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The Effect of Cricket (Orthoptera: Gryllidae) Frass on the Growth of Leafy Vegetables

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The awareness, demand, and usage of organic resources in farming are escalating, particularly in the application of pest control and fertilisers. Organic fertilisers are usually obtained from animals and plants, and this study is focused on cricket frass. A field trial was conducted to determine the effect of cricket frass as an organic fertiliser on the growth of leafy vegetables. Three fertiliser set-ups (cricket frass, NPK [15-15-15], and chicken dung) and one control (without fertiliser) were used. These fertilisers were tested on three leafy vegetables; green spinach, green mustard, and water spinach. The parameters observed and recorded were plant height (cm), number of leaves, and total yield (g). The data were analysed using Minitab 17.0. There was a significant difference ($P \leq 0.05$) in plant height between vegetables fertilised with cricket frass (26.29 cm) and control (14.82 cm). For the number of leaves parameter, a significant difference ($P \leq 0.05$) between vegetables fertilised with cricket frass (11.51 leaves) and control (9.77 leaves) was observed. Similarly, the yield between vegetables fertilised with cricket frass (134.55 g/pot) and control (104.19 g/pot) was also significantly different ($P \leq 0.05$). Therefore, cricket frass has the potential as an alternative organic fertiliser source that could reduce the dependency on chemical fertiliser to increase agricultural yields and production.

Keywords: cricket frass; leafy vegetables; organic fertiliser

I. INTRODUCTION

A more vigorous and systematic effort on all relevant parties is necessary to promote agriculture (FAO, 2009). Leafy vegetable cultivation is the most important crop to small-scale farmers in Malaysia. Therefore, it is crucial to maintain low production cost for sustainable income. Furthermore, vegetable production needs to be enhanced to reduce the dependence on imported vegetables by improving productivity and extending the production areas for vegetables and improving post-harvest methods, marketing logistics facilities, and strengthening organic vegetable market (MOA, 2011). Other than that, the price of organic food such as organic leafy vegetables is much higher compared to the non-organic due to the increment of organic food awareness. Malaysia government encouraged farmers to create new income to fulfil demands with this new trend by optimising the use of natural wastes (Fesol, 2013).

Crickets (*Gryllus bimaculatus*) demonstrated great potential for insect farming purposes, where they are usually utilised as an alternative diet for the growth of catfish (Taufek *et al.*, 2013). However, its extensive use in catfish farming generated a lot of frass (waste from crickets). According to Lovett *et al.* (2002), frass has more

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carbon (C) compared to leaves litter. The deposition of frass may affect the process of decomposition and nutrients in the soil (Weisser & Siemann, 2004) besides stimulating microbial growth (Frost & Hunter, 2004), increase the porosity of soil (Lovett & Ruesink, 1995), and improve soil decomposition (Zimmer & Topp, 2002).

All plants use nitrogen (N) in the form of NO_3^- and NH_4^+. It is an essential element for plant development in improving crop yield and quality and plays a vital role in plant biochemistry and physiology (Leghari *et al.*, 2016).

By 2020, the Department of Agriculture Malaysia is targeting an increase of 242 farms with 'myOrganic' Certificates (DOA 2016). Therefore, this experiment was conducted to investigate the potential of cricket frass as an alternative organic fertiliser for the growth of green mustard, green spinach, and water spinach in a glasshouse.

II. MATERIALS AND METHOD

A. Field Details

The experiment that was carried out in a glasshouse at the Rumah Tumbuhan Universiti Kebangsaan Malaysia (UKM), Bangi Selangor assessed two factors, i.e. fertilisers and leafy vegetables. N1 (chicken dung), N2 (cricket frass), and N3 (NPK [15:15:15] compound fertiliser) were applied on three leafy vegetables grown on 2:1:1 (topsoil: organic: sand) soil. The chemical properties of the soil are presented in Table 1. A control treatment, N0 (without fertilisers) was included. The leafy vegetables evaluated were V1 (green mustard), V2 (green spinach), and V3 (water spinach). There were altogether 12 treatments. The treatments were arranged in a randomised complete block design (RCBD) with four replicates, as shown in Figure 1.

Table 1. Chemical properties of soil

Soil properties	Values
N, %	0.32
P, µg g^{-1}	2.44
K, µg g^{-1}	1574
CEC, cmol kg^{-1}	6.39
Total C, %	3.37
pH value	6.21

The organic fertiliser was applied a week before sowing/transplanting. The nutrients contents are as listed in Table 2. Green mustard was transplanted to the field plots from the nursery tray 12 days after sowing (DAS), green spinach 10 DAS, while the spinach was sown directly. The different DAS values were due to the difference in the germination period. The number of plants needed was three seedlings for each pot, with the plot size used of 4 m × 6 m with pots distance 25 cm × 25 cm to give 48 pots/area.

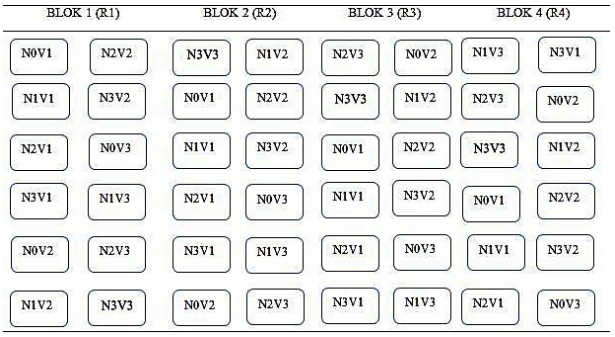

Figure 1. Layout of the experiment. Note N1, N2, N3, N0, V1, V2, V3 were chicken dung, cricket frass, NPK (15:15:15), green mustard, green spinach, water spinach, respectively and R= Replications

The compound fertiliser (15:15:15) was applied at 20 g/pot in two split applications in the first week and the third week after transplanting/sowing. All compound fertilisers were applied on the surface and slightly covered with soil to incorporate the fertilisers with the soil. The application of phosphorus and potassium were based on the recommended rates given by the suppliers. All crops were harvested in the fourth week after planting. Typical agronomic practices were followed for crop management and pest control (DOA, 2006).

Table 2. Nutrient nitrogen content of organic fertiliser

Source of fertiliser	(%) Nitrogen (N)	*Nitrogen (N) g/ leafy vegetables	Fertilisers (g)/ leafy vegetables
Chicken Dung	2.08	3	150
Cricket frass	3.73	3	75
NPK (15:15:15)	15.16	3	20

* Amat (2015)

B. Data Recording

Plant height was measured on 24 DAS for green mustard and 22 DAS for green spinach and water spinach (Lim & Vimala, 2012). The number of leaves was counted, and fresh yield at harvest was recorded for all the vegetables.

Table 3. Mean total height of vegetables in the fourth week when treated with different types of fertilisers

Vegetables	Fertilisers			
	Chicken dung	Cricket frass	NPK	Control
	Mean total height vegetables(cm)			
Green mustard	Bab 12.72±0.97	Ba 14.00±0.81	Ba 15.00±2.10	Bb 8.67±0.38
Water Spinach	Aa 45.43±2.52	Aa 47.00±1.94	Aa 47.04±0.79	Ab 26.84±0.71
Green Spinach	Ba 22.81±0.35	Ba 17.60±4.03	Ba 19.42±3.12	Bb 8.90±0.13

Means by column with the same capital letter are not significantly different according to Tukey's test at $p \leq 0.05$ between vegetables. Means by row with same lowercase letter are not significantly different according to Tukey's test at $p \leq 0.05$ between fertilisers. Means with the same capital letter and lowercase letter are not significantly different according to Tukey's test at $p \leq 0.05$ between vegetables and fertilisers.

C. Chemical Analysis and Proximate

Analyses of soil chemical properties for all treatments included pH measured in a 1:2 ratio (soil: distilled water) slurry using Schott glass electrode pH meter, CEC by leaching with 1 N ammonium acetate buffer (adjusted to pH 7.0), total C percentage by combustion technique, and nutrient (N, P, and K) availability. A total of 30 g of leaf samples was used for each treatment to analyse the concentration of nitrogen and protein content in leaves. Data obtained were compared with the Malaysian Food Act (2004) to identify the maximum permissible rate for metal contamination in particular food. The heavy metals analysed were arsenic (As), mercury (Hg), cadmium (Cd), lead (Pb), and antimony (Sb).

D. Statistical Analysis

Analysis of variance (ANOVA) was used to analyse the data to detect significant differences. The data were analysed using Minitab 17.0 for ANOVA and post hoc Tukey test.

III. RESULTS AND DISCUSSION

A. Plant Height

Table 3 shows the total height of vegetables treated with different fertilisers in the fourth week. There was no significant difference in the height of all vegetables when treated with different fertilisers. However, water spinach showed significant differences with green mustard and green spinach when treated with cricket frass. According to Tildale and Nelson (1981), the growth equation was associated with the supply of plant nutrients. Organic fertiliser increased plant growth and root nutrients absorption ability that affected the plant height (Rahmah & Izzati, 2014).

B. Number of Leaves

Table 4 shows the mean of the total number of leaves of all vegetables in the fourth week upon treatment with different types of fertilisers. Green mustard treated with cricket frass showed significant difference with NPK fertilisers treatment, but no significant difference was detected in the chicken dung and control treatment. However, there was no significant difference in the number of leaves of water spinach in all treatments. On the contrary, no significant difference was observed in green spinach treated with cricket frass in the NPK fertiliser treatment and control, but a significant difference was recorded in the chicken dung treatment. Leaf growth is substantial in plants because this process will determine the surface area of the leaf that serves as a light absorber for the photosynthesis process. Photosynthesis will determine the amount of dry matter that can be supplied for the growth of the tree (Masri & Boote, 1987). Some studies have found that the amount of leaf for legume is the highest in treatments using organic fertilisers (Fatahi *et al.*, 2014).

Table 4. Mean number of total leaves of vegetables treated with different types of fertilisers at the fourth week

Vegetables	Fertilisers			
	Chicken dung	Cricket frass	NPK	Control
	Number of total leaves			
Green mustard	Bb 7.31±0.16	Bb 7.08±0.13	Ca 9.10±0.48	Bb 6.05±0.42
Water Spinach	Aa 15.65±1.32	Aa 15.34±1.29	Aa 15.04±0.02	Aa 12.63±0.79
Green Spinach	Aa 14.34±0.39	Ab 12.11±0.76	Bb 12.06±0.36	Bb 10.63±0.27

Means with the same capital letter and lowercase letter are not significantly different according to Tukey's test at $p \leq 0.05$ between vegetables and fertilisers.

C. Yield

Table 5 shows the mean total yield of all the vegetables after harvest. Green mustard and green spinach indicated significantly different yield between the control and the treatment with fertilisers, while water spinach treated with cricket frass had a significant difference in yield in the NPK fertiliser and the control treatment. A significant difference in total yield was recorded in all vegetables treated with cricket frass. However, the results were influenced by different environment and agricultural practices (Roos *et al.*, 2018). The supply of N and weed control may be the two most important barrier factors in the production of organic crops (Askegaard *et al.*, 2011).

Table 5. Mean total yield of vegetables after harvest when treated with different fertilisers

Vegetables	Fertilisers			
	Chicken dung	Cricket frass	NPK	Control
	Mean total yield			
Green mustard	Ba 103.54±0.02	Ca 101.65± 0.91	Ca 121.54±0.02	Ab 72.7±10.2
Water Spinach	Aa 160.50±7.47	Aa 164.5±4.11	Bb 133.5±0.04	Ab 132.0±0.06
Green Spinach	Aa 154.00±0.09	Ba 137.5±0.02	Aa 156.0±0.02	Bb 107.9±9.96

Means by column with the same capital letter are not significantly different according to Tukey's test at $p \leq 0.05$ between vegetables. Means by row with same lowercase letter are not significantly different according to Tukey's test at $p \leq 0.05$ between fertilisers. Means with the same capital letter and lowercase letter are not significantly different according to Tukey's test at $p \leq 0.05$ between vegetables and fertilisers.

D. Nitrogen and Vegetable Protein Content by Type of Fertiliser Source

The determination of N and protein contents of all vegetables are shown in Table 6. Green mustard has the highest N (0.37 g/100 g) and protein content (2.31 g/100 g) when treated with NPK fertiliser while water spinach had the highest N (0.37 g/100 g) and protein content (2.23 g/100 g) when treated with cricket frass. However, green spinach has the same highest N (0.36 g/100 g) and protein content (2.28 g/100 g) when treated with cricket frass and NPK fertiliser. The element N provides rapid early growth, increases the growth of leafy vegetables, improves protein content of food crops, and promotes the consumption and use of other nutrients including potassium and phosphorus (Bloom, 2015). As observed, the cricket frass provided the N element and affected the protein content in leafy vegetables.

Additionally, waste from insects had the most substantial contribution to the soil nutrient cycle with micronutrient storage through the recycling process (Chen & Forschler, 2016).

Table 6. The content of N and protein found in different vegetables after harvest when treated difference fertilisers

Vegetables	**Fertilisers**	**Nitrogen, g/100g**	**Protein, g/100g**
Green Mustard	Chicken Dung	0.29	1.79
Green Mustard	**Cricket Frass**	**0.33**	**2.05**
Green Mustard	NPK	0.37	2.31
Green Mustard	Control	0.26	1.63
Water Spinach	Chicken Dung	0.32	2.00
Water Spinach	**Cricket Frass**	**0.37**	**2.32**
Water Spinach	NPK	0.33	2.05
Water Spinach	Control	0.28	1.75
Green Spinach	Chicken Dung	0.34	2.15
Green Spinach	**Cricket Frass**	**0.36**	**2.28**
Green Spinach	NPK	0.36	2.28
Green Spinach	Control	0.35	2.21

E. Heavy Metal Content in Vegetables by Type of Fertilisers

Table 7 shows heavy metals content in the vegetables. The overall results showed that As, Hg, Cd, Pb, and Sb contents are at the safe level following the Food Act 1983. The contents of heavy metal are dependent on the type of vegetables. Green mustard showed the highest content of Pb (0.109 mg/kg). According to Darmono (2001), green mustard has a high absorption of heavy metals. Plant parts such as roots, leaves, and stems of vegetables that have been exposed to Pb contamination will not be easily removed through washing techniques, as it has accumulated in that particular part (Itanna, 2002). Additionally, green mustard, green spinach, and water spinach were contaminated with Pb when they were planted near industrial areas and roads (Yusuf *et al.,* 2016). In this study, water spinach had the highest As (0.040 mg/kg) and Cd content (0.027 mg/kg) when treated with chicken dung. Green mustard had the highest Pb content (0.109 mg/kg) when treated with chicken dung, whereas green spinach had the highest Sb content (0.082 mg/kg) when treated with NPK fertiliser. However, there was no Hg detected in all vegetables.

When treated with cricket frass, water spinach had the highest As (0.036 mg/kg) content, while green mustard had the highest Cd content (0.009 mg/kg) and green spinach in Sb content (0.016 mg/kg). Water spinach treated with cricket frass also had the highest Pb compared to the green spinach and green mustard. This could be due to the water spinach absorbing the existing Pb metal in the soil or from the cricket frass itself. According to Chibuike and Obiora (2014), heavy metals such as Pb in the soil do not have any beneficial effects on the organisms; thus, considered detrimental to both plants and animals. Additionally, there was also a study on Pb concentrations on insect repellents, where Pb was detected on Reticulitermes residues (Chen & Forschler, 2016). The waste of the skeleton may have high Pb content because the cricket could bind to the toxic content obtained from plants during the digestive process (Smirle & Isman, 1992). Hence, the quality of food sources for cricket farming significantly affect the result of cyclic waste as organic fertiliser to increase crop growth and ultimately, the yield quality (Kagata & Ohgushi, 2012).

Table 7. The heavy metal content found in different Vegetables of Fertilisers sources in the fourth week after planting in a pot

Vegetables	Fertilisers	Arsenic (As)	Mercury (Hg)	Cadmium (Cd)	Lead (Pb)	Antimony (Sb)
		mg/kg				
Green Mustard	Chicken Dung	0.033	N.D (<0.001)	0.012	0.109	0.007
Green Mustard	**Cricket Frass**	**0.026**	**N.D (<0.001)**	**0.009**	**0.024**	**0.007**
Green Mustard	NPK	0.033	N.D (<0.001)	0.009	0.056	0.009
Green Mustard	Control	0.039	N.D (<0.001)	0.011	0.039	0.008
Water Spinach	Chicken Dung	0.040	N.D (<0.001)	0.027	0.018	0.006
Water Spinach	**Cricket Frass**	**0.036**	**N.D (<0.001)**	**0.003**	**0.048**	**0.009**
Water Spinach	NPK	0.034	N.D (<0.001)	0.008	0.029	0.005
Water Spinach	Control	0.032	N.D (<0.001)	0.008	0.027	0.005
Green Spinach	Chicken Dung	0.015	N.D (<0.001)	0.007	0.012	0.006
Green Spinach	**Cricket Frass**	**0.013**	**N.D (<0.001)**	**0.007**	**0.021**	**0.016**
Green Spinach	NPK	0.015	N.D (<0.001)	0.015	N.D (<0.001)	0.082
Green Spinach	Control	0.019	N.D (<0.001)	0.005	0.008	0.005
Maximum allowable rate (Food Act 1983)		1	0.05	1	2	1

Source : Malaysian Food Act. (2004)

IV. CONCLUSION

Cricket frass exhibited a good waste product effect on green mustard, green spinach, and water spinach in terms of height, the number of leaves, and yield. However, the effect of cricket frass on plant growth indicated significant differences between the mean height of the vegetables, the number of leaves, and the yield of all vegetables versus the NPK and chicken manure fertilisers. The nutritional content results of nitrogen and protein in all vegetables denoted high and almost the same level of cricket frass fertiliser. This shows that cricket frass has sufficient nutrient content for vegetable growing needs. High awareness to ensure that the food products are free from pesticides, chemical residues and heavy metals are also the factors of organic agriculture. The results of the presence of heavy metals in green mustard and green spinach are given as follows: arsenic> lead> cadmium> antimony> mercury, whereas in water spinach is given as follows: lead> arsenic> antimony> cadmium> mercury. The accumulation of each heavy metal in the tested vegetables varied and lead was found to be the highest in water spinach fertiliser with cricket frass. This indicated that the intake of certain heavy metals is dependent on the type of vegetable, and may not be suitable in the water spinach. However, the amount of heavy metal absorbed in all the tested vegetables is below the permitted maximum permissible level. Therefore, it can be deduced that the utilisation of waste as a source of organic fertiliser can promote vegetable growth. In addition, it encourages farmers to adopt a sustainable farming concept with proper waste management and practices of sustainable agricultural techniques that protect the environment and public health.

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