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Exploring Desert Locust (*S. gregaria*) Frass as an Organic Fertilizer for the Growth of Kales (*Brassica oleracea* L.) under Open Field Conditions

Mmbone Sylvia [1], Wanjala F. M. Fredrick [1] and Gohole Linnet [2]

[1]Department of Biological Sciences, University of Eldoret, P.O. BOX 1125-30100, Eldoret, Kenya

[2]Department of Seed Crop and Horticultural Sciences, University of Eldoret, P.O. BOX 1125-30100, Eldoret, Kenya

Abstract

In Kenya, kale (Brassica oleracea L.) is one of the most commonly consumed vegetable crops, however, their yield has been decreasing due to poor soils. An experiment was conducted to investigate the growth performance, yield, chlorophyll content and nutritional quality of kales when planted using decomposed desert locust frass, chicken manure and NPK fertilizers under open field conditions. The experimental design was a randomized complete block design with six treatments namely; A: Plain soil that had no fertilizer (negative control), B: Soil + NPK (10g per planting), C: Soil + chicken manure (2:1), D: Soil +50 g of frass, E: Soil +100 g of frass and F: Soil +150g of frass. Chemical characteristics of organic manures showed that decomposed locust frass had significantly high levels of Phosphorus, Nitrogen, Calcium, Carbon, potassium, sodium, and Magnesium compared to decomposed chicken manure. Data were analyzed in STATGRAPHICS centurion XVI and one-way ANOVA was used to analyze for significant differences in means. Results of the growth performance of kales showed that soil treated with 100 g decomposed frass produced kale plants with a significantly ($p< 0.05$) higher number of leaves than kale plants grown using other fertilizer treatments in the experiment. Kales planted with chicken manure were significantly taller than kales from other fertilizer treatments. Kale leaf chlorophyll content from soil treated with 100 g decomposed frass registered the highest chlorophyll content which was significantly different ($p<0.05$) from chlorophyll content on kales grown using chicken manure, NPK fertilizer, and 50g and 150 g decomposed frass manure. The proximate composition analysis on harvested kale leaves showed that kales planted using 50 g decomposed locust frass had higher nitrogen, phosphorous, and crude fats concentrations compared to kales from other fertilizer treatments. These results shows that decomposed desert locusts frass has the potential to be used as an organic fertilizer in cropping system.

Keywords: Kale, poor soils, desert locust frass, growth performance, nutritional quality.

Correspondence: mmbonesylvia459@gmail.com

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Introduction

Most soils in Kenya are of poor quality having low organic matter in addition to very high concentrations of acid, excessive aluminum, and calcium deficiency (Agustiyani *et al.* 2021). The depleted soils can therefore be solved through composted organic manure, which will significantly improve the soil quality and over time increase the soil nutrient levels, thus increasing crop performance and yield (Quilliam *et al*., 2019). In addition, organic manures/fertilizers have also been found to supply crops with secondary nutrients such as magnesium, sodium, and calcium together with other micronutrients that play an essential role in the utilization and uptake of macronutrients by plants (Anyega *et al.,* 2021). The most commonly used organic manures in crop production around the world include poultry manure (Soremi *et al*., 2017), and manure from livestock (Rayne & Aula, 2020), which is however not easily accessible by many crop producers due to many not being able to domesticate these animals. Insect frass has also the potential to be used as alternative organic manure in crop production.

Small-scale insect farming for food and feed leads to the production of huge amounts of frass which is collected as a waste product (Poveda *et al*., 2019). Therefore, to contribute to a circular economy and to look at zero wastage, it is important to capitalize on all components of insects including their frass as an organic fertilizer. Frass is a solid insect waste material that has been converted to a microbially rich substance through insect food digestion that results in a higher product in organic matter (Chavez & Uchanski, 2020). Insect frass contains a combination of uneaten feeds, faeces, and exuviae or exoskeleton produced during the molting period and when these substrates are decomposed, they can be used as organic fertilizer in crop production, thereby leading to improved crop productivity (Anyega *et al.,* 2021).

There is however insufficient information on insect frass as organic fertilizer despite intensive research in exploiting insects as food and feed. However, some research has been carried out using black soldier fly frass as organic fertilizer in various crops and cropping systems (Quillam *et al.,* 2019; Beesigamukama *et al.,* 2020; Anyega *et al.,* 2021; Agustiyani *et al.,* 2021). Some experiment has also been conducted on the Basil plant using mealworm frass (*Tenebrio molitor*) (Poveda *et al.,* 2019). The desert locust's frass can also be explored as organic fertilizer in vegetable crops since the frass is rich in nitrogen as a result of the insect-consuming vegetation (Kietza *et al.,* 2021). The locust frass fertilizer can be used in the growth of vegetables such as *Brassica oleracea* (kales) which is a popular leafy vegetable crop grown in many parts of Kenya mainly for the domestic market (Anyega *et al.,* 2021). Kale is a highly valued vegetable since it is a very healthy food source that contains high levels of vitamins, prebiotic carbohydrates, carotenoids, and minerals (Migliozzi *et al.,* 2015). However, the poor soil quality in Kenya (Agustiyani *et al.* 2021) may lead to low production of kales for consumption. To increase kale production, an improvement in soil fertility is therefore required.

The use of desert locust frass as an organic fertilizer is a relatively new concept and information on its performance on the growth of vegetables such as kales is largely unknown. The adoption of a new product like fertilizer in any farming system requires information on its performance in terms of influence on the growth of crops, and yield in comparison to existing fertilizers. The performance of decomposed desert locust frass for kales in comparison to chicken manure and existing artificial fertilizers has not been studied. Therefore, the current study aimed to determine the effects of decomposed desert locust frass on the growth performance, nutritional quality, and chlorophyll content of kales in comparison with chicken manure and artificial fertilizer.

Materials and methods

Study area

This experiment was carried out at the University of Eldoret (0°32' 51.3972" N, 35°12'16' 11.2044'' E) at an altitude of 2,140 m above sea level. The University of Eldoret area receives a mean annual rainfall of 1124 mm with temperatures ranging between 17°C and 26°C (Chebet *et al*., 2017). The experiment was carried out between January to March 2022.

Preparation of chicken manure, locust frass manure, and soil for the experiment

Chicken manure collected from a chicken house near Eldoret University was moistened with water and allowed to decompose naturally for 28 days before being used in the experiment. Desert locust frass collected throughout the rearing period of the insect was moistened with water and allowed to decompose naturally for 28 days before the commencement of the experiment. Commercial fertilizer NPK was used as a positive control in the experiment while non-amended soil was used as a negative control.

Soil that had not been used for any plant growth for at least a year was excavated from a farm near the University of Eldoret and was used as a growth medium in the experiment. The soil was air-dried and sieved through a 2mm mesh before the experiment. Four kilograms (4 kg) of soil each was then filled in (15 x 30cm) 36 gunny bags respectively ready for planting.

Certified *Brassica oleracea* L (kale) seeds were sourced from an agrovet in Eldoret town, Uasin Gishu county, seedlings were raised in a nursery and were ready for transplanting 21 days after germination.

Experimental setup of several soil organic fertilizers treatments on kales

The experiment was carried out in an open field in a randomized complete block design (RCBD). There were six treatments of different organic manure and NPK fertilizer (growth medium) which were replicated six times. The six growth medium treatments included;

- A: Plain soil that had no fertilizer (negative control)
- B: Soil + NPK (10g per planting)
- C: Soil + chicken manure (2:1)
- D: Soil +50 g of frass
- E: Soil +100 g of frass
- F: Soil +150g of frass.

The growth medium treatments described above were added randomly to each of the 36 gunny bags and seedlings from the nursery bed were then transferred to each treated gunny bag.

Measurement of kale leaf chlorophyll content: In vivo assay

The relative chlorophyll content was determined using the atLEAF CHL PLUS meter. Each leaf was marked in three representative points and the average was calculated. This method was intended to overcome the influence of the non-uniform distribution of chlorophyll in the leaf, hence producing more representative data. The chlorophyll was measured between 10 am and 11 am every week from week three after transplanting the kales up to week seven for all the treatments (Limantara *et al*., 2015).

Proximate analysis of *Brassica oleracea* leaves, locust frass, and chicken manure

Chemical analysis of the manures before and after decomposition was analyzed using the standard methods of (AOAC 1999). At week seven of growth, kale leaves were randomly selected and harvested, from each plant of the six treatments. They were then cleaned in running tap water and taken to the chemistry laboratory at the University of Eldoret and proximate analysis for fat, crude fiber, and minerals; that is, nitrogen, potassium, and phosphorus determined using the standard methods of (AOAC 1999).

Data collection

The plant growth of kales was determined by collecting data on the following parameters; plant height and the number of leaves were recorded weekly from the time of transplanting (week one) to week seven. Chlorophyll content in the leaves of kales was also measured every week from week three of transplanting to week seven. At week seven, the kale leaves grown using different manure treatments were randomly selected and their nutritional composition analysis was determined.

Statistical analysis

Data from the field experiment on a cumulative number of leaves of kale, their height, and chlorophyll content measured were entered in Excel software and analyzed in STATGRAPHICS centurion XVI. One-way ANOVA was used to analyze for significant differences in mean. Means with a significant difference were separated using Fisher's least significant difference (LSD). All statistical analyses were considered significant when the P value was less than 0.05 ($p < 0.05$).

RESULTS

Characteristics of organic fertilizers used to grow *Brassica oleracea* (kales)

The amounts of nutrients in chicken manure and locust frass were evaluated before and after 28 days of decomposition. Fresh and decomposed locust Frass had high amounts of macro and micronutrients compared to chicken manure. Decomposed desert locust frass had significantly high levels of Phosphorus, Nitrogen, Calcium, Carbon, potassium, sodium, and Magnesium compared to decomposed chicken manure (Table 1).

Table 1: Chemical characteristics of the experimental organic manures

Minerals	Frass manure		Chicken manure			
	Fresh	decomposed	Fresh	decomposed	F-Ratio	p-Value
P (%)	2.53±0.01^{a}	2.30±0.09^{b}	1.63±0.01^{c}	1.20±0.02^{d}	528.86	0.0000
N (%)	9.76±0.14^{a}	7.56±0.17^{c}	9.36±0.10^{b}	7.12±0.08^{d}	303.42	0.0000
Ca (Mg/100g)	1.47±0.08^{a}	1.06±0.05^{c}	1.31±0.01^{b}	0.92±0.08^{d}	46.84	0.0000
C (%)	24.16±0.45^{a}	20.88±0.24^{c}	23.08±0.30^{b}	19.40±0.39^{d}	109.43	0.0000
K (%)	2.41±0.45^{a}	1.91±0.48^{ab}	1.60±0.27^{b}	1.44±0.48^{b}	3.04	0.0930
Na (%)	3.93±0.14^{a}	3.48±0.08^{c}	3.70±0.03^{b}	2.77±0.04^{d}	104.11	0.0000
Mg (Mg/100g)	14.03±0.74^{a}	10.35±0.18^{b}	8.04±0.58^{c}	5.99±0.25^{d}	144.90	0.0000

^{abcd} Mean values (±S. E) in the same row having the same superscripts are not significantly different at p < 0.05, as assessed by Fisher's least significant difference, N = 3
(Source: Author, 2021)

Effect of decomposed locust frass, chicken manure, and NPK fertilizer on the growth of kales

The number of kale leaves increased throughout the experiment. From week one to week four after transplanting, the number of kale leaves did not vary significantly (p< 0.05) due to different organic manures and NPK fertilizers used (Table 2). However, a significant difference in the number of leaves was observed from week five to week seven of transplanting the kales. Soil treated with 100 g decomposed frass produced kale plants with a significantly (p< 0.05) higher number of leaves than kale plants grown using NPK fertilizer, soil + chicken manure, soil + 50 g frass, soil+150g frass, and untreated soil (negative control) (Table 2).

The plant height of kales grown using decomposed locust frass, chicken manure and NPK (fertilizers) followed an increasing trend throughout the experiment (Table 3). From week one to week four after transplanting, there was no significant difference in the plant height due to different fertilizer treatments in the soil at p< 0.05. However, a height difference was seen from week five to week seven of the growth of kales, where the application of soil + chicken manure produced significantly taller kale plants than where locust frass, NPK fertilizer, and plain soil were applied (Table 3)

Table 2: Effect of decomposed locust frass, chicken manure, and NPK fertilizer on growth of *Brassica oleracea* leaves

Week	Soil (-ve control)	Soil + NPK (10g per pot)	Soil + chicken manure (2:1)	Soil+50g frass	Soil+100g frass	Soil+150g frass	F ratio	P value
Wk1	2.83±0.41	3.17±0.75	3.33±0.52	3.50±0.84	3.33±0.52	3.00±0.63	0.92	0.4843
Wk2	5.00±0.58	5.33±0.82	5.17±0.75	5.50±1.38	5.83±1.72	4.83±0.75	0.70	0.6307
Wk3	6.67±1.03	7.17±1.47	7.67±0.82	7.67±1.97	8.17±1.83	6.83±1.33	0.91	0.4864
Wk4	8.33±1.00	9.17±1.60	9.33±1.03	9.50±1.87	8.50±1.38	11.00±2.68	2.00	0.107
Wk5	9.50±0.76^{a}	11.00±1.41^{b}	11.33±1.51^{bc}	11.33±1.51^{bc}	12.67±1.97^{c}	10.67±1.86^{ab}	2.92	0.0282
Wk6	10.17±0.98^{a}	12.50±1.87^{b}	13.00±2.10^{bc}	12.83±1.47^{bc}	14.83±1.83^{c}	11.67±1.86^{ab}	4.81	0.0024
Wk7	11.00±0.63^{a}	14.17±1.83^{bc}	15.00±2.10^{cd}	14.50±1.38^{bc}	16.67±1.63^{d}	12.83±1.47^{ab}	9.06	<0.0001

^{abcd} Mean values (±S. E) in the same row having the same superscripts are not significantly different at p < 0.05, as assessed by Fisher's least significant difference, N = 3
(Source: Author, 2021).

Table 3: Effect of decomposed locust frass, chicken manure, and NPK fertilizer on growth of *Brassica oleracea* height

Week	Soil	Soil + NPK (10g per pot)	Soil+ chicken manure	Soil+50g frass	Soil+100g frass	Soil+150g frass	F-ratio	p-Value
Wk1	6.33±1.63	5.17±1.13	6.50±1.38	5.75±0.99	5.92±1.36	6.08±0.66	0.89	0.5013
Wk2	8.08±1.66	6.50±1.48	8.25±1.81	7.08±0.86	7.42±1.91	6.83±0.41	1.36	0.267
Wk3	9.42±1.74	8.42±1.72	10.42±1.83	8.58±1.11	9.42±2.58	8.50±0.77	1.22	0.3228
Wk4	10.92±1.56	10.00±2.45	13.25±2.51	11.33±1.63	11.33±2.56	10.83±1.69	1.57	0.198
Wk5	13.25±0.8^{a}	12.25±2.88^{a}	17.17±2.32^{b}	14.33±2.80^{ab}	14.00±3.08^{a}	13.25±2.73^{a}	2.63	0.0439
Wk6	14.73±0.99	14.08±3.11	18.08±1.99	16.17±2.48	15.67±2.99	14.67±2.75	2.01	0.1057
Wk7	16.50±1.22	16.17±3.79	19.83±2.14	17.92±2.04	17.67±2.75	16.50±2.55	1.75	0.1536

[ab] Mean values (±S.E) in the same row having the same superscripts are not significantly different at $p < 0.05$, as assessed by Fisher's least significant difference, N = 3
(Source: Author, 2021).

Leaf chlorophyll content of *Brassica oleracea* leaves from kales grown using decomposed locust frass, chicken manure, and NPK fertilizer

Leaves chlorophyll content of kales grown using decomposed locust frass, chicken manure, and NPK fertilizer was significantly different for all treatments ($p<0.05$) throughout the experiment. Throughout the experiment, kale leaf chlorophyll content from soil treated with 100 g decomposed frass registered the highest chlorophyll content which was significantly different ($p<0.05$) from chlorophyll content on kales grown using chicken manure, NPK fertilizer, and 50g and 150 g decomposed frass manure. However, kale leaves from untreated soil (negative control) had the lowest amount of chlorophyll content compared to kale from other soil treatments throughout the experiment period (Table 4)

Table 4: Leaf chlorophyll content of *Brassica oleracea* leaves grown using different organic fertilizers

Week	Soil(-ve control)	Soil+NPK (10g per pot)	Soil + chicken manure (2:1)	Soil+ 50g frass	Soil+100g frass	Soil+ 150g frass	F-Ratio	P-Value
Wk 3	45.48 ± 2.01^{a}	49.03 ± 4.07^{bc}	47.47 ± 3.17^{ab}	49.90 ± 1.72^{bc}	51.57 ± 1.71^{c}	49.93 ± 1.35^{bc}	4.31	0.0045
Wk 4	47.05 ± 1.97^{a}	52.33 ± 3.81^{b}	51.43 ± 1.63^{b}	51.95 ± 1.32^{b}	53.88 ± 0.47^{b}	51.68 ± 1.80^{b}	7.21	0.0002
Wk 5	49.57 ± 1.65^{a}	54.27 ± 3.90^{bc}	54.03 ± 1.60^{bc}	54.17 ± 1.89^{bc}	56.20 ± 1.00^{c}	53.52 ± 2.04^{b}	5.90	0.0007
Wk 6	51.50 ± 1.37^{a}	56.57 ± 4.14^{b}	56.83 ± 2.05^{b}	57.55 ± 2.56^{b}	57.93 ± 2.05^{b}	56.48 ± 1.87^{b}	5.29	0.0013
Wk 7	53.83 ± 1.67^{a}	59.95 ± 5.68^{b}	60.95 ± 2.85^{b}	61.92 ± 2.08^{b}	61.68 ± 3.23^{b}	58.45 ± 2.17^{b}	5.31	0.0013

[abc] Mean values (±S. E) in the same row having the same superscripts are not significantly different at $p < 0.05$, as assessed by Fisher's least significant difference, N = 3
(Source: Author, 2021)

Nutritional quality of kales grown using different fertilizers

The highest percentage of ash was recorded in kales harvested from soil that was treated with chicken manure while ash content from kales leaves harvested from soil treated with NPK recorded the lowest amount with a significant difference ($F_{0.05}$ (5, 12) =282.31, $p <0.0001$). Kale leaves harvested from soil that was not treated with fertilizer (negative control) had high amounts of fat content (7.47±0.40%), however, there was no significant difference in the amount of fats in kale leaves grown in the soil treated with NPK, chicken manure, soil + 50g of frass and soil +150g of frass at $p<0.05$.

Table 5: Nutritional composition of Brassica oleracea leaves grown from different organic fertilizers

Components	Soil	Soil+NPK	Soil+chicken manure	Soil+50g frass	Soil+100g frass	Soil+150g frass	F-ratio	p-Value
Ash (%)	12.80 ± 0.26^{a}	11.60 ± 0.20^{b}	18.33 ± 0.50^{e}	17.93 ± 0.25^{e}	14.60 ± 0.20^{c}	13.77 ± 0.12^{d}	282.31	0.0000
Fat (%)	7.47 ± 0.40^{c}	7.05 ± 0.18^{bc}	6.90 ± 0.18^{b}	6.87 ± 0.29^{b}	6.43 ± 0.10^{a}	6.97 ± 0.08^{b}	6.02	0.0052
Crude fiber (%)	6.20 ± 0.10^{a}	6.10 ± 0.56^{a}	6.17 ± 0.35^{a}	5.83 ± 1.10^{a}	4.37 ± 0.55^{b}	6.00 ± 0.10^{a}	4.53	0.0150
N (%)	4.65 ± 0.05^{a}	5.07 ± 0.03^{b}	4.94 ± 0.02^{c}	4.77 ± 0.03^{d}	3.77 ± 0.09^{e}	2.34 ± 0.06^{f}	1232.69	0.0000
K (%)	8.20 ± 0.38^{cd}	7.50 ± 1.46^{bcd}	7.02 ± 0.55^{abc}	8.61 ± 0.48^{d}	6.06 ± 0.73^{a}	6.70 ± 0.48^{ab}	4.56	0.0146
P (%)	0.54 ± 0.00^{a}	0.53 ± 0.01^{d}	0.48 ± 0.00^{b}	0.48 ± 0.00^{c}	0.52 ± 0.01^{d}	0.32 ± 0.00^{a}	876.17	0.0000

[abcde] Mean values (±S. E) in the same row having the same superscripts are not significantly different at $p < 0.05$, as assessed by Fisher's least significant difference, N = 3
(Source: Author, 2021).

The crude fiber content of kale leaves from soil treated with 100g decomposed locust frass recorded the lowest amount of fiber, while crude fiber of kale leaves from soil treated with the remaining fertilizers recorded high amounts of crude fiber which were however not significantly different at $p<0.05$. Nitrogen content of kale leaves planted with soil +NPK fertilizer had the highest percent (5.07±0.03%) while kale leaves from soil treated with 150g decomposed frass recorded the lowest percentage of nitrogen with a significant difference ($F_{0.05}$ (5, 12) =1232.69, p<0.0001). Kale leaves from Soil treated with 50 g of decomposed frass resulted in leaves with the highest percent of Potassium (K) while kale leaves from soil treated with 100 g frass had the lowest percent among all kale leaves from other treatments. A high percentage of phosphorus in kale leaves was recorded in plants that were planted in untreated soil (negative control) while kale leaves from soil treated with 150 g frass resulted in plants with significantly low levels of Phosphorus (Table 5).

Discussion

There is limited information on insect frass especially locust frass as organic fertilizer even though there has been intensive research in exploiting insects as food and feed. The chemical characteristics of desert locust frass in the present study revealed that it had concentrations of minerals that were comparable to those found in chicken manure, and this confirms its high fertilizer potential. The current study, therefore, provides evidence of the possibility of incorporating decomposed desert locust frass as an organic fertilizer for improving the growth, yield, and nutritional quality of vegetables. Subsequently, incorporating decomposed desert locust frass into the kitchen gardens to improve crop production could provide an additional source of income through the production of edible insects for both food and feed, while at the same time producing locust frass organic fertilizer as a viable placement, or complement for expensive synthetic fertilizers.

Kales planted using the composted locust frass of 100g performed better than other fertilizer treatments in terms of increasing the number of leaves, chlorophyll content, and nutritional quality of kales. The high growth rate and yield associated with kale grown using 100g of decomposed locust frass may be due to the better availability and supply of nutrients from the newly introduced frass manure (Beesigamukama *et al.,* 2020). The increased yield could also be attributed to the complementary and synergistic effects of frass fertilizer on the growth of crops and yield. The low growth of kales planted in plain soil (untreated) indicates high levels of nutrient depletion in the soil that was used for the experiment in this study as well as it could be due to phytotoxicity that is found in the soil (Anyega *et al*., 2021). The high chlorophyll content in kales planted with 100 g decomposed locust frass signifies higher amounts of green pigments responsible for the production of food for plants.

The higher nitrogen, phosphorous, and crude fats concentrations achieved in kales using decomposed 50 g locust frass as an organic fertilizer indicate that besides enhancing better growth in crops and increasing the chlorophyll content of crops, decomposed desert locust frass has also the potential to improve the nutritional quality of vegetable grown. The higher concentrations of nitrogen, phosphorous, and crude fats achieved using 50 g locust frass can be linked to the high nitrogen uptake and other nutrients by kale grown utilizing this organic manure (Anyega *et al*., 2021).

There are however no studies done yet using decomposed desert locust frass as organic fertilizer in crop production, nonetheless, a few studies have been done using black soldier fly frass (BSFF) fertilizer. A study done by Anyega *et al*., (2021) using BSFF fertilizer on the growth of kales among other crops investigated, indicated that the use of BSFF fertilizer in the growth of kales had a positive influence on the growth as the number of leaves and height of kales increased with weeks of growth compared to the other fertilizers used in the same experiment. Studies have also been done on the growth of pakchoi (*Brassica rapa L*) using BSFF fertilizer, and the results showed a maximum increase in the number of leaves and plant height of pakchoi when BSFF was used in planting compared to control and NPK treatment that was used in the study (Agustiyani *et al*., 2020). Other studies were done on growing maize using BSFF fertilizer and the results also showed an increase in the height of maize plants when compared to other artificial fertilizers that were used in the experiment (Beesigamukana *et al*., 2020). Chlorophyll content was observed to be higher in Pakchoi (*Brassica rapa L*) leaves whose plants were grown using 15% BSSF fertilizer (Agustiyani *et al*., 2020). These observations indicate that insect frass has the potential to increase chlorophyll content in crops.

The performance of kales, when planted using 100 g decomposed desert locust frass, resulted in better performance of kales with a high number of leaves (yield), high chlorophyll content, and high nutritional quality kale leaves. Therefore, the present research provides proof that soil treated with decomposed desert locusts as organic manure can create favourable soil conditions for the cultivation of kale leading to increased crop yields.

Conclusion

This study shows the high efficiency of desert locust decomposed frass as a fertilizer to increase the growth and nutrition of kales, so it has the potential to be used as an organic fertilizer similar to chicken manure. However, information on the growth performance and nutritional quality of plants grown with decomposed desert locust frass is still very scarce. Therefore, the current study is the foundation for future research work.

Recommendations

Due to its mineral composition, the utilization of locust frass as an organic fertilizer has shown potential for use in cropping systems and thus may assist in reducing the utilization of artificial/synthetic fertilizers and thus assist in the improvement of feasible agriculture. However, more research on cropping systems is needed to understand whether locust frass can be used as a replacement for synthetic fertilizers or not. This study was hence used as a benchmark since no study has been carried out yet using decomposed desert locust frass as an organic fertilizer.

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References

Agustiyani, D., Agadi, R., Arinafril, Nugroho, A. A., & Antonius, S. (2021). The effect of application of compost and frass from Black Soldier Fly larvae (*Hermetia illucins* L.) on growth of Pakchoi (*Brassica rapa* L.). *Earth and Environmental Science,* 762*,* 012036. DOI: 10.1088/1755-1315/762/1/012036

Anyega, A. O., Korir, N. K., Beesigamukama, D., Changeh, G. J., Nkoba, K., Subramanian, S., van Loon, J. J. A., Dicke, M., & Tanga, C. M. (2021). Black Soldier Fly-Composted Organic Fertilizer Enhances Growth, Yield, and Nutrient Quality of Three Key Vegetable Crops in Sub-Saharan Africa. *Frontiers of Plant Science,* 12,680312. DOI: 10.3389/fpls.2021.680312

Association of Official Analytical Chemists, AOAC. (1999). *Official methods of analysis of the Association of Analytical Chemists* (16th ed.). Washington, D.C.pp 600-792

Beesigamukama, D., Mochoge, B., Korir, N. K., Fiaboe, K. K. M., Nakimbugwe, D., Khamis, F.M., Dubois, T., Subramanian, S., Wangu, M. M., Ekesi, S., & Tanga, V. M. (2020). Biochar and gypsum amendment of agro-industrial waste for enhanced black soldier fly larval biomass and quality frass fertilizer. *PLoS ONE* 15 (8), e0238154. DOI: https://doi.org/10.1371/journal. pone.0238154

Chavez, M., & Uchanski, M. (2020). Insect left-over substrate as plant fertilizers. *Journal of Insects as Food and Feed,* 7(5),683-694. DOI: 10.3920/JIFF2020.0063

Chebet, A., Ruth, N., Nekesa, O. A., Ng'etich, W., Julius, K., & Scholz, R. W. (2017). Efforts toward Improving Maize Yields on Smallholder Farms in Uasin Gishu County, Kenya, through Site-specific, Soil-testing-based Fertiliser Recommendations: A Transdisciplinary Approach. *East African Agricultural and Forestry Journal*, 82(2-4), 201-213

Kietzka, G. J., Lecoq, M., Samways, M. J. (2021). Ecological and human diet value of locusts in a changing world. *Agronomy*. 11(9),1856. DOI: https://doi.org/10.3390/agronomy11091856

Limantara, L., Dettling, M., Indrawati, R., Indriatmoko., Brotosudarmo, T. H. P. (2015). Analysis on the chlorophyll content of Commercial Green Leafy vegetables. *Procedia Chemistry*, 14,225-231.

Migliozzi, M., Thavarajah, D., Thavarajah, P., & Smith, P. (2015). Lentil and kale: Complementary nutrient-rich whole food sources to combat micronutrient and calorie malnutrition. *Nutrients*, *7*(11), 9285-9298.

Poveda, J., Jiménez-Gómez, A., Saati-Santamaría, Z., Usategui-Martín, R., Rivas, R. & García-Fraile, P., (2019). Mealworm frass as a potential biofertilizer and abiotic stress tolerance-inductor in plants. *Applied Soil Ecology,* 142,110-122.

Qilliam, R. S., Nuku-Adeku, C., Maquart, P., Little, D., Newton, R., & Murray, F. (2019). Integrating Insect Frass bio-fertilizers into sustainable Peri-urban agro-food systems. *Journal of Insects as Food and Feed*, In Press. DOI: 10.3920/JIFF2019.0049

Rayne, N. & Aula, L. (2020). Livestock Manure and the Impacts on Soil Health. A Review. *Soil Systems*, 4,64. DOI: 10.3390/soilsystems4040064

Soremi, A., Adetunji, M., Adejuyigbe, C., Goke, B., & Azeez, J. (2017). Effects of Poultry Manure in some Soil Chemical Properties and Nutrient Bioavailability to Sotbean. *Journal of Agriculture and Ecology Research International,* 11(3),1-10. DOI:10.9734/JAERI/2017/32419