International Journal of Agricultural Technology 2025 Vol. 21(4):1597-1604
DOI: https://doi.org/10.63369/ijat.2025.21.4.1597-1604
Available online http://www.ijat-aatsea.com
ISSN 2630-0192 (Online)

The effects of rate and timing of cricket frass application on Kalmegh (*Andrographis paniculata*) production in low-fertility soils

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Toonsiri, P. and Klangsinsirikul, S. (2025). The effects of rate and timing of cricket frass application on Kalmegh (*Andrographis paniculata*) production in low-fertility soils. International Journal of Agricultural Technology 21(4):1597-1604.

Abstract The findings indicated that the varying rates of cricket frass application affected parameters such as shoot height, shoot fresh weight, and shoot dry weight. The treatment that applied cricket frass at 48 kg ha^{-1} yielded the highest values for shoot height (49.52 cm), shoot fresh weight (31.89 g $plant^{-1}$), and shoot dry weight (8.69 g $plant^{-1}$). Considering the various periods for applying cricket frass before planting, the results showed that the timings significantly impacted only the shoot fresh weight. Applying cricket frass 0 day before transplanting (applying on the same day as transplanting) resulted in the highest shoot fresh weight (23.40 g $plant^{-1}$). Additionally, interactions between the rate of cricket frass application and the timing of cricket frass application before planting were observed in relation to shoot height, shoot fresh weight, and shoot dry weight of kalmegh. Specifically, applying cricket frass at a rate of 48 kg ha^{-1} on the same day as transplanting led to the highest shoot fresh weight (34.46 g $plant^{-1}$) and shoot dry weight (9.55 g $plant^{-1}$). Therefore, cricket frass showed potential as a fertilizer for enhancing the yield of kalmegh *(Andrographis paniculata)* in low-fertility soils.

Keywords: Kalmegh, Organic fertilizer, Cricket frass

Introduction

Certainly, cricket frass, which is the waste produced from cricket farming, has proven effective in providing nutrients to plants. This indicates its significant potential as a valuable organic fertilizer, supporting the goal of achieving zero waste (Wanjugu *et al*., 2023; Andrianorosoa Ony *et al.,* 2024).

While the incorporation of insect frass as an organic soil amendment has gained traction for promoting sustainable agricultural practices, research focusing on optimizing the application rates and timing for cricket frass, especially in low-fertility soils, remains limited. Existing studies have highlighted both the advantages and challenges associated with the utilization of cricket frass. For instance, the findings of Butnan and Duangpukdee (2021)

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revealed that an application rate of 160 kg ha^{-1} significantly enhanced the growth of red amaranth; however, excessive application led to stunted plant growth. Furthermore, Kagata and Ohgushi (2012) discovered that the quality of frass, influenced by the insects' diet, plays a crucial role in determining its effectiveness as a fertilizer. While research conducted by Halloran *et al*. (2017) and Wantulla *et al*. (2023) highlights the environmental sustainability of insect farming and the use of frass as an organic fertilizer, knowledge about the targeted application of cricket frass for medicinal plants is lacking.

Evidence from studies by Ogaji *et al*. (2022) and Wanjugu *et al*. (2023) indicates that cricket frass can contribute to enhancing the growth and yield of crops such as spring onions and *Cleome gynandra*. However, concerning the medicinal herb Kalmegh (*Andrographis paniculata*), existing research efforts by Basak *et al*. (2020) and Chouhan *et al*. (2023) have primarily focused on exploring the effects of traditional organic amendments like vermicompost and chemical fertilizers. Although Detpiratmongkol *et al*. (2014) and Khushboo Khan *et al*. (2015) have highlighted the potential of organic manures in improving Kalmegh cultivation, the application of cricket frass has not been addressed.

The proposed study aimed to investigate the efficiency and potential of cricket frass as a fertilizer for enhancing Kalmegh yields and examined different application rates and timings in low-fertility soil conditions to offer thorough guidelines for optimizing the use of cricket frass for Kalmegh production.

Materials and methods

Experimental research design

This study was conducted in a greenhouse from July 2022 to October 2022 by using a 3 x 3 factorial experimental design in a Randomized Complete Block Design (RCBD), consisting of three replications. The first factor comprised three levels of cricket frass application rates of 0, 48, and 96 kg ha^{-1}. The second factor encompassed three timing levels for applying cricket frass before transplanting at 0, 7, and 14 days prior to transplanting.

Crop management

The seeds of Kalmegh (cultivar Phichit 4-4) were sown in trays filled with peat moss. Two kilograms of soil were placed into each pot, and the soil was mixed with cricket manure at application rates specified in the experimental design. After each application, both treated and control (untreated soil) units were

watered at the same application intervals. When the sixth leaf appeared, uniform seedlings were selected and transplanted into the pots. After growing for 92 days, the Kalmegh plants were harvested.

Cricket frass analysis

Before conducting the experiment, cricket frass was analyzed for its chemical properties. The pH and electrical conductivity (EC) were measured in a 1:10 frass-to-water suspension using digital pH and conductivity meters, respectively. Organic carbon content was determined using the Walkley-Black procedure. Total nitrogen (TN) was measured using the Kjeldahl method. Total phosphorus (TP) was assessed with the vanadomolybdophosphoric acid method, and total potassium (TK) was measured using a flame photometer.

Soil analysis

The chemical properties of soil samples were analyzed before and after the experiments. The soil samples were air-dried and sieved to less than 2 mm prior to analysis. Soil pH and electrical conductivity (EC) were measured in a 1:1 soil-to-water suspension using digital pH and conductivity meters, respectively. Organic matter content was analyzed using the Walkley-Black procedure. Total nitrogen (TN) was determined by the Kjeldahl method. Available phosphorus (Avai. P) was tested using the Bray II method. Exchangeable potassium (Exch. K) was extracted with ammonium acetate and measured by flame photometer.

Data collection

The Kalmegh (*Andrographis paniculata*) was harvested on October 18, 2022. After the harvest, data were collected for shoot height and shoot fresh weight. The fresh shoots were then oven-dried at 80°C for 48 hours, after which the dry weights were recorded.

Statistical analysis

The collected data were analyzed statistically according to 3 x 3 factorial experimental design in a randomized complete block design (RCBD). Analysis of Variance (ANOVA) was used to determine significant differences among treatments. The significant results from ANOVA were subjected to further statistical analysis with the use of LSD Test at 0.05 probability level.

Results

Chemical properties of cricket frass

Cricket frass was analyzed to determine its chemical properties (Table 1), and the results showed that the properties of the cricket frass were in accordance with the criteria for organic fertilizer as specified by the Department of Agriculture (DOA, 2012).

Table 1. Chemical properties of cricket frass

Properties	**pH**	**EC (dSm^{-1})**	**OM (%)**	**TN (%)**	**TP (%P_2O_5)**	**TK (%K_2O)**
Cricket frass	6.86[1/]	1.63[1/]	72.23[2/]	5.36[3/]	1.40[4/]	3.00[5/]
DOA Notification	-	≤ 10	≥ 20	≥ 1.0	≥ 0.5	≥ 0.5

[1/] The pH and electrical conductivity (EC) determined with a 1:10 frass-to-water extraction
[2/] Organic carbon (C) determined with a Walkley-Black procedure,[3/] Total nitrogen (TN) determined with a Kjeldahl method, [4/] Total phosphorus (TP) determined with a vanadomolybdophosphoric acid method and [5/] Total potassium (TK) determined with a flame photometer

Chemical properties of soil

Soil samples collected before and after the experiments were analyzed to determine their chemical properties (Table 2). The results revealed that the soil exhibited low fertility prior to the experiment. Following the experiment, there was a notable improvement in the chemical properties of the soil, particularly in the nutrient levels in the treatment where cricket frass was applied. Additionally, the study demonstrated that the application of cricket frass was significantly improved in various soil properties. Higher rates of frass application (96 kg ha^{-1}) and longer periods before transplanting (14 days) resulted in the most enhancements. Considering the interaction, it was found that there was an interaction between the rate of cricket frass application and the timing of its application before transplanting. The study found that applying cricket frass at a rate of 96 kg ha^{-1} 14 days before transplanting resulted in the lowest pH value (5.72), while the electrical conductivity (1.350 dS m^{-1}), organic matter content (0.91%), total nitrogen content (0.045%), available phosphorus content (270.26 ppm), and exchangeable potassium content (253.83 ppm) of the soil after transplanting were shown significantly the highest. Conversely, applying cricket frass at a rate of 0 kg ha^{-1} on the day of transplanting (0 days before transplanting) resulted in the highest pH value (6.52), but the electrical conductivity (0.841 dS m^{-1}), total nitrogen content (0.62%), and available phosphorus content (7.73

ppm) of the soil after planting were significantly lowest as compared to the other treatments.

Table 2. Chemical properties of soil before and after the experiment

Properties	pH [1/]	EC [1/] (dSm^{-1})	OM [2/] (%)	TN [3/] (%)	Avai. P [4/] (ppm)	Exch. K [5/] (ppm)
Soil before the experiment						
	5.22	0.839	0.52	0.026	7.18	6.68
Soil after the experiment						
R: Rate of the cricket frass application (kg ha^{-1})						
0	6.09a	0.841c	0.66c	0.033c	9.60c	26.16c
48	5.91c	0.971b	0.79b	0.039b	112.39b	73.01b
96	6.01b	1.244a	0.87a	0.044a	239.35a	221.53a
F-test	**	**	**	**	**	**
T: Time period for applying cricket frass prior to transplanting (days)						
0	6.32a	0.961c	0.74b	0.037b	102.76c	109.72b
7	5.97b	0.998b	0.74b	0.037b	121.04b	103.90b
14	5.72c	1.097a	0.84a	0.042a	137.54a	135.44a
F-test	**	**	**	**	**	*
R (kg ha^{-1}) x T (days)						
0 x 0	6.52a	0.841f	0.62d	0.031d	7.73g	32.53d
0 x 7	5.82e	0.843f	0.61d	0.031d	7.94g	31.01d
0 x 14	5.93d	0.840f	0.75c	0.037c	13.13g	12.62d
48 x 0	6.23b	0.869f	0.74c	0.037c	92.94f	67.39c
48 x 7	6.01d	0.942e	0.80c	0.038c	114.99e	73.62c
48 x 14	5.50g	1.101d	0.87b	0.043b	129.23d	80.78c
96 x 0	6.22b	1.172c	0.86b	0.043b	207.62c	203.67b
96 x 7	6.09c	1.210b	0.85b	0.043b	240.18b	207.08b
96 x 14	5.72f	1.350a	0.91a	0.045a	270.26a	253.83a
F-test	**	**	**	**	**	**
Mean	6.00	1019.2	0.77	0.04	120.45	106.95
C.V. (%)	1.20	2.69	3.68	3.68	5.38	14.83

[1/] Soil pH and electrical conductivity (EC) determined with a 1:1 soil-to-water extraction, [2/] Organic matter (OM) determined with a Walkley-Black procedure, [3/] Total nitrogen (TN) determined with a Kjeldahl method, [4/] Available phosphorus (Avai. P) determined with a Bray II method and [5/] Exchangeable potassium (Exch. K) determined with a flame photometer, Notes: * = significantly different at $P \leq 0.05$ and ** = significantly different at $P \leq 0.01$. Mean values in a column followed with the same superscript letters are not significantly different according to the least significant difference (LSD) test.

Yield of Kalmegh

Kalmegh plants were harvested at 92 days of age, and their shoot height, shoot fresh weight, and shoot dry weight were measured to determine yield. The effects of different rates and timing of cricket frass application on the growth of Kalmegh (*Andrographis paniculata*) was presented in Table 3. The results indicated that the application of fertilizer improved the growth of Kalmegh across

all treatments; however, the application of 48 kg ha^{-1} demonstrated the highest shoot height (49.52 cm), shoot fresh weight (31.89 g plant^{-1}), and shoot dry weight (8.69 g plant^{-1}) among the treatments. Additionally, the time period before transplanting at 0, 7, and 14 days was examined. The shoot fresh weight was significantly higher when frass was applied at 0 and 14 days before transplanting, with values of 23.40 g plant^{-1} and 22.89 g plant^{-1}, respectively, compared to 20.60 g plant^{-1} at 7 days. However, shoot height and shoot dry weight were not significantly affected by the time period. When considering the interaction between application rates and time period, the combination of 48 kg ha^{-1} applied 0 days before transplanting resulted in the highest shoot height (50.06 cm), fresh weight (34.46 g plant^{-1}) and dry weight (9.55 g plant^{-1}) as compared to control group (0 kg ha^{-1}) at 0, 7 and 14 days before transplanting.

Table 3. Shoot height, shoot fresh weight, and shoot dry weight of Kalmegh

Properties	**Shoot height (cm)**	**Shoot fresh weight (g plant^{-1})**	**Shoot dry weight (g plant^{-1})**
R: Rate of the cricket frass application (kg ha^{-1})			
0	37.30b	8.58c	2.73c
48	49.52a	31.89a	8.69a
96	47.06a	26.42b	6.52b
F-test	**	**	**
T: Time period for applying cricket frass prior to transplanting (days)			
0	43.44	23.40a	6.28
7	44.58	20.60b	5.64
14	45.86	22.89a	6.03
F-test	ns	*	ns
R (kg ha^{-1}) x T (days)			
0 x 0	32.43c	6.02e	1.77e
0 x 7	35.43c	5.66e	1.83e
0 x 14	44.04b	14.05d	4.60d
48 x 0	50.06ab	34.46a	9.55a
48 x 7	47.88ab	27.59b	7.97bc
48 x 14	50.63a	33.63a	8.56b
96 x 0	47.84ab	29.71b	7.51c
96 x 7	50.43ab	28.54b	7.13c
96 x 14	42.92b	21.00c	4.93d
F-test	**	**	**
Mean	44.63	22.30	5.98
C.V. (%)	19.60	21.68	21.63

Notes: ns = non-significant; * = significantly different at $P \leq 0.05$; ** = significantly different at $P \leq 0.01$. Mean values in a column followed with the same superscript letters are not significantly different according to the least significant difference (LSD) test.

Discussion

An initial soil analysis before planting was low fertility, but post-planting improved soil properties with higher nutrient levels. This improvement is likely due to nutrients from cricket frass and root exudate, which enhanced the soil microbial community and stimulated nutrient mineralization (Zhao *et al*., 2021). Applying cricket frass increased nutrient content for soil microorganisms, which decomposed the frass and released nutrients to promote plant health. This composting process produced organic acids, potentially increasing soil acidity and lowering pH (Brady and Weil, 1996). This study is aligned with Ogaji *et al*. (2022), which decreased soil pH after cricket frass application.

Treatments with cricket frass applied 14 days before transplanting showed higher electrical conductivity, organic matter, nitrogen, phosphorus, and potassium as compared to applications 7 days before or on the day of transplanting. These findings are consistent with Azeez and Van Averbeke (2010) and Sriraj *et al*. (2022), who found that higher applications of organic amendments increased nutrient levels over time. Therefore, these findings indicated that cricket frass can effectively enhance soil fertility, with more substantial effects which increased the application rates and extended periods before transplanting to improve crop productivity (Butnan and Duangpukdee, 2021).

The highest average growth and yield of Kalmegh were achieved with 48 kg ha^{-1} of cricket frass when applied on the day of transplanting. Higher rates of 96 kg ha^{-1} was applied for 14 days before transplanting stunted growth and reduced yield due to osmotic stress from excess nutrients disrupting the plant's water balance (Castañeda and González, 2021). This is similar to Andrianorosoa Ony *et al.* (2024), who found that excessive cricket frass reduced plant growth.

This study indicated that Kalmegh yield can be increased by applying cricket frass at the optimal rate of 48 kg ha^{-1} on the day of transplanting. However, this study was conducted in a controlled greenhouse environment using only one variety of Kalmegh, Phichit 4-4, further experiments are needed to conduct under various conditions.

Acknowledgements

This study was supported by a budget grant from Ubon Ratchathani University, for which we are very grateful. We sincerely thank Ms. Nopamat Namdeang for her support during the fieldwork and laboratory phases of this study. We appreciate the Faculty of Agriculture for providing essential facilities and resources, and we thank the agricultural staff for their assistance in both field and lab work. Additionally, we extend our gratitude to the Phichit Agricultural Research and Development Center and the Chiang Mai Seed Research and Development Center for providing the Kalmegh seeds. This study would not have been possible without the contributions of these individuals and institutions.

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(Received: 30 June 2024, Revised: 12 January 2025, Accepted: 15 January 2025)