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# Effects of Dairy Farm Effluent Compost on Growth and Yield of Pak Choy (*Brassica rapa* L.) in Pot System

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**ABSTRACT** Compost produced from dairy farm waste has been reported to be useful to increase and sustain crop yield. However, there is little known about this in Sabah. Thus, the present study was carried out to investigate the effects of locally produced dairy farm effluent compost (DEC) on the growth and yield of two Pak Choy varieties: *Brassica rapa* L. 'Curly Dwarf Pak Choy' (CDP) and 'Shanghai Dwarf Pak Choy' (SDP). Pot experiments (18L pot size) of 8 treatments were laid out in a completely randomized design; the treatments were four mixtures of DEC and infertile soil (0:100, 25:75, 50:50 and 100:0, % w/w) with or without addition of 6g of NPK 15:15:15 fertilizer. The media (DECM) was first used to grow the CDP for two cycles and then the SDP for another two cycles. At the end of each cycle (42 – 45 day), growth was measured as height (cm), leaf number, leaf area ($cm^2$) and root (g) to shoot (g) ratio (R:S). Yield was measured as fresh and dry matter weights of CDP and SDP (g/plant). It was found that CDP grown on the media with DEC addition did not grow well during the first cycle, indicating the unreadiness of the DEC for a use. In subsequent cycles, there was a significant increase in height, leaf number, leaf area and fresh and dry matter weights of CDP and SDP grown on compost media compared to that on control media (100% soil). The data indicated that 25:75 DECM is satisfactory to increase the yield of CDP and SDP. The highest yield of CDP was 71g/plant (214g/pot), achieved at 50:50 DECM, but this was not significantly higher than that at 25:75 DECM. In fact, addition of DEC into the media beyond 25% did not significantly increase the yield of CDP. The highest yield of SDP was 47g/plant (141 g/pot) and this was achieved at 25:75 DECM. NPK fertilizer supplement to DECM had significant effect on the yield of SDP, but for CDP, the effect was limited only in 50:50 DECM, meaning at a first use, soil with addition of properly composted DEC does not necessarily need to be supplemented with NPK fertilizer to increase crop yield; however, to sustain the yield, NPK addition is necessary. Well composted DEC has a potential to be used as soil amendment for improving leafy vegetable production without the need of fertilizer application, during the first or second planting cycle.

**KEYWORDS:** Dairy farm waste; Organic compost; Manure recycling; *Brassica rapa;* Infertile soil treatment.
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**Full Paper**



## INTRODUCTION

Pak Choy (*Brassica rapa* L.) is one of the popular leafy vegetables in Malaysia. However, the local production of this vegetable, is low and thus, it has to be imported to meet the demand. The cost of import has been estimated to be RM87 million a year, which is exceeding the export values by 77% (FAMA, 2017). To mitigate this problem, it is reasonable to increase the local production of Pak Choy. Leafy vegetables, nevertheless, require a high supply of nutrient to grow in a short period of time. Because of this, there is a trend that local farmers would use chemical fertilizer excessively to meet the production target and the local demand of Pak Choy. The excessive use of chemical fertilizers can be costly to the farmers, and also detrimental to the environment. With the increasing awareness among consumers about the negative effects of excessive chemical fertilizer applications on health and the benefits of quality, safe and nutritious foods, cultivation of crop organically including Pak Choy has been becoming popular. By shifting from using chemical fertilizers to recycling animal wastes, increasing Pak Choy production to meet demands seems promising, since animal waste is known to sustain soil health and improve crop yields.

Properly composted wastes obtained from cattle farming, which are mostly manures, can be used as a compost to improve soil condition and increase crop yield (Masarirambi *et al.*, 2013; Amos *et al.*, 2015; Sanni, 2016; Mantovani *et al*., 2017). Manures can serve as a slow release fertilizer; the nutrients are released slowly while the manures decompose, reducing the risk of nutrient toxicity and thus, supporting better root development and higher crop yields. Worldwide manure production associated with cattle farming has increased with the current intensified cattle farming practices of over one thousand million heads (FAO, 2018). In Sabah, it was estimated to be over one million metric tons a year (Mokhtar & Chia, 2000). The current production is expected to be much higher, since the population of cattle in Sabah has increased by 20% over 2011–2017 (DVS, 2018). This large amount of waste production provides an opportunity for local farmers in Sabah to use the almost zero-cost wastes for production of organic vegetables. However, there is still lack of knowledge in Sabah on the use of dairy farm effluent compost (DEC) for leafy vegetable production. In fact, in Malaysia, little is known on the effects DEC on growth and yield of leafy vegetables.

Therefore, the present study was carried out to determine the best ratio of DEC and Silabukan soil for growth and yield of two Pak Choy varieties; 'Curly Dwarf Pak Choy' (CDP) and 'Shanghai Dwarf Pak Choy' (SDP), and to measure the effectiveness of using DEC to increase the yield of these varieties. The results obtained will be useful for local vegetable farming in Sabah to use as a basis to decide the best amount of DEC to apply for higher Pak Choy production.

## METHODOLOGY

*Experimental set up*

This study was carried out in a translucent roof insect-proof rainshelter (≈ greenhouse) in the Faculty of Sustainable Agriculture (FSA), Universiti Malaysia Sabah, Sandakan, from April to November 2018. Between 6am to 6pm, the temperature in the shelter was 23°C – 37°C and the relative humidity was 46% – 98%. Eight ratios of DEC and Silabukan soil, or the treatments, were studied (Table 1). The DEC was collected from a dairy farm in Keningau, Sabah, and the soils were collected from the Banana research plot in the FSA. The soils were dried, ground manually using mortar and pestle, and sieved to remove gravels and debris. The DEC and soil were weighed according to the target ratios, mixed, and placed in 18L pots.

Table 1. Dairy farm effluent compost media (DECM) tested.

| Treatment | (%) DEC : Soil |
|---|---|
| **A** | 0:100 (100% infertile soil, control) |
| **B** | 25:75 |
| **C** | 50:50 |
| **D** | 100:0 |
| **$A_1$** | 0:100 + NPK fertilizer |
| **$B_1$** | 25:75 + NPK fertilizer |
| **$C_1$** | 50:50 + NPK fertilizer |
| **$D_1$** | 100:0 + NPK fertilizer |

The soil, compost and media in each pot (after the first two production cycles) were sampled for analyses of selected chemical properties. The samples were collected to the depth of 10 cm around the root zone using garden trowel and were air-dried and ground manually using mortar and pestle prior to analysis. Analyses of pH, organic matter (OM) and organic carbon (OC) content of the soil and media were carried out following the procedures described by Motsara & Roy (2008). The media



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were found to be acidic, had low OM content and OC content (Table 2). Treatment D, however had slightly higher OM and OC contents compared to the other treatments.

Table 2. pH, organic matter (OM) and organic carbon (OC) content of the compost (DEC), soil and media (DECM: A-D without or with NPK addition).

| Treatment | pH | OM % | OC % |
|---|---|---|---|
| **100% Compost (DEC)** | 7.8a | 57.39a | 33.28a |
| **100% Soil** | 4.2gh | 2.03d | 1.18d |
| **A (0:100)** | 4.4g | 9.18c | 5.32c |
| **B (25:75)** | 5.6bc | 10.42c | 6.04c |
| **C (50:50)** | 5.7b | 14.87c | 8.62c |
| **D (100:0)** | 5.3de | 36.63b | 21.25b |
| **$A_1$ (0:100 + NPK)** | 4.1h | 1.73d | 1.00d |
| **$B_1$ (25:75 + NPK)** | 5.4cd | 10.00c | 5.80c |
| **$C_1$ (50:50 + NPK)** | 5.1f | 15.20c | 8.81c |
| **$D_1$ (100:0 + NPK)** | 5.2ef | 32.67b | 18.95b |
| **Mean** | 5.3 | 16.34 | 9.47 |
| **Significance** | P<0.01 | P<0.01 | P<0.01 |

The treatments were laid out in a completely randomized design of five replications per treatment. A trial production cycle was first carried out, assessing the yield of CDP. This trial was then followed by four production cycles. CDP was planted in the first two cycles, and SDP, in the last two cycles. The NPK 15:15:15 fertilizer treatment was applied at 20 days after sowing (DAS) and 30 DAS. The fertilizer was added at 150kg/ha, or 6g/pot once standardized against the surface area of the media in the pots.

*Seed germination, plant planting and maintenance*

The seeds of the CDP or SDP (purchased from Sin Seng Huat Seeds Sdn. Bhd.) were germinated directly on the media. Three shallow holes (about 1cm deep) of equal distance from one another and from the pot wall were made and the seeds were sown in the holes. The seeds and the plants (germinated from the seeds) were watered with 500ml of tap water twice a day, at 8am and 4pm, respectively. At 10 DAS, the first thinning was carried out by cutting the seedling at the base using scissors, leaving six plants per pot. At 20 DAS, the second thinning was carried out, leaving only three plants per pot until the CDP and SDP were harvested. The CDP was harvested at 42 DAS, and the SDP at 45 DAS. Throughout of the experiment, pest and weeds were monitored daily and removed manually by hand.

*Growth assessment*

Growth was evaluated based on the height (cm), leaf number, leaf area ($cm^2$), and root (g) to shoot (g) ratio (R:S) of CDP and SDP. Before harvesting, the height of CDP and SDP were measured using a 30cm long standard scale as the length from the soil surface to the highest free-standing point of the crown. Number of leaves was counted including leaves that were just beginning to unfold, or once the leaf was $1cm^2$ or greater. After harvesting, CDP and SDP were rinsed with water to remove soil particles, and excess water on the plants was dried using laboratory grade tissue. Leaf area was measured using leaf area meter (C1202 Leaf Area Meter, CID Bio-Science Inc). Roots were separated from the shoots by cutting at the soil line. The shoots and roots of CDP and SDP were dried in oven (Model FD 23 – 20L, Binder) at 80°C for 42 hours, or until constant weight was attained, and weighed immediately using a top balance (Model TLE3002E, Mettler Toledo). The root (R) to shoot (S) ratio per sample was calculated based on the root and shoot dry matter weights.

*Yield and effectiveness of DEC assessment*

Yield was measured as the fresh and dry matter weights (g/plant) of the harvested CDP and SDP. Fresh weight was measured just after harvesting using the top balance. Shoot dry matter weight was extracted from the R:S assessment explained above. Effectiveness of DEC in improving yield was measured as the differences between yields (g) of CDP or SDP grown on DECM and control media (Treatment A: 100% soil), and between yields (g) of CDP or SDP grown on DECM with and without NPK addition in the first and second production cycles. The CDP and SDP were also diagnosed visually for nutrient-related deformity following the symptoms of nutrient disorder explained by Resh (2013) and Hamlin (2007).

*Statistical analysis*

The effects of the DEC, with and without an addition of NPK 15:15:15 fertilizer, on the growth and yield of CDP and SDP were compared by performing the ANOVA on the data obtained. The means were separated by the least significant difference (LSD) method. All statistical analyses were carried out using SAS Version 9.4 (SAS Institute Inc., 2002)

## RESULT

*Growth performance*

There were significant increments in height, leaf count, leaf area and root to shoot ratio of both the CDP and SDP grown on DECM (Figure 1). The data indicated that addition of 25% DEC into the soil (25:75 DECM) was satisfactory to increase the growth of the CDP (Figures 1a, c & e). The growth performance improved further under 50% addition of DEC into the soil (50:50 DECM). Addition beyond of 50%, however, had no significant effect on the growth performance of CDP. The addition of NPK fertilizer to DECM had not significantly improved the growth of CDP (Figures 1b, d & f). It was also found that in the second production cycle of CDP, once after the addition of DEC, the root mass increased 98%, which was the highest mass obtained in 50% DEC addition. A similar trend of growth performance under DEC treatment was also observed for the SDP, but unlike that of CDP, the addition of NPK fertilizer to DECM had significantly improved the growth of SDP (Figures 1b, d & f). For SDP, the root mass increment was 84%, which was also achieved in 50% DECM.

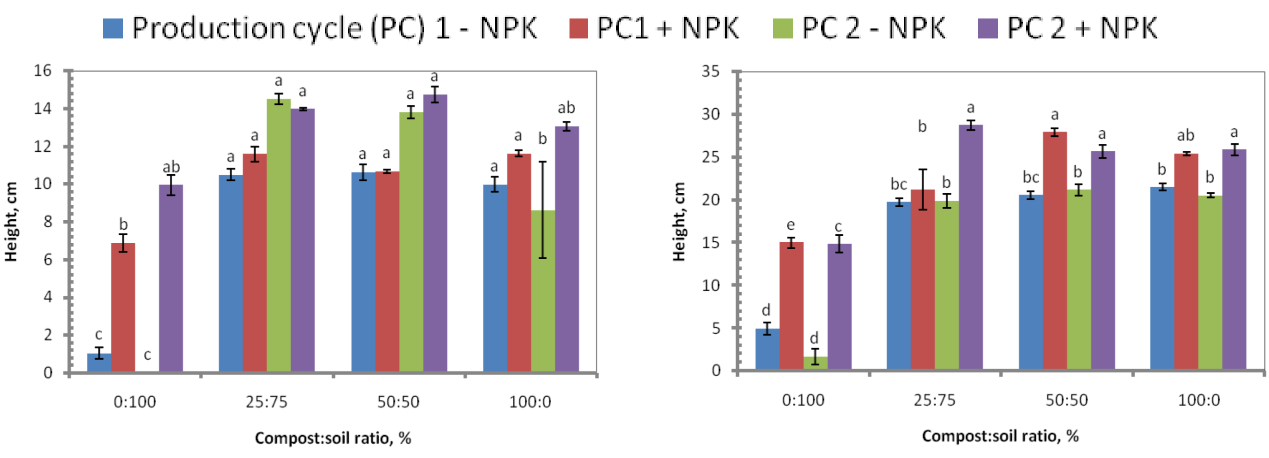


Figure 1a. Height of CDP at different DECM. (Error bars in Figure 1a–1f show standard error).

Figure 1b. Height of SDP at different DECM.

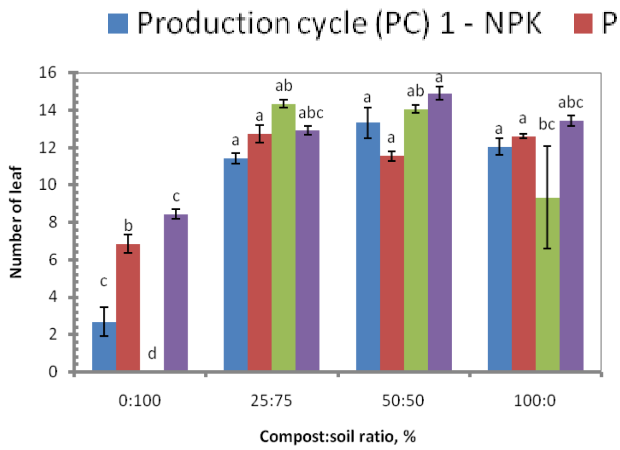


Figure 1c. Leaf number of CDP at different DECM.

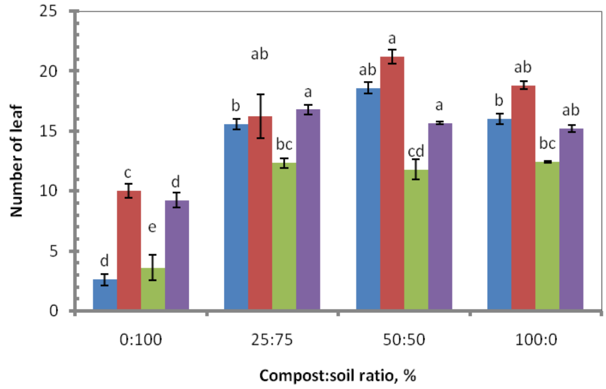


Figure 1d. Leaf number of SDP at different DECM.

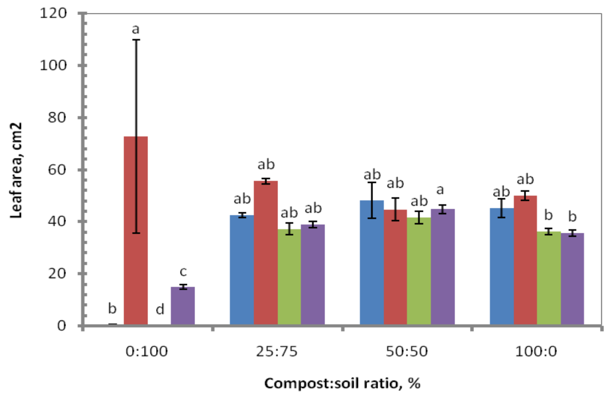


Figure 1e. Leaf area of CDP at different DECM.

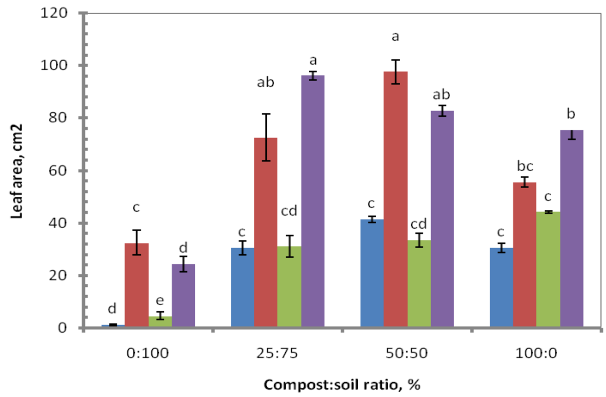


Figure 1f. Leaf area of SDP at different DECM.

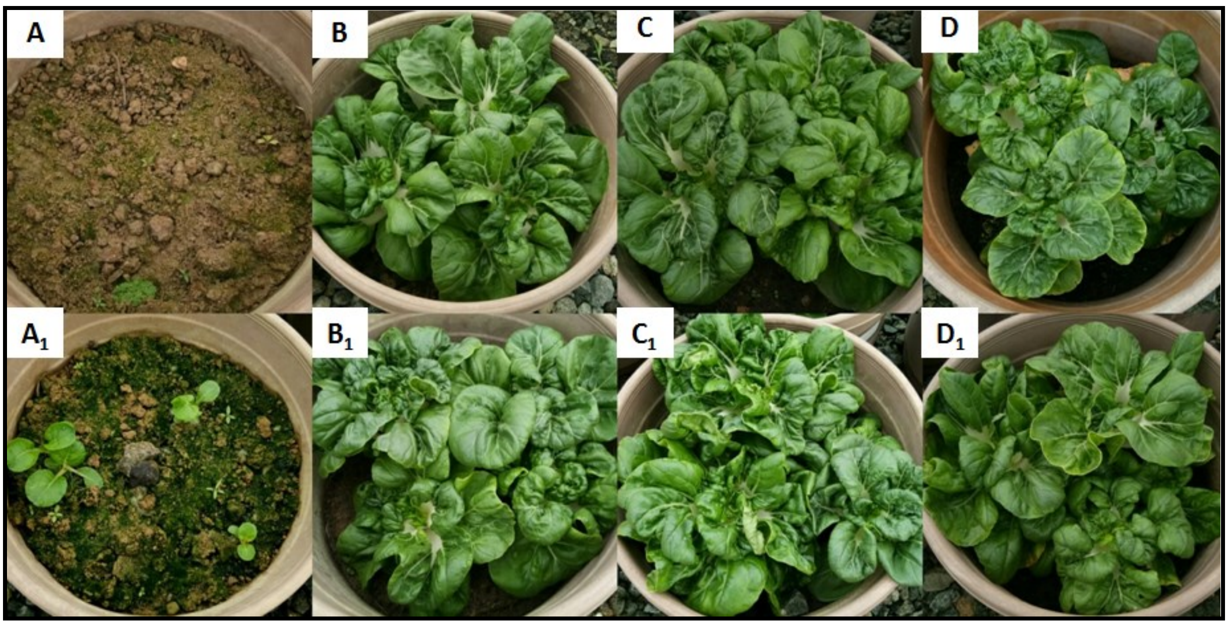


Figure 2. Pictures of CDP grown in different DECM at 42 DAS. A= 0:100 (control); $A_1$= 0:100 + NPK; B= 25:75; $B_1$= 25:75 + NPK; C= 50:50; $C_1$= 50:50 + NPK; D=100:0; and $D_1$= 100:0 + NPK.


Figure 3. Pictures of SDP grown in different DECM at 42 DAS. A= 0:100 (control); $A_1$= 0:100 + NPK; B= 25:75; $B_1$= 25:75 + NPK; C= 50:50; $C_1$= 50:50 + NPK; D=100:0; and $D_1$= 100:0 + NPK.

*Yield and effectiveness of DEC*

The addition of 25% DEC into the soil (25:75 DECM) was found to have satisfactorily increased the yield of the CDP and SDP compared to that in 100% soil (Figure 4). In the trial production cycle, however, fresh matter yield of CDP was fairly low in all treatments (Table 3). Addition of NPK fertilizer during that cycle has also failed to improve the yield of CDP. In the actual production cycles, the highest yield of CDP was 71g/plant (214g/pot), achieved at 50:50 DECM, but this was not significantly higher than that at 25:75 DECM. In fact, the addition of DEC into the media beyond 25% did not significantly increase the yield of CDP. The highest yield of SDP was 47g/plant (141g/pot) and this was also achieved at 25:75 DECM. It was also found that the addition of DEC into the media beyond 25% did not significantly increase the yield of SDP. NPK fertilizer addition to DECM had significantly increased the yield of SDP especially in 25:75 DECM, but the scale of the effect of the fertilizer was lowering with increment of DEC addition into the media (Figure 4b). For CDP, the effect of the fertilizer was limited only in 50:50 DECM of production cycle 2.

Table 3. Fresh and dry matter yield of CDP in the trial production cycle.

| Treatment | Fresh matter yield, g/plant | Dry matter yield, g/plant |
|---|---|---|
| **A (0:100)** | 0.24b | 0.028b |
| **B (25:75)** | 1.14b | 0.070b |
| **C (50:50)** | 0.83b | 0.072b |
| **D (100:0)** | 3.80a | 0.26a |
| **$A_1$ (0:100 + NPK)** | 0.77b | 0.06b |
| **$B_1$ (25:75 + NPK)** | 0.82b | 0.07b |
| **$C_1$ (50:50 + NPK)** | 0.25b | 0.03b |
| **$D_1$ (100:0 + NPK)** | 0.32b | 0.03b |
| Mean | 1.02 | 0.08 |
| Significance | P<0.1 | P<0.01 |

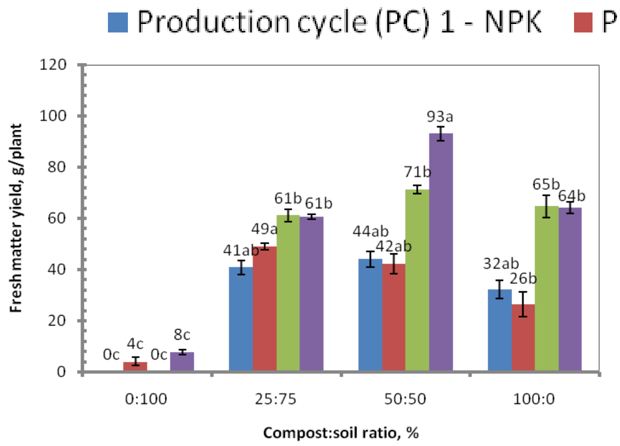


Figure 4a. Yield (fresh weight) of CDP. (Error bars in Figure 4a–4d show standard error).

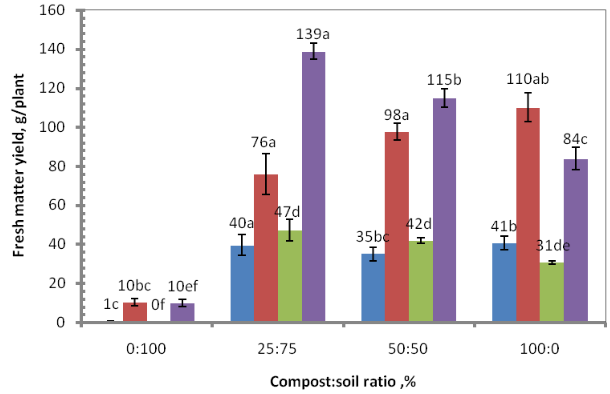


Figure 4b. Yield (fresh weight) of SDP

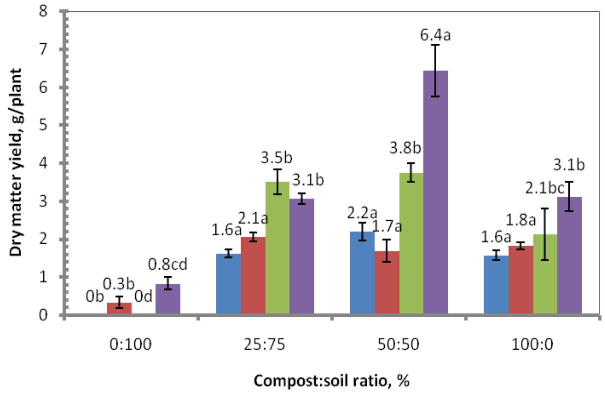


Figure 4c. Dry matter yield of CDP

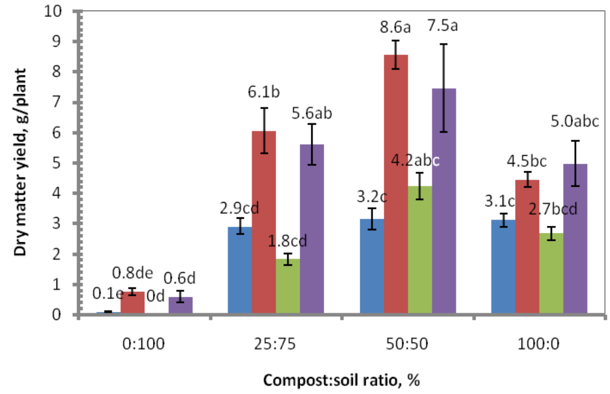


Figure 4d: Dry matter yield of SDP

The changes in yield of CDP and SDP indicated the effectiveness of using different DEC to soil mixture to increase the fresh matter yield of Pak Choy. For CDP, the yield change when grown in DECM was more or less the same (Figure 5a). Addition of NPK in the second production cycle was not effective to further increase yield, except in 50:50 DECM (Figure 5b). The yield of SDP grown in different DEC to soil mixture was consistently low in both production cycles (Figure 5a). Addition of NPK fertilizer increased SDP yield with increment of DEC to soil in the third production cycle, however yield change showed the opposite trend in the subsequent production cycle. The yield change of CDP between DEC with and without NPK fertilizer treatments indicated the effectiveness of DECM to sustain the yield of CDP in the first two cycles; however, addition of NPK fertilizer was needed to sustain the yield of SDP in the next two cycles.

In the fourth production cycle, SDP showed 'whip-tail' symptom indicating a severe deficiency of the microelement molybdenum. This symptom was observed only in SDP grown in DECM without NPK fertilizer application with descending severity from 25:75> 50:50> 100:0 DEC to soil mixture. However, this was not observed when SDP was supplemented with NPK fertilizer.



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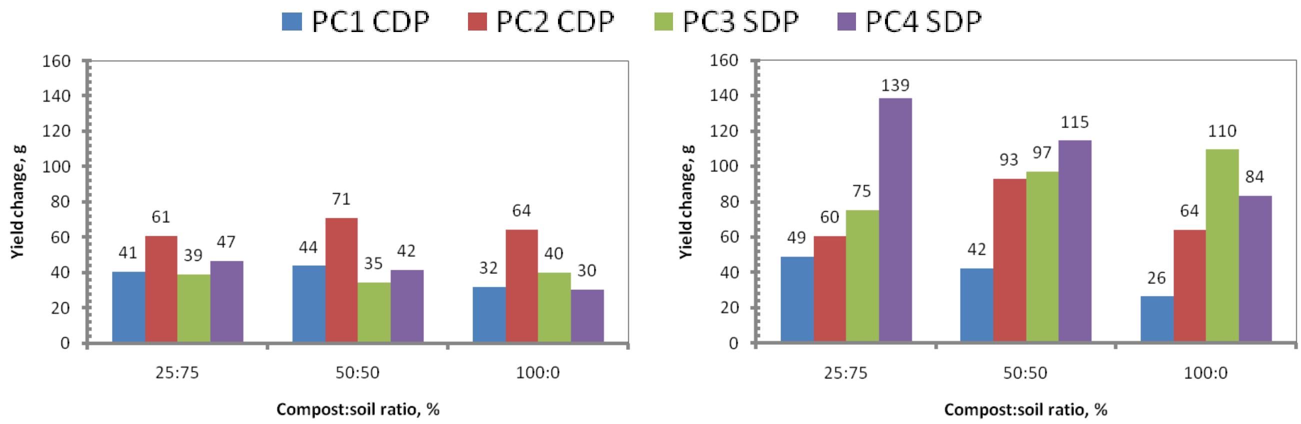


Figure 5a. Effectiveness: DEC-NPK vs. control     Figure 5b. Effectiveness: DEC+NPK vs. control

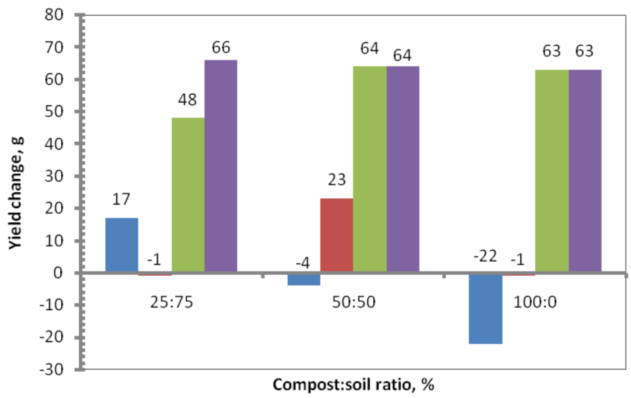


Figure 5c. Effectivness: DEC+NPK vs. DEC-NPK

## DISCUSSION

*CDP and SDP Growth*

The addition of cattle manure improves physical condition, chemical properties and organic matter content of soils (Ikpe & Powel, 2002; Ewulo, 2005; Tucker *et al.*, 2015). Addition of DEC improved the clayey structure of Silabukan soil, facilitating a better root growth and nutrient uptake, and thus enhanced the growth of the CDP and SDP. This was observed in the increased fresh root mass of CDP and SDP, once grown in the media, especially in 50:50 DECM. Silabukan soil is a common soil formation in Sabah, which is known to have low fertility (Afandi *et al.*, 2016). The unimpressive growth performance of the CDP and SDP in treatment A (100% soil) is thus due to the poor condition and low fertility of the Silabukan soil used in the experiment. It was acidic and had low OM and OC contents (Table 2). In other words, its condition is unfavourable for root growth and nutrient uptake. The OM content and pH of the media improved once added with DEC especially at 25% and 50% rate (Table 2). The pH improved to 5.6-5.7, which is within of the range (pH 5.5-6.5) that has long been known (see Sprague, 1964) where most nutrients are available for plant uptake. The effect of increased OM content of soil organic matter resulted in the increase of height, leaf number and leaf area of CDP and SDP when grown in DECM. This is because OM serves as a storehouse for nutrients, increasing nitrogen pools and higher CEC (Guimarães *et al.*, 2012) for the benefits of plants.

The addition of NPK fertilizer to DECM had significantly improved the growth of SDP, but this was not observed for the CDP. The former is attributed to the abundant nutrient availability in the media from the DEC and NPK. The latter trend, however, could not be explained based on the available data. On another hand, the trend indicates that fertilizer addition is not required for the first two production cycles of CDP using DEC media especially 50:50 DEC media treatment.

*CDP and SDP Yield*

Dairy manure contains abundant essential macro- (N, P, K, Mg and Ca, s) and micro-elements (Mn, Cu, Zn, B, Fe and Mo) (Stowell & Bickert, 1995). This is true as addition of only 25% of DEC to soil had significantly improved the yield of both CDP and SDP. As addition of DEC to soil improves soil physical structure fertility, roots are able to absorb more nutrients that are available in the media, hence higher yield. However, 50:50 DECM maintained the highest dry matter accumulation in both CDP and SDP, indicating a higher nutrient availability in 50:50 DEC to soil mixture.

The advantages of DEC, nevertheless, will depend on the maturity level and the amount of DEC added. The microbial biomass in the media uses up oxygen as DECM decomposes, creating a competition for oxygen with the plant roots (Mathur *et al*., 1993). Immature compost also contains high amount of ammonia and other phytotoxic substances, which is toxic for root development and plant growth (Zucconi *et al*., 1981). Immaturity and unreadiness of the DEC for use is expected to be the reason for the failure of the CDP to grow well on DECM in the trial production cycle (Table 3). Plant nutrient uptake during that production cycle was low as indicated by the failure of the plants to grow well even with chemical fertilizer addition. In the subsequent production cycles, the condition of the DECM has improved to support a better yield performance of the CDP and SDP.

Based on the data, it can be suggested that 25% DEC addition (25:75 DECM) is the minimum amount required to improve the yield of the CDP. The maximum amount would be 50%, since the addition beyond of the amount had not significantly increased the yield of the CDP and SDP anymore. The poor yield achieved once the DEC addition is beyond 50% can be associated with the poor soil structure and root development after over addition of compost. The rapid conversion of organically bound N into $NO_3$-N in heavy application of manure is highly prone to nutrient leaching, particularly $NO_3$-N (Ahmad *et al*., 2016), which explains the reduction in SDP yield when grown in 100% DECM (Figure 4b). The 100% DEC treatment may have loss a significant amount of nutrients throughout the experiment from plant uptake, as well as nutrient leaching due to high porosity of organic manure (Eghball, 2002).

*Effectiveness of DEC*

The data from this study indicated that an addition of DEC into soil (DECM) is effective to increase the yield of CDP and SDP. Reutilizing the DECM had also increased the yield of CDP by over 33% and 17% for SDP (Figure 5a). Decomposition of DECM increases over time as it was being utilized. The high organic matter content in organic manures stores nutrients which are being released through time (Sharma & Mittra, 1991). This consistent yield increase between each production cycle is explained as more nutrients were released and are available for uptake between each production cycle. The addition of NPK fertilizer was not necessary to increase the yield of CDP (Figure 5c). Addition 25% DEC alone was already satisfactory to enhance the yield of CDP. However, addition of NPK fertilizer was helpful to increase yield of SDP by an average of 64% in the subsequent production cycles. As leafy vegetables are quite nutrient demanding, local farmers are getting used to apply a higher or an excessive amount of chemical fertilizers to increase their crop produce, which can be costly, but the yield could be just similar to that of using compost. For example, there was a hydroponic experiment operated adjacent to the pot experiment in the present study. The yield achieved from the hydroponic system was 76g/plant (unpublished data), which is similar to the highest yield obtained in DECM (Figure 4a). This is a good indication that costs for unnecessary fertilizer application can be reduced with the use of DECM.

## CONCLUSION

DEC has a potential to be used as an effective amendment for infertile soil (soil of low nutrient content to support optimum plant growth) to improve the height, leaf number, leaf area, and fresh and dry matter weight, or the growth and yield of leafy vegetables as was found for Pak Choy in the present study. The benefits of using DEC, however, will depend on the maturity and amount of the compost added into the soil. It is expected that the use of immature DEC or over addition of the compost will impede the growth and yield of the vegetables. It can be recommended that 25% addition of DEC to soil is the minimum amount required to improve the growth and yield of the vegetables. The maximum addition would be 50%, as addition beyond of this amount was found to be no longer effective. Moreover, addition of DEC to soil can be expected to increase leafy vegetable yield up to at least 60%. However, since this study was conducted in a pot system, field application of DEC for vegetable production has to be investigated to expand further the application of DEC and the production of organic vegetables.

## ACKNOWLEDGEMENTS

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