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Cricket frass: The high-quality organic fertilizer for vegetable growth improvement

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ABSTRACT: Recycling cricket frass into soil organic amendment is cost-saving from chemical fertilizer use and addresses the environmental risk from mismanagement of farm waste in cricket keeping. Worldwide, the limited study on cricket frass as a soil amendment has resulted in no recommendation of the optimum rates for crop production. The current study, therefore, aimed at estimating the effect of different rates of cricket frass on the growth of a vegetable. A red amaranth (*Amaranthus tricolor*) was used as the test plant. Five treatments (i.e., unamended, chemical fertilizer, and cricket frass rated at 0.5, 1, and 2 t/rai) and three replications were conducted under a pot experiment based on a completely randomized design. Height and leaf number of amaranth were examined as representative growth parameters. Higher rates of cricket frass from 0.5 to 1 t/rai led to higher amaranth growth. Nonetheless, an increase in the rate to 2 t/rai brought about decreases in the growth. A half-ton per rai of cricket frass could render amaranth growth comparable to the recommended chemical fertilizer rate. The optimum rate of cricket frass was 1 t/rai. The results demonstrated that cricket frass was a high-quality organic fertilizer for vegetable production.

Keywords: Cricket manure; New organic fertilizer; Optimum application rate; Organic amendment

Introduction

In Thailand currently, there are a number of cricket keepers on over 20,000 farms (Hanboonsong et al., 2013). These farms produced a large amount of waste— cricket frass, which is averaged to 44 t/farm/year (Halloran et al., 2017). The frass is composed of excrement, certain body parts of the dead, and residues of instant feeding and supplements (e.g., pumpkin and grasses). Mismanipulation of cricket frass leads potentially to deleterious environmental impacts, e.g., eutrophication and greenhouse gas emission. Recycling the frass into a soil amending material can address the environmental risks and meet the BCG model of government policy which includes bioeconomy, circular economy, and green economy.

Unlike conventional organic fertilizers, cricket frass is rich in plant nutrients and likely promptly used as a soil amendment. It promises particularly for growth improvement of vegetables of which nutrient deficiency is commonly found principally in organic crop production (Hartz and Johnstone, 2006). Nutrient contents of the frass are, for example, 2.3 – 2.6%N, 1.6 – 2.0%P, and 1.8 – 2.3%K (Halloran et al., 2017). These elements are higher than those of chicken manure which is acknowledged as the plant nutrient-rich material (1.7%N, 1.33%P, and 1.58% K) (Halloran et al., 2017). Cricket frass is a very new organic fertilizer; therefore, only a few studies pertaining to its impacts on soil and plant have been reported. Amongst the limit reports, its worth contribution to plant yields has been illustrated. For example, Treelokes (2013) demonstrated that the application of crick frass (2.4%N, 1.1%P, and 2.6%K) at the rate of 2.5 t/rai produced vegetable yields higher than other organic fertilizers, i.e., cow manure (1.5%N, 0.7%P, and 0.7%K) and compost (1.0%N, 0.6%P, and 0.8%K). In another study, Darby et al. (2018) showed that 0.506 and 0.613 t cricket frass/rai increased the yield of sweet corn (3.39 and 4.07

t/rai) over no cricket frass application (2.61 t/rai). Unfortunately, the corn yield response to chemical nor other organic fertilizers was not reported.

Because of the limited studies, the optimum rates for crop production have not been recommended yet. The current study, therefore, aimed to evaluate the effects of application rates of cricket frass on growth of a vegetable. We hypothesized that increases in the frass rates would raise vegetable growth, and at some higher levels, the detrimental effect would occur.

Materials and methods

A coarse-textured soil employed in this study was collected from the Field Research Facilities of the Plant Science Section, Sakon Nakhon Rajabhat University. The soil was air-dried, crushed, and sieved to pass through a 2-mm sieve. The initial properties of the soil are shown in **Table 1**. Cricket frass was obtained from a cricket keeping farm in Sakon Nakhon. Contaminant matters, e.g., body parts of the dead and residues of instant and supplementary feeds, were removed.

Table 1 Initial properties of a coarse-textured soil used in this study

Soil	Initial soil property †											
	pH	EC	LR	OM	TN	NH_4^+	NO_3^-	P	K	Ca	Mg	Fe
Coarse-textured soil	5.55	0.01	296	6.7	0.09	3	3	54	74	72	12	43

† pH = pH measured in soil:H_2O to 1:5; EC = electrical conductivity (mS/cm); LR = lime requirement (kg $CaCO_3$/rai); OM = organic matter (g/kg); TN = total nitrogen (g/kg); NH_4^+ = ammonium (mg/kg); NO_3^- = nitrate (mg/kg); P = available phosphorus (mg/kg); K = extractable potassium (mg/kg); Ca = extractable calcium (mg/kg); Mg = extractable magnesium (mg/kg); Fe = extractable iron (mg/kg)

Data sources: Butnan et al. (2019)

A pot experiment based on a completely randomized design with three replications was conducted under a greenhouse installed with an evaporative cooling system. The average air temperature of the greenhouse over the study period was 28.4°C. Treatments included unamended, chemical fertilizer, and three cricket frass rates, i.e., 0.5, 1, and 2 t/rai. In the chemical treatment, chemical fertilizers graded 46-0-0, 18-46-0, and 0-0-60 were calculated and applied to achieved the recommendation rate of 50 kg N/rai (312.5 kg N/ha), 16 kg P/rai (100 kg P/ha), and 16 kg K/rai (100 kg K/ha) (Chakhatrakan, 2003). As for the cricket treatments, a 2-kg air-dry soil was put into a pot and mixed thoroughly with cricket frass at their designed rates. The mixtures were incubated with water at 65% of water holding capacity (WHC) for 15 days. A red amaranth (*Amaranthus tricolor*) was seeded and nursed in a nursery plug tray, and one seedling was transplanted to a pot after 15 days after planting (DAP). Soil moisture content of each pot was leveled at 65% of WHC over the experiment period. Height and leaf number of amaranth were measured at another two days from 15 DAP till aboveground biomass was harvested (39 DAP).

Repeated measure analysis of variance based on a completely randomized design was performed to evaluate the effects of cricket frass rates on amaranth growth. Fisher's least significant difference was used to compare the treatment means. Significant differences were at $P \leq 0.05$. Statistical analyses were performed by the SAS package version 9.1 (SAS Institute, Cary, NC, USA)

Results and discussion

Soil amendments had a significant effect on amaranth growth, i.e., height and leaf number, and the effect depended on days after planting (**Table 2**). The effect of soil amendments on height was observed from 21 DAP onwards (**Figure 1a**), while that on leaf number was from 24 DAP (**Figure 1b**). At the end of the study (39 DAP), the results confirmed our hypotheses that height and leaf number increased with raising the frass rates from 0.5 to 1 t/rai. Both height and leaf number dropped when treated 2 t/rai as compared to its lower rate. The lowest cricket frass (0.5 t/rai) produced the amaranth height comparable to the recommended rate of chemical fertilizer. From 35 DAP till the harvest, increases in leaf number under chemical fertilizer but decreases under other treatments were still mysterious.

Our results demonstrated that cricket frass was a high-quality organic fertilizer for the enhancement of vegetable growth. As limit reports pertaining to cricket frass's effect on soil and plant, its benefits on plant growth improvement were herein based on the mechanisms grasped from previous studies upon mainly chicken manure because they are probably similar characteristics. Cricket frass may enhance amaranth growth via increasing nutrient availability, alleviating elemental phytotoxicities, and promoting plant growth by hormone-like molecules.

Table 2 Repeated measure analysis of variance pertaining to the effects of cricket frass rates (Treatment) and days after planting (Time) on amaranth's height and leaf number over 39 days of the experiment

Source of variance	Degree of freedom	P-value	
		Height (cm)	Leaf number (Leaf number/plant)
Treatment	4	***	***
Time	8	***	***
Treatment x Time	32	***	***

*** = $P \leq 0.001$

Cricket frass was very high in plant nutrients. Halloran et al. (2017) reported that the frass of *Gryllus bimaculatus* contained 2.58%N, 1.55%P, and 1.78%K, and *Acheta domesticus* had 2.27%N, 2.02%P, and 2.26%K. These nutrient contents were much higher than the critical values (1%N, 0.22%P, and 0.41%K) proclaimed in the Standard of Organic Fertilizer ruled under the Department of Agriculture (2005). Rich in nutrient contents in the frass of both crickets was consistent with Hue (1992) and Hue and Licudine (1999), who amended chicken manure to tropical soils and found higher availabilities of soil N, P, Ca, S, and Cl. Plant growth improvement by animal manures was also attributed to remediation of Al, Fe, and Mn phytotoxicities. Animal manure and in particular chicken manure possessed organic molecules, e.g., acetic, citric, gallic, oxalic, succinic, salicylic, tannic, and tartaric acids, and catechol, to complex and inactivate Al, Fe, and Mn, which are principally phytotoxic in tropical soils (Hue, 1992; Hue and Licudine, 1999; Escobar and Hue, 2008). Our ideal mechanism on complexation of cricket frass derived organic molecules with phytotoxic elements in soil are shown in Equation 1:

$$\text{Complex} + M_{(active)} \longrightarrow \text{Complex—}M_{(inactive)} \qquad \text{Equation 1}$$

where Complex means cricket frass-derived organic molecules, e.g., acetic, citric, gallic, oxalic, succinic, salicylic, tannic, and tartaric acids, and catechol, and M represents phytotoxic elements, e.g., Al, Fe, and Mn.

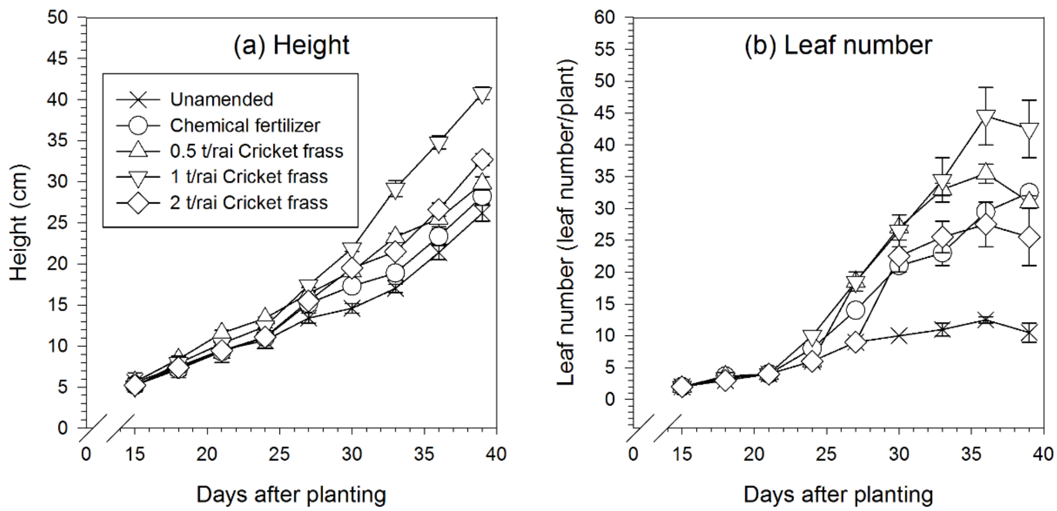
In addition, promoting amaranth growth by cricket frass in this study might be the effect of increased soil pH. The pH increase by the release of NH_3 from mineralization of manure-derived organic N can detoxify phytotoxic elements (Escobar and Hue, 2008). The reactions were illustrated in Equations 2 and 3.

$$R\text{-}CH\text{-}NH_2\text{-}COOH + 0.5\ O_2 \longrightarrow R\text{-}CO\text{-}COOH + NH_3 \qquad \text{Equation 2}$$

$$NH_3 + H_2O \longrightarrow NH_4^+ + OH^- \qquad \text{Equation 3}$$

where R-CH-NH_2-COOH is organic N derived from animal manure.

To promote plant growth, hormone-like molecules produced from animal manures and behaved like cytokinins were put forwards by Hue (1992).



Treatment	Days after planting								
	15	18	21	24	27	30	33	36	39
Unamended	ns	ns	b	b	d	d	e	d	e
Chemical fertilizer	ns	ns	b	b	c	c	d	c	d
0.5 t/rai Cricket frass	ns	ns	a	a	b	b	b	b	c
1 t/rai Cricket frass	ns	ns	ab	a	a	a	a	a	a
2 t/rai Cricket frass	ns	ns	b	b	c	b	c	b	b

Treatment	Days after planting								
	15	18	21	24	27	30	33	36	39
Unamended	ns	ns	ns	c	c	c	c	d	d
Chemical fertilizer	ns	ns	ns	b	b	b	b	c	b
0.5 t/rai Cricket frass	ns	ns	ns	c	a	a	a	b	b
1 t/rai Cricket frass	ns	ns	ns	a	a	a	a	a	a
2 t/rai Cricket frass	ns	ns	ns	c	c	b	b	c	c

Figure 1 Height (a) and leaf number (b) of amaranth as affected by different application rates of cricket frass as comparison with unamended and chemical fertilizer. Vertical bars are standard deviation. The accompanying tables beneath the graphical data demonstrate the mean comparisons within a time interval (days after planting, DAP). Similar letters within a DAP are not significantly different ($P \leq 0.05$, Fisher's least significant difference)

The adverse effect of 2 t/rai of cricket frass could be resulted from high salt concentrations due to excessive application rate. A salt effect attributed to the excessive amount (~6 t/rai) of chicken manure to the Paaloa soil (a humid tropical Ultisol) and getting detrimental to *Desmodium intortum* was also observed by Hue (1992). High concentrations of soil Na, P, N, and other ions bringing about decreases in plant growth were reported by Hue (1992), Hue and Licudine (1999), and Eghball and Power (1999). In addition, imbalance or deficiency of micronutrients, e.g., Fe and B, was possibly rendered by high soil pH due to a high amount of animal manure (Hue, 1992). Furthermore, higher Mn dissolution and toxicity, which were acted by manure-derived organic molecules, could be a deleterious effect of the overuse of manure amendment (Escobar and Hue, 2008).

Conclusions

The results of this study clearly showed that cricket frass was a high-quality organic fertilizer for vegetable production. The optimum cricket frass rate for amaranth was 1 t/rai. Application of cricket frass just as the rate as 0.5 t/rai could produce amaranth growth comparable to the recommended rate of chemical fertilizer. Two ton per rai of cricket frass was not recommended because it depressed amaranth growth.

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