm 0.19 cd
	1500 kg ha ⁻¹	6.78 \pm 0.69 bc	12.83 \pm 2.05 abc	8.62 \pm 1.56 e
	2000 kg ha ⁻¹	8.67 \pm 1.00 a	14.44 \pm 3.03 ab	12.94 \pm 1.86 a
Banana peel compost	1000 kg ha ⁻¹	5.11 \pm 0.51 de	11.00 \pm 0.50 cd	8.22 \pm 0.69 de
	1500 kg ha ⁻¹	7.33 \pm 0.33 b	11.67 \pm 2.03 cd	10.86 \pm 0.43 bc
	2000 kg ha ⁻¹	8.22 \pm 0.51 a	15.00 \pm 1.96 a	11.39 \pm 1.42 ab

Here, SD represent standard deviation. In each column, values sharing similar letter(s) do not differ significantly while dissimilar letter(s) differ significantly

Table 3. Interaction effect compost types and their rates on dry matter accumulation of Malabar spinach

Compost type	Rate (kg ha ⁻¹)	Shoot weight (g) \pm SD	Plant fresh weight (g) \pm SD	Plant dry weight (g) \pm SD
Control (No compost used)		5.95 \pm 1.46 g	6.59 \pm 1.71 g	0.43 \pm 0.13 f
Jackfruit peels compost	1000	9.64 \pm 1.42 f	10.00 \pm 1.56 f	0.54 \pm 0.03 ef
	1500	13.86 \pm 0.46 de	15.28 \pm 0.38 de	0.88 \pm 0.19 cd
	2000	23.5 \pm 0.50 b	25.5 \pm 0.50 b	1.36 \pm 0.17 b
Mango peels compost	1000	11.14 \pm 0.66 f	12.39 \pm 0.98 f	0.67 \pm 0.08 de
	1500	16.28 \pm 3.00 c	17.95 \pm 2.57 c	0.98 \pm 0.10 c
	2000	28.72 \pm 0.90 a	30.78 \pm 0.86 a	1.77 \pm 0.18 a
Banana peels compost	1000	11.82 \pm 1.09 ef	12.75 \pm 1.56 ef	0.65 \pm 0.14 def
	1500	15.00 \pm 0.94 cd	16.42 \pm 1.19 cd	1.03 \pm 0.13 c
	2000	25.54 \pm 1.37 b	28.00 \pm 2.00 b	1.59 \pm 0.36 ab

Here, SD represent standard deviation. In each column, values sharing similar letter(s) do not differ significantly while dissimilar letter(s) differ significantly

Treatment	Treatment	LN	SL	RL	PFW	PDW
Treatment	1					
LN	1.00	1				
SL	0.93	0.91	1			
RL	0.99	1.00	0.89	1		
PFW	0.97	0.96	0.99	0.95	1	
PDW	-0.18	-0.25	0.17	-0.29	0.03	1

Fig. 2. Pearson correlation matrix among growth and yield attributes against different rates for jackfruit peel compost on Malabar spinach. The green, red and yellow color represents positive, negative, and neutral correlation, respectively. Here, L N, S L, R L, P F W, P D W represents leaf number, shoot length, root length, plant fresh weight, plant dry weight, respectively

Treatment	Treatment	LN	SL	RL	PFW	PDW
Treatment	1					
LN	0.98	1				
SL	1.00	0.98	1			
RL	0.87	0.91	0.84	1		
PFW	0.98	0.95	0.95	0.93	1	
PDW	0.12	-0.02	0.03	0.19	0.28	1

Fig. 3. Pearson correlation matrix among growth and yield attributes against different rates for mango peel compost on Malabar spinach. The green, red and yellow color represents positive, negative, and neutral correlation, respectively. Here, L N, S L, R L, P F W, P D W represents leaf number, shoot length, root length, plant fresh weight, plant dry weight, respectively

Treatment	Treatment	LN	SL	RL	PFW	PDW
Treatment	1					
LN	0.99	1				
SL	0.97	0.94	1			
RL	0.97	0.99	0.90	1		
PFW	0.97	0.92	0.99	0.90	1	
PDW	0.01	-0.09	-0.03	-0.02	0.12	1

Fig. 4. Pearson correlation matrix among growth and yield attributes against different rates for banana peel compost on Malabar spinach. The green, red and yellow color represents positive, negative, and neutral correlation, respectively. Here, L N, S L, R L, P F W, P D W represents leaf number, shoot length, root length, plant fresh weight, plant dry weight, respectively

respectively. The second highest result of PFW (28.00 g pot⁻¹), and PDW (1.59 g pot⁻¹) was obtained for banana peel compost @ 2000 kg ha⁻¹

Among the different types of fruit composts, the highest growth and yield attributes were found significantly higher for mango peel compost as compared with jackfruit peel compost, but it was

insignificant with banana peel compost. Leaf number, root length, shoot length, PFW, and PDW of mango peel were observed to be 7.11, 12.61 cm, 10.56 cm, 20.37 g pot⁻¹, and 1.14 g pot⁻¹, respectively, whereas the lowest value was observed to be 5.89, 10.05 cm, 9.70 cm, 15.66 g pot⁻¹, 17.06 g pot⁻¹, and 0.93 g pot⁻¹, respectively, for jackfruit peel compost (Figs 5 A & B).

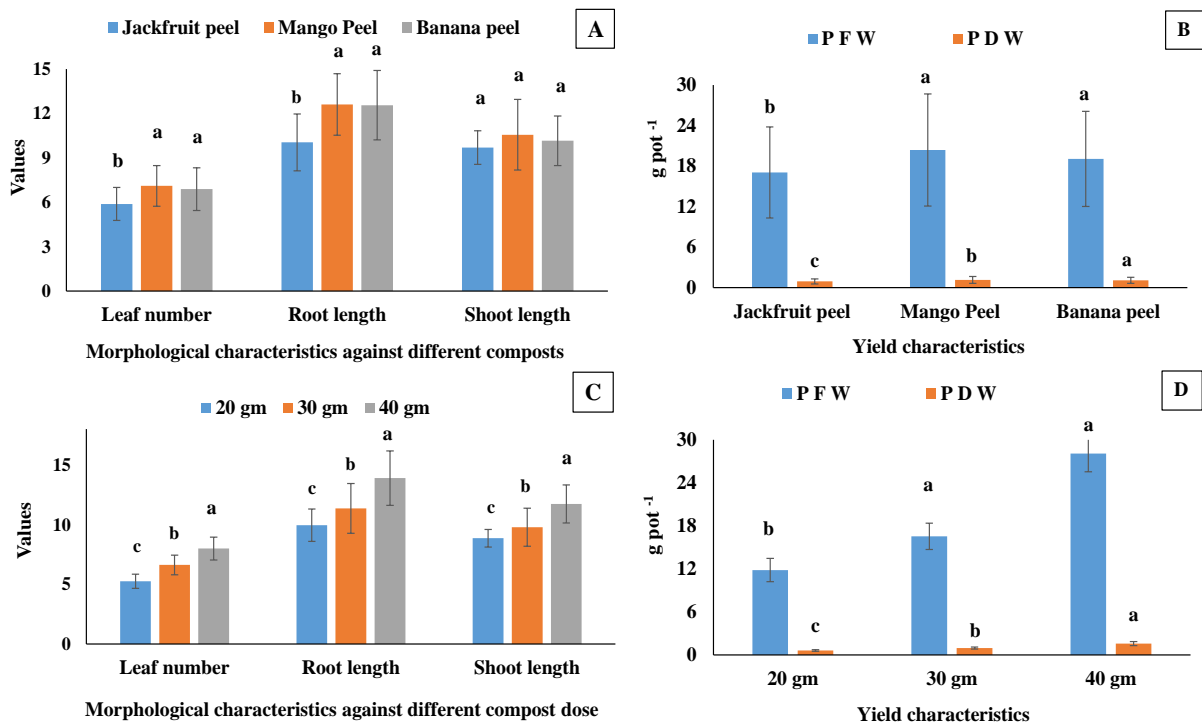


Fig. 5. Growth and yield attributes of Malabar spinach; (A) leaf number, root and shoot length against different composts; (B), plant fresh weight (PFW) and dry weight (PDW) against different composts; (C) leaf number, root and shoot length against different rates; (D), plant fresh weight (PFW) and dry weight (PDW) against different rates. A bar of each figure having similar letter(s) do not varied significantly whereas, dissimilar letter(s) varied at 5% level of probability. The error bar represents standard error

On the contrary, among different compost doses, 2000 kg ha⁻¹ produced the highest growth and yield attributes as compared with the other composts. Leaf, root length, shoot length, PFW, and PDW of mango peel were observed at 8.00, 13.90 cm, 11.74 cm, 28.09 g pot⁻¹, and 1.58 g pot⁻¹, respectively, whereas the lowest value was observed at 5.25, 9.95 cm, 8.86 cm, 10.86 g pot⁻¹, 11.84 g pot⁻¹, and 0.62 g pot⁻¹, respectively, for jackfruit peel compost (Figs 5 C & D). Leaf number, shoot and root length @2000 kg ha⁻¹ accounted for a 34.26, 28.40, and 25.51% increase compared with @1000 kg ha⁻¹, whereas a 57.85, and 60.58% increase in PFW, and PDW was observed for applying @2000 kg ha⁻¹ compared with @1000 kg ha⁻¹.

4. DISCUSSION

The analysis of the soil sample confirms that it's clay-textured soil with moderate organic carbon and high cation exchange capacity, which was also investigated by Nasrin et al. 2023. Though there was no additional fertilizer added to the experiment during the study period, plant

nutrition was covered by the nutrients in the soil. The highest growth and yield attributes were observed for 2000 kg ha⁻¹ treatment whereas opposite results have been obtained for control where there was no addition of any types of compost. Among the composts, the growth and yield of Malabar spinach were significantly higher in mango and banana peel compost than jackfruit peel composts.

The study showed a strongly positive correlation for leaf number, shoot and root length, and plant fresh weight, but a negative or no correlation was investigated in plant dry weight for jackfruit peel compost. A similar result was also observed for mango peel and banana peel compost in this study. Similar finding also reported by Sakpere et al., (2018) that fruit peels considered to be a promising organic fertilizers in respect of leaf area and shoot height were enhancement. According to different compost doses, leaf number was positively correlated where linear regression was observed: R² = 0.88, R² = 0.91, and R² = 0.92 for jackfruit, mango, and banana peel, respectively (Fig. 6 A, B, and C). Similarly,

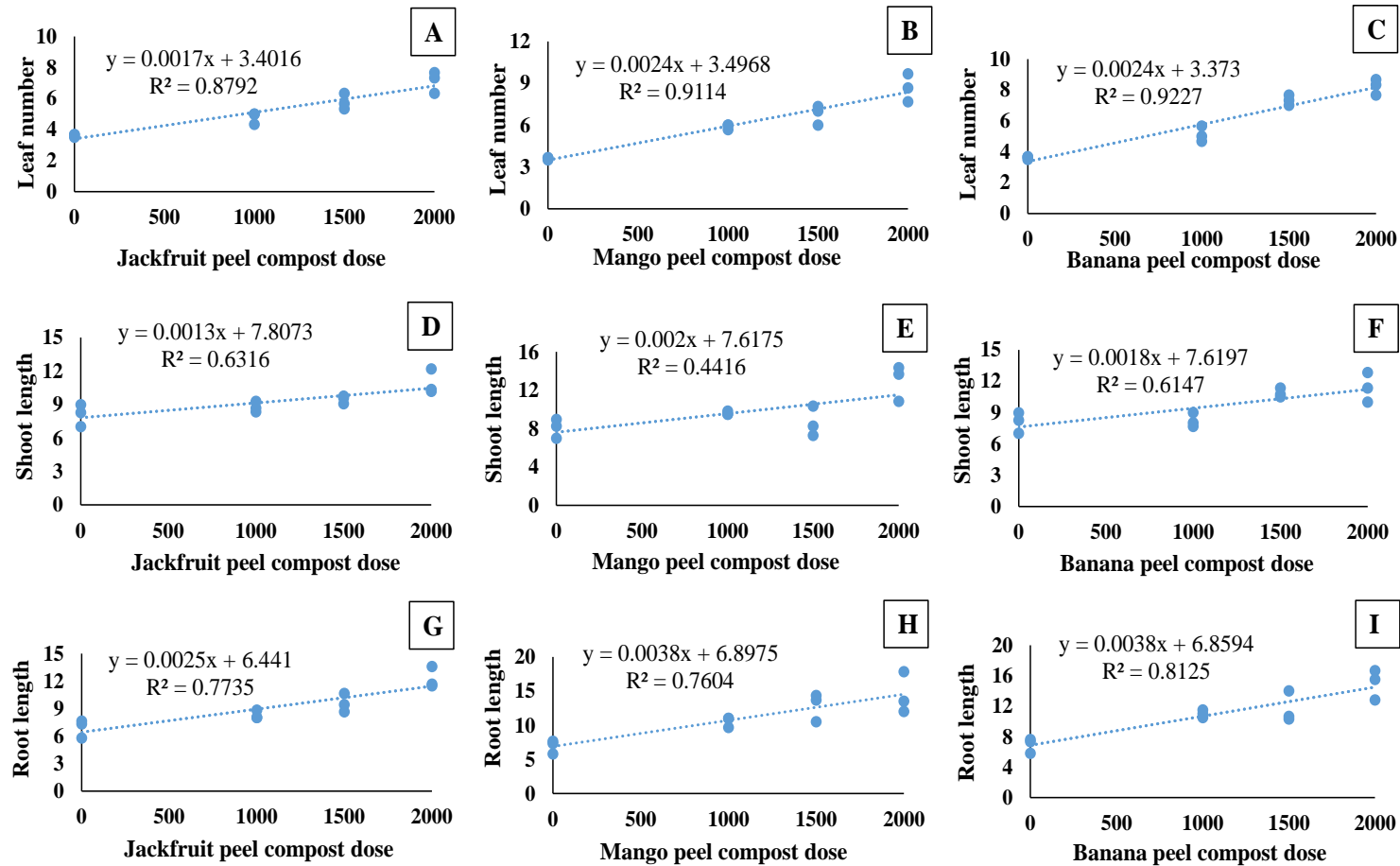


Fig. 6. Regression analysis of growth of Malabar spinach; Relationship of leaf number with Jackfruit peel compost (A), Mango peel compost (B) and banana peel compost (C); Relationship of shoot length with Jackfruit peel compost (D), Mango peel compost (E) and banana peel compost (F); Relationship of root length with Jackfruit peel compost (G), Mango peel compost (H) and banana peel compost (I). The dotted lines are fitted by linear regression

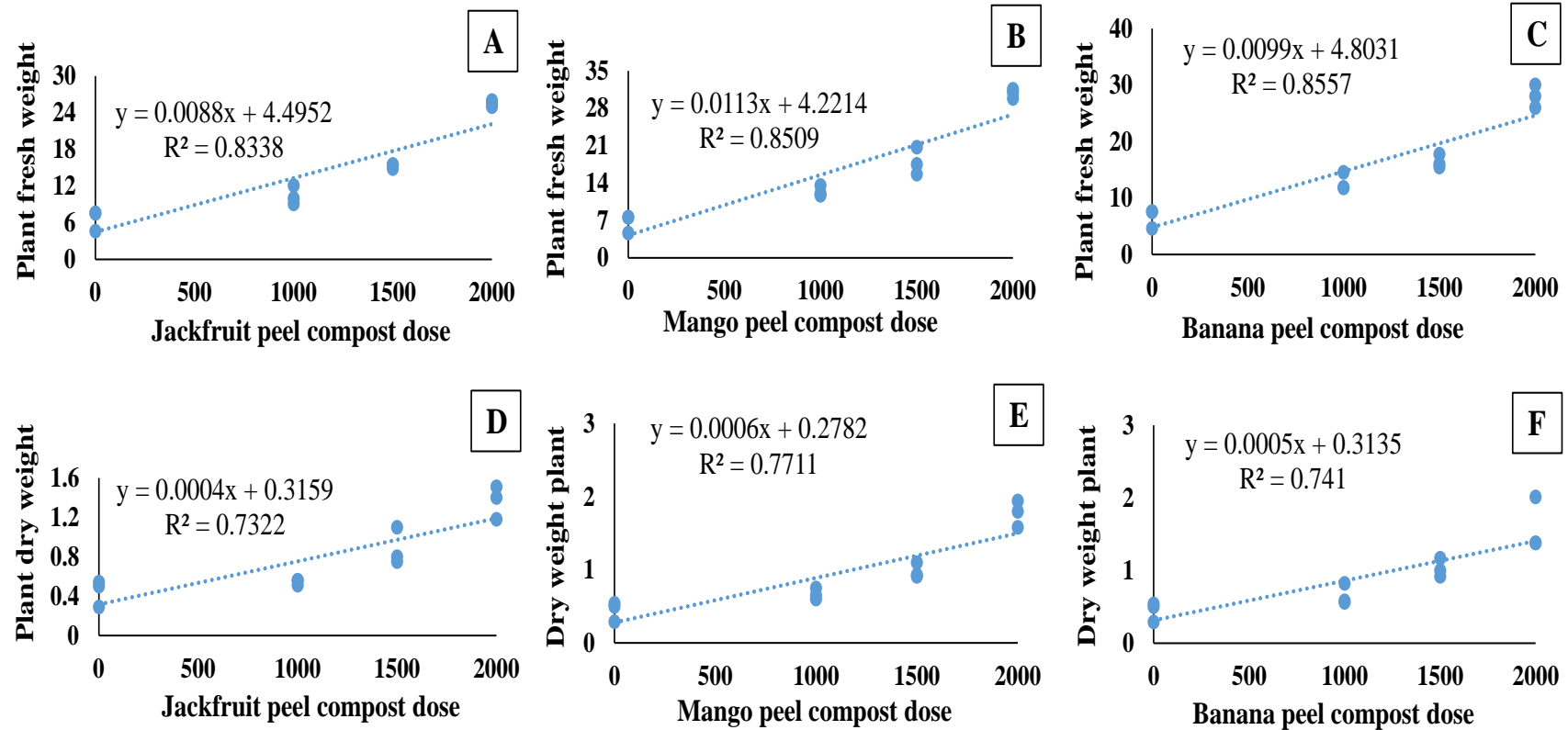


Fig. 7. Regression analysis of yield attributes of Malabar spinach; Relationship of plant fresh weight with Jackfruit peel compost (A), Mango peel compost (B) and banana peel compost (C); Relationship of plant dry weight with Jackfruit peel compost (D), Mango peel compost (E) and banana peel compost (F). The dotted lines are fitted by linear regression

for shoot length, it was also positively correlated, and $R^2 = 0.63$, $R^2 = 0.44$, and $R^2 = 0.61$ were observed for jackfruit, mango, and banana peel, respectively (Fig. 6 D, E, and F). The other morphological attribute root length showed a obtaining a value of $R^2 = 0.86$ (Fig. 7, F). In the case of plant dry weight, it was negatively correlated with different compost doses, and the R^2 value was obtained: $R^2 = 0.73$, $R^2 = 0.77$, and $R^2 = 0.74$, respectively (Fig. 7, G and I). Throughout the study, all the rates of compost treatments were better than the no compost control with respect to all growth parameters. Variation in growth and yield was due to the nutrient uptake of plants from the soil, where a high dose of fertilizer may release the highest amount of available nutrients for plants. Afrin and Billah (2020) reported that 2000 kg ha⁻¹ decomposed orange peel compost performed better than 1000 and 1500 kg ha⁻¹ for the growth and yield of Red Amaranth. Another study by Teshome (2022) investigated 1500 kg ha⁻¹ banana peel compost, which obtained a higher result than that of 1000 and 500 kg ha⁻¹ on Swiss chard growth. On the other hand, Muchena et al. (2021) obtained the best growth in 30 t ha⁻¹ compared to 10 and 20 t ha⁻¹ in the case of mushroom substrate application.

Among the composts, mango peel compost performs the best morphologically due to the fact that it has a relatively higher nutrient content than the other peel composts, which may stimulate plant growth. Our study aligns with Tsan et al. (2018), who investigated mango, fish wastes, and sugar compost extract of 2:1:1 applied to soil, which gives better plant growth than the other ratios of 1:1:1 and 3:1:1. A study of Tran et al. 2021 proposed that jackfruit fiber mixed with coconut fiber resulted in better results than the other composts. Though we have obtained mango peel compost as the best contributor, Khairnar and Nair (2019) investigated banana peel powder as the best organic fertilizer, better than eggshell and sweet lime powder. The results of the study were similar to the findings of Teshome (2022), Civeira (2010), Imthiyas and Seran (2014).

5. CONCLUSION

Compost is one of the best sources of organic matter for improving soil health. The growth and biomass accumulation of Malabar spinach were substantially influenced by the application of different types and rates of compost made from different types of fruit peels. From the findings of

strong positive correlation with jackfruit, mango, and banana peel, having values of $R^2 = 0.77$, $R^2 = 0.76$, and $R^2 = 0.81$, respectively (Fig. 6 G, H, and I). From the study, plant fresh weight was strongly correlated with a linear regression this research, we can conclude that compost prepared from mango and banana peels at a rate of 2000 kg ha⁻¹ suitable for crop growth and biomass accumulation. Additionally, the use of seasonal fruit peels for compost preparation may reduce the waste load from the environment and ultimately minimize the environmental pollution. These results, however, are limited to a single-pot trial and cannot be applied to other situations. Field tests will be the main focus of future research to support this suggestion.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

All the authors of this article hereby declared that any kind of generative AI technologies (ChatGPT, COPILOT etc.) and text-to-image generators have not been used throughout the writing and editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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