Growth and Yield of Screenhouse-grown potted Pechay (*Brassica rapa* L. ssp. *chinensis* cv. Black Behi) in selected Davao-produced Composts

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Abstract

Pak choi (Brassica rapa subsp. chinensis), locally called pechay, is a nutritious and sought-after vegetable among Asian consumers as its edible petioles and green leaves are suitable in various recipes. The use of composts and organic amendments is integral to organic agriculture which is promoted in Davao City, Philippines. However, there are no published local studies in the city on the effect of recently formulated composts on crops. Thus, this study explored how these compost amendments affect the growth and yield of potted Black Behi pechay under screenhouse conditions using a completely randomized design. Results revealed that germination was higher in seeds sown in pure potting mix (90 to 94 %) and vermicompost-amended potting mixes (94 to 100 %) than with Dr. Bo's Biofertilizer (DBB) (75 to 92%). Mean plant height (18.42 cm), leaf length (10.31 cm) and leaf width (5.89 cm) were highest in plants grown in potting mixes amended with 20% Tacunan vermicompost (Tacunan). Furthermore, there were pest and disease incidences in plants under all treatments but the least incidence was observed in plants grown in DBB. Total fresh weight (14.71 g), dry weight (0.76 g) and marketable fresh weight (12.19 g) obtained were exhibited by plants grown in 20% Tacunan. Total biomass, however, was highest in the urea-amended potting mix (15.42%). Results revealed that the application of composts positively influenced the growth and development of Black Behi pechay with 20% Tacunan as the recommended amendment.

Keywords: compost, germination, organic farming, pak choi, Philippines

1. Introduction

Non-heading Chinese cabbage or pak choi (*Brassica rapa* subsp. *chinensis*) was first grown in 5th century China as a distinct subspecies under the family Brassicaceae (Laczi *et al*., 2011). Worldwide, cabbage and other *Brassica* cultivation were estimated at 2.4 M ha with 69.4 M tons of production in 2018 (Food and Agriculture Organization of the United Nations STAT [FAOSTAT], 2019). The main producers are from the southern and central regions of China and Taiwan (Dixon, 2006) with China as the lead producer (FAOSTAT, 2019) while the Philippines contributes to Brassica cultivation at around 121,000 tons for 7,800 ha of land (FAOSTAT, 2019). Native pechay production in the Philippines is around 47,500 metric tons in 2020 (Philippine Statistics Authority, 2020).

Pechay, the local name for pak choi (Ragasa *et al*., 2016), has several cultivars in the country including rapid maturing 'Black Behi,' which has long, slender and succulent petioles (Jimenez *et al*., 2016). Flavonoids, hydroxycinnamic acids and glucosinolates are the primary bioactive components of pechay and have significant antioxidant activity as supported by previous phytochemical studies (Cartea *et al*., 2011). Glucosinolates in pechay are also known to be inhibitory against cancer (Zang *et al*., 2015; Ragasa *et al*., 2016). For every 100 g of the edible portion of pechay, 252-mg potassium, 1.0-g dietary fiber, 105-mg calcium, 65-mg sodium, 45-mg vitamin C and 19-mg magnesium were found (United States Department of Agriculture, 2014). Because of such nutritional value, immature pechay leaves are incorporated in making salad dishes, while leaves and petioles of mature plants can be partnered in boiled vegetable soups (Opeña *et al*., 1988), or cooked by stir-frying or steaming (Myers *et al*., 1998).

Globally, food demand is increasing; hence, farmers have devised various approaches to agriculture (Staugaitis *et al*., 2008). Chemical fertilizers have long been considered to be the most efficient means of increasing crop yields across the world; however, their adverse effects on the soil, water and habitat restrict their usage in long-term cultivation practices (Adekiya and Agbede, 2017). Under sustainable agriculture, growers apply alternative cost-effective methods such as crop rotation, biological pest control and the use of composts and organic fertilizers, which help reduce negative environmental implications (Siavoshi *et al*., 2010). As such, organic farming is becoming popular with 35,000 organic farms in about 14,000 ha in the Philippines last 2013 (Tamayo *et al*., 2013).

This sustainable farming method gave the opportunity for studies on organic farming such as cucumber production in Claveria, Northern Mindanao (Elmundo *et al*., 2015) in response to the demand for organic produce in the country (Tamayo *et al*., 2013). In vermicomposting, the interaction between earthworms and microorganisms decomposes solid organic waste yields an organic fertilizer, which provides additional nutrients required for plant growth (Sudrajat *et al*., 2021). On the other hand, a high-temperature composting method uses thermophilic bacteria strains such as YMO81T for *Calditerricola satsumensis* and YMO722T for *Calditerricola yamamurae* (Moriya *et al*., 2011). High-heat composting was introduced in Davao City in 2017 by Davao Thermo Biotech Corporation (DTBC). Available under the brand name Dr. Bo's Biofertilizer (DBB), DTBC compost is a mixture of biodegradable garbage of Davao City including animal, vegetable and fruit wastes (R. Puentespina Jr., personal communication, March 17, 2017).

While plants may only require very small amounts of nutrients, soluble mineral nutrients obtained from soil amendments such as manure in soil improve plant growth (Waniyo *et al*., 2013; Han *et al*., 2016) and organic fertilizers improve vegetable yield (Li *et al*., 2017). Amendments enhance yield and nutritive quality aside from plant health due to the beneficial impacts of compost on the soil microbiome (Pant *et al*., 2009). To date, there is no published scientific study on the effects of locally available composts on screenhouse pechay production in Davao City. This is because pechay is conventionally grown in the open field (Gonzaga *et al*., 2017) under conventional farming with inputs such as synthetic fertilizers and pesticides. With the decline in agricultural lands and the rise of modern farming techniques, the Davao City Agriculture Office promotes organic agriculture and urban/container gardening. Hence, this study aimed to investigate the effects of three locally-produced composts on the growth and yield of screenhouse-grown potted Black Behi pechay.

2. Methodology

2.1 Place of Study

Pechay seeds were germinated and seedlings were transplanted and grown in pots in the screenhouse of the University of the Philippines Mindanao in Davao City, Philippines. Postharvest assessment of the harvested crops was done in the Severo T. Bastian Jr. Plant Science Laboratory of the College of Science and Mathematics. Soil and compost samples were sent to the Bureau of Soils and Water Management Laboratory of the Department of Agriculture Region XI (DA-XI-BSWML) for analysis before cultivation.

2.2 Cultivar, Potting Mix, Treatment Preparation and Soil Analyses

Black Behi (Ramgo®, Ramgo International Corporation, Philippines), a cultivar that may be grown year-round and with 25- to 30-day maturity period (Jimenez *et al*., 2016) was used in this study. The basal potting mix was composed of three parts topsoil, four parts garden soil and three parts charcoaled rice hull. All these materials were locally sourced. The succeeding sources and components were used to make compost amendments at 10% and 20% w/w concentrations: a) Department of Agriculture XI – Bureau of Animal Industry (DA) vermicompost, which mainly uses horse and cow manure mixed with plant biomass like fallen leaves, vegetable, fruit wastes and coconut husk fiber; b) Tacunan (Tacunan) vermicompost, which is commercially available vermicompost from a private farm in Barangay Tacunan, Tugbok District, Davao City that uses goat and cow manure mixed with plant wastes such as vegetable scraps and fruit peels; and c) DBB (Davao Thermo Biotech Corporation, Philippines) high-heat compost – a heterogeneous mix of Davao City biodegradable wastes composted under high temperatures using thermophilic bacteria (YMO strain) in Barangay Binugao, Toril, Davao City. After two trials on seed germination, 20% DBB consistently resulted in very low germination at 0 to 5%. As such, the concentration for DBB treatments was reduced from 10% DBB to 5 and 20% DBB to 10% to achieve at least a 75% germination rate.

A treatment with urea was also prepared to represent conventional nutrient amendment with a recommended dose for a starter solution of 4 g per L of water. After transplanting, plants were given a basal application of 0.36-g urea per 25 x 25 cm polyvinyl chloride pot at bi-weekly intervals, which served as the positive control. The negative control was basal potting mix alone without any nutrient amendment.

Composite samples of basal potting and potting mix from bulk mixes of each treatment were then collected using a garden shovel and placed inside sterile polypropylene bags. A total of 1 kg for basal potting mix and 1 kg for each treatment was packed in polyethylene bags for physical and chemical analyses by the DA XI-BSWML.

2.3 Cultivation and Environmental Conditions

A single-layered shade net overhead the screen house was covered by a polyethylene sheet which helped mitigate the effects of rainfall. Plants were grown with a mean relative humidity of 36% (VWR Traceable Hygrometer, VWR International, United States), 32 °C mean temperature, and 8,440 lux mean light intensity (Sper Scientific Light Meter, Sper Scientific Direct, United States). Watering was done through a dipper using stored deep well water with frequency based on the substrate being formed into a ball without dispersing. Weeds and potential pests were manually removed weekly; no pesticides were applied since infested plants were below the 5% population threshold level.

2.4 Seedling Production, Crop Establishment and Harvest

Seeds were germinated and seedlings were grown in 32-hole polyethylene trays with each hole at 2.5-cm diameter. Each treatment had two replicate trays or a total of 64 holes with one seed per hole. Upon sowing, seeds were placed at a small depression in the soil with a depth of around 5 mm per hole. Seeds were then lightly covered with soil. Seed trays were randomly placed in the screenhouse; each was covered with clear plastic wrap, which was removed when small green shoots started to appear. Seedlings at 15 days after sowing (DAS) were transplanted to 25 x 25 cm polyvinyl chloride pots at one seedling per pot. Harvesting was done as suggested by Jimenez *et al.* (2016) at 49 DAS.

2.5 Data Collection

2.5.1 Germination

After the first day of sowing, pechay seeds were checked daily for epicotyl emergence. Emerged seeds were treated as germinated; data were recorded daily until 15 DAS.

2.5.2 Growth and Development Parameters

Leaf length was measured along the midrib from the tip of the lamina to the point where the petiole and lamina intersected. Leaf width, on the other hand, was measured perpendicular to the midrib from both ends between the broadest lobes of a lamina. Plant height was determined from the base of the shoot or the top of the soil to the tip of the longest pechay leaf. The measurement of leaf parameters was based on the methods of Kalisz *et al.*

(2013). Leaf characteristics were measured weekly using a ruler and approximated within one decimal place (0.1 cm) for length, width and height – similar to the methods employed by Rouphael *et al.* (2010). One modification in the study is that for the leaf length and width, the middle leaf was measured from the first week after transplant towards the juvenile phase within two months until harvest. Observable leaf color per week was accounted for using a devised leaf color scale of 3 for dark green, 2 for medium green and 1 for light green based on the leaf color range observed. For the incidence of damages caused by pests or diseases, a devised damage scale was used with the following scoring system: 1 for no pest/disease incidence, 2 for 1 to 10% of the population per treatment with pest or disease damage, 3 for >10 to 20% of population per treatment, 4 for > 20 to 30% of population per treatment and 5 for > 30% of population per treatment.

2.5.3 Harvest Parameters

Fresh Weight and Total Biomass

Samples used for fresh weight determination were processed following the methods of Pan and Sasanatayart (2016). Upon harvest, plants were lightly rinsed with water and then drained to remove attached soil particles prior to fresh weight and dry biomass determination loosely based on the methods of Kalisz *et al.* (2013). Modifications from the original methods were employed in the study wherein aboveground shoot parts such as petiole and leaves; roots were separated before assessment of fresh weight. Damaged and non-marketable petiole and leaf biomass were also separated and measured. All parts recorded for fresh weight were then placed in a dry paper bag and dried in an oven (FN120, NÜVE, Turkey) at 70 °C for 72 h.

Marketability and Yield

Data for total leaf count were acquired by monitoring the number of leaves that reached at least 1 cm in length in every plant under each replicate of treatment regardless of quality. Leaves with no mechanical or pest and disease damages were included among marketable leaves. Deformed and undersized leaves with visible damages were also accounted for in every plant. The total yield at harvest on each treatment was measured as the sum of all fresh weights per treatment (Kalisz *et al.*, 2013).

2.6 Experimental Design and Data Analysis

The experiment was laid out in a completely randomized design with eight nutrient treatments (six with composts, one with urea and one with potting mix alone). Statistical Package for Social Sciences (SPSS) version 22 (International Business Machines (IBM) Corp., 2013) was used for descriptive statistics, multivariate analysis of variance of growth and harvest parameters and Duncan's multiple range test for mean comparison at α = 0.05 for all parameters.

3. Results and Discussion

3.1 Seed Germination Percentage

The germination percentage for seeds grown under various treatments was statistically significant (α < 0.05) for all observed days. At 3 DAS, seeds under 20% Tacunan vermicompost and positive control registered the highest percent germination although it did not vary with 10% DA vermicompost and Tacunan while 10% amendment of DBB had the least germination (Table 1). At five DAS, all seeds under 20% Tacunan germinated while 20% DA vermicompost lagged in germination at 86%. Upon reaching day seven, 10% Tacunan in the potting mix resulted in 100% germination (Table 1).

Pechay seed germination in vermicomposts varied although a high percentage of germination on 10% DA vermicompost and both concentrations of Tacunan vermicompost were similar to previous studies. Adding vermicompost to the potting mix medium increased seed germination and growth in tomatoes and cucumbers, respectively (Arancon *et al*., 2007; Edwards *et al*., 2006). Lower germination on 20% DA vermicompost supports the results of Ievinsh (2011) wherein early plant growth was observed to be susceptible to the detrimental impacts of vermicompost use. An increased amount of fertilization on media, particularly exogenous nitrogen (N) levels, has been shown to reduce seed germination and lead to toxic effects (Pérez-Fernández and Rodríguez-Echeverría, 2003).

Based on physical and chemical analyses by DA XI-BSWML of the composts studied, data revealed that the highest in N was from DBB (Table 2) yet 10% DBB exhibited the lowest germination at 3 DAS (Table 1).

Table 1. Percentage germination (%) at 3, 5 and 7 days after sowing (DAS) of pechay sown in polyethylene seed trays with variously amended potting mix

Nutrient treatment	Germination percentage (±SD) at DAS*		
	3	5	7
No amendment (100% potting mix)	90[ab] (±8.84)	94[abc] (±4.42)	94[abc] (±4.42)
Urea (0.36 g/pot)	97[a] (±4.42)	98[ab] (±2.21)	98[a] (±2.21)
10% DA	94[a] (±0.00)	97[ab] (±4.42)	97[a] (±0.00)
10% Tacunan	95[a] (±6.63)	97[ab] (±4.42)	100[a] (±0.00)
5% DBB	81[bc] (±8.84)	92[abc] (±2.21)	92[ab] (±2.21)
20% DA	81[bc] (±4.42)	86[c] (±11.05)	86[b] (±11.05)
20% Tacunan	97[a] (±0.00)	100[a] (±0.00)	100[a] (±0.00)
10% DBB	75[c] (±13.26)	91[bc] (±4.42)	94[ab] (±0.00)
P	0.00	0.01	0.00
CV (%)	9.03	4.52	4.63

KEY: Potting mix = 3:4:3 topsoil, garden soil and charcoaled rice hull; control (-) = contains potting mix only; C (+) = potting mix + 0.36 g urea per pot; *means within a column with common letter/s are not significantly different at $\alpha = 0.05$; germination percentage was rounded up to whole number.

Table 2. Percentage of total N, P_2O_5, K_2O, pH and organic matter of commercially available vermicomposts used for potted pechay grown in a screenhouse

Code	Description of sample	Total N (%)	P_2O_5 (%)	K_2O (%)	pH	OM[1] (%)
Tacunan	Tacunan vermicompost	0.79	0.83	0.50	6.8	10.13
DA	Department of Agriculture – Region XI vermicompost	0.50	0.29	0.31	6.4	12.17
DBB	Dr. Bo's Biofertilizer®	2.09	3.12	0.65	8.0	22.00

*Analyses by Department of Agriculture Region XI – Bureau of Soils and Water Management Laboratory (DA XI-BSWML), Davao City for the submitted composite samples; [1]OM = organic matter

Yang (2018) studied the effect of NPK fertilizer on *Capsella bursa-pastoris* and showed that high N retarded its germination while balanced NPK resulted in rapid germination. In addition, the lowest germination at 5 and 7 DAS was obtained by 20% DA (Table 1), which might be due to deficient phosphorus (P) and potassium (K) (Yang, 2018). However, germination under 10% DA was not significantly different from 100% potting mix (Table 1); results could be supported by Adhikari (2009), who mentioned that varying fertilizer amounts generally had an insignificant influence on germination. Warman and Anglopez (2010) studied vermicomposts as a plant growth medium and stated that vermicompost might be inhibitory for germination as results showed that germination was highest on unamended soil. Contrary to this, Zaller (2007) mentioned that varying the ratio of vermicompost mixed with soil had a positive effect on germination.

3.2 Plant Growth and Development Measurements

3.2.1 Plant Height

The height of plants grown under various treatments was statistically significant ($\alpha < 0.05$). Plants grown in 20% Tacunan were the tallest, while the shortest was from treatments with urea or 10% DBB at 7 days after transplant (DAT). At 21 and 35 DAT, 20% Tacunan continued to produce the tallest plants while the shortest were from 10% DBB, urea, or potting mix with no nutrient amendment (Table 3).

Table 3. Mean plant height (cm±SD) at 14, 28 and 42 days after transplanting (DAT) of screenhouse-grown potted pechay cultivated in variously amended potting media

Nutrient amendment	Mean height (cm±SD) at DAT*		
	14	28	42
No amendment (100% potting mix)	7.46^{bc} (±1.18)	9.69^{c} (±2.07)	14.08^{c} (±3.26)
Urea (0.36 g/pot)	5.48^{d} (±1.00)	9.06^{c} (±1.52)	12.28^{c} (±2.95)
10% DA	7.85^{b} (±1.24)	11.64^{b} (±2.32)	17.07^{ab} (±4.29)
10% Tacunan	7.34^{bc} (±1.44)	10.53^{bc} (±1.95)	16.51^{ab} (±3.15)
5% DBB	6.99^{c} (±1.52)	10.47^{bc} (±2.99)	16.00^{b} (±4.44)
20% DA	7.05^{c} (±1.08)	11.61^{b} (±2.09)	16.54^{ab} (±3.21)
20% Tacunan	9.74^{a} (±1.53)	13.35^{a} (±1.96)	18.42^{a} (±2.80)
10% DBB	6.06^{d} (±1.19)	9.12^{c} (±2.96)	13.50^{c} (±4.16)
P	0.00	0.00	0.00
CV (%)	16.38	12.83	12.39

KEY: Potting mix = 3:4:3 topsoil, garden soil and charcoaled rice hull; control (-) = contains potting mix only; C (+) = potting mix + 0.36 g urea per pot; *means within a column with common letter/s are not significantly different at $\alpha = 0.05$.

Treatments with vermicompost amendments resulted in higher mean plant heights (Table 3) compared with plants grown in DBB and both controls. A similar response was observed in sorghum (*Sorghum bicolor* L. Moench) and shallot (*Allium cepa* L. Aggregatum) in which a higher dosage of vermicompost significantly increased plant height (Nohong *et al.*, 2020; Triharyanto *et al.*, 2021).

3.2.2 Leaf Length and Leaf Width

For the leaf length, all treatments varied ($\alpha < 0.05$) until five weeks after transplanting. Plants grown in 20% Tacunan vermicompost produced the longest leaves at 7, 21 and 35 DAT, while the urea-amended medium produced the shortest leaves (Table 4). Mean differences for leaf width were significantly different (α < 0.05) among various compost amendments and 20% DA gave plants with the widest leaves (Table 5).

Table 4. Mean leaf length (cm±SD) at 14, 28 and 42 days after transplanting (DAT) of screenhouse-grown potted pechay cultivated in variously amended potting media

Compost amendment	Leaf length (cm±SD) at DAT*		
	14	28	42
No amendment (100% potting mix)	2.74^{c} (±0.54)	4.64^{cd}(±1.14)	6.59^{c} (±1.91)
Urea (0.36 g/pot)	1.94^{e} (±0.43)	3.42^{e} (±1.09)	5.24^{d}(±2.09)
10% DA	3.13^{b} (±0.71)	6.09^{b} (±1.69)	8.52^{b}(±2.46)
10% Tacunan	2.53^{cd}(±0.53)	4.91^{cd}(±1.28)	8.02^{b}(±2.36)
5% DBB	2.48^{cd}(±0.67)	5.34^{b} (±1.37)	8.00^{b}(±2.56)
20% DA	2.84^{bc}(±0.51)	5.92^{c} (±1.58)	8.22^{b}(±2.11)
20% Tacunan	3.76^{a} (±0.94)	7.22^{a} (±1.37)	9.73^{a}(±1.98)
10% DBB	2.32^{d} (±0.51)	4.52^{d} (±1.40)	6.64^{c}(±2.19)
P	0.00	0.00	0.00
CV (%)	18.97	20.63	17.12

KEY: Potting mix = 3:4:3 topsoil, garden soil and charcoaled rice hull; control (-) = contains potting mix only; C (+) = potting mix + 0.36 g urea per pot; *means within column with different letters are significantly different using Duncan multiple range test at α = 0.05.

Table 5. Mean leaf width (cm±SD) at 14, 28 and 42 days after transplanting (DAT) of screenhouse-grown potted pechay cultivated in variously amended potting media

Nutrient amendment	Leaf width (cm±SD) at DAT*		
	14	28	42
No amendment (100% potting mix)	1.22^{d} (±0.38)	2.24^{e} (±0.67)	3.17^{d} (±1.09)
Urea (0.36 g/pot)	1.94^{b} (±0.46)	3.71^{b} (±0.80)	5.22^{ab} (±1.37)
10% DA	1.64^{c} (±0.42)	3.11^{cde}(±0.78)	4.70^{b} (±1.37)
10% Tacunan	1.59^{c} (±0.44)	3.25^{cd} (±0.89)	4.64^{b} (±1.35)
5% DBB	1.83^{bc}(±0.41)	3.51^{bc} (±0.98)	4.73^{b} (±1.33)
20% DA	2.31^{a} (±0.60)	4.23^{a} (±0.85)	5.49^{a} (±1.03)
20% Tacunan	1.34^{d} (±0.29)	2.83^{de} (±0.93)	3.90^{c} (±1.29)
10% DBB	1.22^{d} (±0.38)	2.24^{e} (±0.67)	3.17^{d} (±1.09)
P	0.00	0.00	0.00
CV (%)	21.82	20.70	18.75

KEY: Potting mix = 3:4:3 topsoil, garden soil and charcoaled rice hull; control (-) = contains potting mix only; C (+) = potting mix + 0.36 g urea per pot; *means within column with different letters are significantly different using Duncan multiple range test at α = 0.05.

Higher concentrations of goat and cow dung mixed in the 20% Tacunan vermicompost contributed to greater leaf width. This is supported by a study by Awodun *et al*. (2007) on pepper (*Capsicum annuum*) in which an increased goat manure ratio resulted in longer leaves. Further evidence was provided by Zaman *et al*. (2017) regarding the effects of higher amounts of cow manure on *Stevia rebaudiana*. The addition of cow dung on vermicompost alongside goat manure on Tacunan vermicompost also improved leaf width like the study on amaranth (*Amaranthus hybridus*) (Sanni, 2016).

Vermicompost application on pechay was favored over negative control in this study. This finding was similar to the report of Pant *et al*. (2009) on pak choi wherein the control without amendment had a corresponding lower N level that resulted in minimal leaf growth. In addition, Utami *et al*. (2018) have shown that a mixture of soil, compost and rice husk yielded the highest leaf area indicating sufficient N in the specific organic treatment for maximum leaf growth and higher N aids in leaf formation wherein broader leaves with greener color directly affect the rate of photosynthesis; hence, improving the yield of leafy plants such as pechay in this study.

3.3 Harvest Quality at 49 DAS

3.3.1 Leaf Length and Leaf Width at Harvest

Statistical analysis revealed significantly different values for leaf length and leaf width parameters at harvest ($\alpha < 0.05$). The longest and widest leaf was from plants grown in 20% Tacunan compared with all the other plants grown under other treatments (Table 6).

Table 6. Mean leaf length and width (cm±SD) of potted pechay with various nutrient amendments and grown under a screenhouse at 49 days after sowing (DAS)

Nutrient amendment	49 DAS	
	Leaf length (cm±SD)*	Leaf width (cm±SD)*
No amendment (100% potting mix)	7.43^{c} (±1.88)	4.14^{c} (±1.20)
Urea (0.36 g/pot)	5.74^{d} (±2.18)	3.39^{d} (±1.10)
10% DA	9.41^{ab}(±2.26)	5.67^{ab}(±1.26)
10% Tacunan	8.63^{b} (±2.21)	5.04^{b} (±1.34)
5% DBB	8.67^{b} (±2.55)	5.04^{b} (±1.33)
20% DA	8.99^{b} (±2.10)	5.33^{ab}(±1.39)
20% Tacunan	10.31^{a}(±1.96)	5.89^{a} (±1.16)
10% DBB	7.20^{c} (±2.21)	4.37^{c} (±1.24)
P	0.00	0.00
CV (%)	16.23	16.14

KEY: Potting mix = 3:4:3 topsoil, garden soil and charcoaled rice hull; control (-) = contains potting mix only; C (+) = potting mix + 0.36 g urea per pot; *means within column with different letters are significantly different using Duncan multiple range test at $\alpha = 0.05$.

3.3.2 Leaf Color and Damage Incidence

Visual quality parameters were significantly different (α = 0.05) for plants grown under various treatments. Mean values for leaf color suggested a dark green color for plants in 5% DBB (Table 7). Plants in other treatments generally had green color with negative control having the lightest green (Table 7). The highest incidence of damage caused by pests was in controls and 20% Tacunan with 10% DBB having no damage (Table 7). For disease, the damage was highest in 20% Tacunan and 10 and 20% DA while the least was in plants grown under a urea-amended potting mix (Table 7).

Table 7. Mean scores for leaf color and incidence of damage (disease and pest damage) of screenhouse-grown potted pechay cultivated in variously amended potting media and harvested at 49 days after sowing (DAS)

Nutrient amendment	Mean score for leaf color[1*]	Mean score for incidence of damage[2]	
		Pest*	Disease*
No amendment (100% potting mix)	2.05^{c} (±0.83)	2.80^{a} (±1.79)	3.00^{a}(±1.87)
Urea (0.36 g/pot)	2.40^{abc}(±0.50)	3.00^{a}(±1.87)	1.00^{c}(±0.00)
10% DA	2.20^{bc} (±0.62)	1.80^{b} (±1.79)	3.00^{a}(±1.87)
10% Tacunan	2.35^{abc}(±0.49)	2.20^{b} (±1.64)	2.20^{b}(±1.64)
5% DBB	2.65^{a} (±0.49)	1.75^{b} (±1.50)	2.5^{b}(±1.73)
20% DA	2.40^{abc}(±0.60)	1.60^{b} (±1.34)	2.4^{a}(±1.95)
20% Tacunan	2.45^{abc}(±0.51)	2.80^{a} (±1.64)	3.60^{a}(±1.52)
10% DBB	2.55^{ab} (±0.51)	1.00^{c} (±0.00)	2.40^{b}(±1.95)
P	0.05	0.05	0.05
CV (%)	7.42	61.24	46.48

KEY: Potting mix = 3:4:3 topsoil, garden soil and charcoaled rice hull; control (-) = contains potting mix only; C (+) = potting mix + 0.36 g urea per pot; *means within column with different letters are significantly different using Duncan multiple range test at α = 0.05.

Nutrition of plants affects the morphology and physiology of the plant which may either increase or decrease the capacity of the plant to deter pests and limit the entry of pathogens. Generally, plants that are nutrient deficient have a lower tolerance to pests, and deviating from an optimum nutritional state increases susceptibility to pests. Hence, the nutrient supply must not be deficient or excessive (Huber *et al.*, 2012). Zakka *et al.* (2016) investigated the impact of poultry manure amendments on an insect-infested pumpkin (*Cucurbita maxima* L.), and results showed that pest incidence and damaged fruits and leaves were significantly higher in the treatment amended with the highest amount of poultry manure. Organic fertilizers, which are often richer in N than P and K, elevate the prevalence of plant disease and insect infestations. Consequently, the application of poultry manure with high N content resulted in a higher incidence of aphids (*Aphis gossypii* Glov.), grasshoppers (*Zonocerus variegatus* L.) and flea beetles (*Podagrica sjostedti* Jacoby) on chili pepper (*Capsicum annuum* L.) (Suwanarit, 2019).

Pest incidence is more likely to occur in young and developing plants in which visual appearance such as leaf color could initiate a response from pests. One example is that areas of yellow-reflecting leaf surface, showing visible signs of nutrient deficiency, provide a site for selected aphid species to settle down (Holopainen *et al*., 2009). Based on an extensive literature review by Lu *et al*. (2007), the use of N fertilizer promoted rice damage from insects by expanding the pests' food options, food intake, survival, development, reproduction and population. Meanwhile, a field experiment on loam soil with high available K by Akhtar *et al*. (2010) revealed that K fertilization significantly decreased the occurrence of leaf blight *Septoria* on tomato fruits. Higher fertilization leads to enhanced crop production but subsequently increased the proliferation of brown planthopper (*Nilaparvata lugens*) – a common pest of rice (*Oryza sativa* L.) (Rashid *et al*., 2017). As to the effect of fertilizers having high amounts of phosphorus, Kulagod *et al*. (2011) also reported a similar trend of increased incidence of blue beetle populations (*Leptispa pygmaea* Baly) and damage to rice crops.

3.3.3 Total Fresh Weight and Fresh Weight Distribution

Significant differences among treatments were observed in total fresh weight and fresh weight distribution of pechay plant parts ($\alpha < 0.05$). The heaviest plants were from 10% DA, 20% DA and 20% Tacunan but were not significantly different from 5% DBB. The total fresh weight of plants grown in urea was the lowest among all treatments (Table 8). In terms of plant parts, petioles comprised most of the fresh weight compared with leaves or roots (Table 8). Petioles from plants grown in all treatments significantly comprised most of the fresh weight than with plants grown in urea (Table 8). Furthermore, based on the percentage from the fresh weight, leaves and roots of plants grown in urea had higher values compared with all the other treatments (Table 8).

Xu *et al*. (2005) mentioned that quality parameters and total production of various crops such as pechay are better when cultivated organically rather than relying on chemical fertilization. Gonzales *et al*. (2015) used goat manure, carbonized rice hull ash and rice straw as organic fertilizer in varying the ratios of garden soil, which resulted in higher fresh weight relative to basal potting mix alone.

Table 8. Total fresh weight (g±SD) and fresh weight distribution (%±SD) of leaves, petioles and roots of screenhouse-grown potted pechay cultivated in variously amended potting media and harvested at 49 DAS

Nutrient amendment	Total fresh weight (g±SD)*	Fresh weight distribution (%±SD)*		
		Leaves	Petioles	Roots
No amendment (100% potting mix)	4.33[d] (±3.31)	38.31[b] (±4.28)	56.50[a] (±4.27)	5.19[b] (±1.18)
Urea (0.36 g/pot)	1.70[e] (±0.73)	47.13[a] (±3.32)	44.10[b] (±6.30)	8.77[a] (±6.44)
10% DA	13.75[a] (±8.04)	38.45[b] (±2.73)	57.48[a](±2.14)	4.07[b] (±1.07)
10% Tacunan	9.00[bc](±4.49)	36.03[b] (±0.06)	60.05[a](±0.55)	3.92[b] (±0.51)
5% DBB	11.83[ab](±8.09)	38.61[b] (±4.31)	57.05[a](±5.87)	4.34[b](±1.59)
20% DA	12.17[a] (±6.95)	36.84[b] (±2.29)	59.58[a](±2.40)	3.59[b] (±0.59)
20% Tacunan	14.71[a] (±7.49)	35.26[b] (±0.95)	58.47[a] (±1.71)	6.27[b] (±1.81)
10% DBB	7.75[c] (±4.27)	37.91[b] (±1.53)	58.46[a] (±1.70)	3.63[b] (±1.61)
P	0.00	0.01	0.00	0.00
CV (%)	47.75	11.17	10.45	37.89

KEY: Potting mix = 3:4:3 topsoil, garden soil and charcoaled rice hull; control (-) = contains potting mix only; C (+) = potting mix + 0.36 g urea per pot; *means within a column with common letter/s are not significantly different at $\alpha = 0.05$.

3.3.4 Total Dry Weight, Total Biomass and Biomass Distribution

Total dry weight, total biomass and biomass distribution of plants grown in various treatments were significantly different ($\alpha \leq 0.05$). The highest total dry weight was from plants grown in 20% Tacunan, while the lowest total dry weights were from plants grown in controls and 10% DBB (Table 9). Based on the proportion of biomass relative to dry weight, the heaviest total biomass was obtained from plants grown in urea, but it was not significantly different from plants grown in 10% DBB (Table 9). In terms of biomass distribution in plant parts, biomass was highest in leaves followed by petioles and then roots. The highest leaf biomass distribution was from plants grown in urea, 10% DA and 10% Tacunan. The highest petiole biomass distribution was from plants grown in 5% DBB and 10% DBB, while the highest root biomass distribution was from plants grown in potting mix alone, 20% DA or 20% Tacunan but were not significantly different from the other treatments except urea (Table 9).

In a study by Utami *et al*. (2018), the treatment that utilized charcoal husk and compost as organic fertilizer resulted in the heaviest dry weight in pak choi compared with the control without soil amendment. Irawan and Kafiar (2015) highlighted that dry biomass is indicative of greater nutrient uptake of plants from the growth medium as well as more efficient photosynthesis.

Table 9. Total dry weight (g±SD), total biomass, and biomass distribution (%±SD) in leaves, petioles, and roots of screenhouse-grown potted pechay cultivated in variously amended potting media and harvested at 49 days after sowing

Nutrient amendment	Total dry weight (g±SD)*	Total biomass (%)*	Biomass distribution (%±SD)*		
			Leaves	Petioles	Roots
No amendment (100% potting mix)	0.25^{d}(±0.14)	5.99^{b} (±2.21)	48.97^{b} (±5.87)	40.61^{b} (±5.00)	10.42^{a} (±1.48)
Urea (0.36 g/pot)	0.25^{d} (±0.18)	15.42^{a} (±6.94)	52.41^{a} (±6.13)	41.46^{b} (±5.28)	6.12^{b} (±2.33)
10% DA	0.63^{b}(±0.32)	5.11^{b} (±2.16)	51.15^{a} (±4.34)	39.52^{b} (±5.66)	9.32^{ab} (±2.92)
10% Tacunan	0.48^{c} (±0.18)	5.02^{b} (±1.16)	51.38^{a} (±3.22)	41.37^{b} (±3.85)	7.24^{ab} (±1.35)
5% DBB	0.50^{c} (±0.22)	4.45^{b} (±0.90)	48.37^{b} (±5.60)	43.82^{a} (±05.74)	7.81^{ab} (±2.41)
20% DA	0.59^{bc}(±0.31)	4.80^{b} (±1.00)	49.09^{b} (±8.79)	41.22^{b} (±4.86)	9.69^{a} (±4.77)
20% Tacunan	0.76^{a} (±0.33)	5.82^{b} (±3.26)	49.38^{b} (±4.01)	40.27^{b} (±4.48)	10.35^{a} (±1.26)
10% DBB	0.38^{d} (±0.18)	10.25^{ab}(±1.12)	47.29^{b} (±7.48)	44.89^{a} (±7.62)	7.82^{ab} (±1.83)
P	0.00	0.01	0.05	0.05	0.04
CV (%)	35.78	13.22	11.29	12.48	31.74

KEY: Potting mix = 3:4:3 topsoil, garden soil and charcoaled rice hull; control (-) = contains potting mix only; C (+) = potting mix + 0.36 g urea per pot; *means within a column with common letter/s are not significantly different at $\alpha = 0.05$.

3.3.5 Marketable and Non-Marketable Fresh Weight

Fresh weights of pechay grown under various treatments were significantly different ($\alpha < 0.05$). Plants grown under 20% Tacunan had the highest marketable weight but were comparable to 10% DA, 5% DBB and 20% DA. Treatments with urea or no amendment had the least marketable weight. In terms of non-marketable plant parts, treatment with the highest marketable fresh weight also produced the highest non-marketable weight such as in 20% Tacunan and DA and 10% DA vermicomposts that were comparable with 5% DBB. Similarly, treatments with the lowest marketable fresh weight also resulted in the lowest non-marketable yield such as in urea and potting mix alone (Table 10).

Fertilizer addition results in some physiological changes in the tissues involved in water uptake that could alter stomatal conductance, leaf water potential and hydraulic capacity of roots. There is then a correlation between fertilization and the efficiency of water transport and most importantly its tolerance to drought, which contributes to weight loss (Faustino *et al*., 2013). Hence, for fresh weight marketability, a study on pechay by Gonzales *et al*. (2015) was used as the basis wherein greater than or equal to 24 g was considered marketable; a lesser weight was non-marketable. Islam *et al*. (2019) reported that *Brassica oleracea* showed a significant relationship between the usage of cow dung and the highest fresh weight while minimum values were observed in the control (i.e., no organic amendment).

Table 10. Marketable and non-marketable shoot at fresh weight (g±SD) of screenhouse-grown potted pechay grown in various nutrient amendments in the potting mix and harvested at 49 days after sowing (DAS)

Nutrient amendment	Fresh weight (g±SD)*	
	Marketable	Non-marketable
No amendment (100% potting mix)	3.78^{d} (±3.08)	0.66^{bcd}(±0.51)
Urea (0.36 g/pot)	1.30^{d} (±0.63)	0.24^{d} (±0.24)
10% DA	12.20^{a} (±6.65)	1.18^{abc}(±1.25)
10% Tacunan	8.89^{bc}(±3.26)	0.82^{bcd}(±0.61)
5% DBB	10.62^{ab}(±7.24)	1.12^{abc} (±0.80)
20% DA	10.72^{ab}(±6.39)	1.37^{ab} (±1.88)
20% Tacunan	12.19^{a} (±6.38)	1.70^{a} (±1.43)
10% DBB	7.25^{c} (±4.08)	0.48^{cd} (±0.25)
P	0.00	0.00
CV (%)	44.79	47.94

KEY: Potting mix = 3:4:3 topsoil, garden soil and charcoaled rice hull; Control (-) = contains potting mix only; C (+) = potting mix + 0.36 g urea per pot; *means within a column with common letter/s are not significantly different at $\alpha = 0.05$.

3.3.6 Dry Biomass of Marketable and Non-marketable Pechay

Dry biomass was significantly different for pechay ($\alpha < 0.05$) grown under various treatments. Marketable dry biomass was highest in plants grown under 20% Tacunan while least in urea and potting mix alone (Table 11). For the non-marketable parts, only plants with 20% Tacunan vermicompost amendment produced higher biomass while all the other treatments were lower and comparable to each other (Table 11).

Kumar *et al*. (2020) discovered that on soil polluted with metals, mustard (*Brassica juncea*) dry biomass increased considerably when added with organic amendments wherein farmyard manure was found to be the most effective. This is supported by Rathore *et al*. (2019), who stated that the major factor in increasing dry matter production, or the entire plant biomass, is the amendment of soil by organic fertilizers.

Table 11. Total marketable vs. non-marketable shoot dry biomass (g±SD) of screenhouse-grown potted pechay cultivated in variously amended potting media and harvested at 49 DAS

Nutrient amendment	Dry biomass (g±SD)*	
	Marketable	Non-marketable
No amendment (100% potting mix)	0.17^{d} (±0.11)	0.04^{b}(±0.03)
Urea (0.36 g/pot)	0.21^{d} (±0.17)	0.03^{b}(±0.02)
10% DA	0.52^{a} (±0.27)	0.06^{b}(±0.04)
10% Tacunan	0.41^{bc}(±0.14)	0.05^{b}(±0.05)
5% DBB	0.40^{bc}(±0.19)	0.05^{b}(±0.03)
20% DA	0.48^{ab}(±0.27)	0.04^{b}(±0.02)
20% Tacunan	0.56^{a} (±0.23)	0.10^{a}(±0.09)
10% DBB	0.36^{c} (±0.19)	0.04^{b}(±0.03)
P	0.00	0.00
CV (%)	33.55	39.55

KEY: Potting mix = 3:4:3 topsoil, garden soil and charcoaled rice hull; control (-) = contains potting mix only; C (+) = potting mix + 0.36 g urea per pot; *means within a column with common letter/s are not significantly different at $\alpha = 0.05$.

4. Conclusion and Recommendation

'Black Behi' pechay plants grown in potting mix with 20% Tacunan vermicompost had the best average values for quality parameters including height and leaf morphological traits even though DBB was observed to have the highest N, P and K and organic matter contents among the composts. Results of the study recommend the usage of 20% Tacunan vermicompost as an amendment to the potting mix of pechay grown under screenhouse conditions.

For further improvement of this study, various factors such as the expansion of amendment concentrations, side-dressing of amendments, or combination of organic and inorganic amendments can be explored to achieve good harvest and post-harvest data.

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