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Effects of cricket frass on vegetative growth of *Cleome gynandra*

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Insect farming as food and feed has gained popularity. Insects require less land and water and are efficient in feed-food conversion, making them a sustainable alternative source of protein for food fortification and feed formulation. Some insects play a vital role in bio-remediation of organic waste as they feed on waste breaking it down to frass that has the potential to be used as an organic fertilizer in food production. Insects therefore, have great potential to contribute to climate-smart farming. This research explored the potential of cricket frass as an organic fertilizer for growing *Cleome gynandra*. Different levels of cricket frass and cow manure were as follows: 10, 15, and 20 t/ha; 100, 150, and 200 kg/ha of Di-ammonium Phosphate (DAP) and a control (no fertilizer) were used for the experiments. One experiment was sent in a controlled environment inside a greenhouse and a second one in the open field. In the greenhouse, Completely Block Design (CBD) was used while in the open field Randomized Complete Block Design (RCBD) was used. Parameters observed were plant height, number of leaves and biomass weight. Results showed that crops treated with frass gave longest plants, most number of leaves and had the heaviest biomass weight.

Key words: Organic farming, frass, chemical fertilizer, small-scale farmers.

INTRODUCTION

Poor soil fertility is the most significant constraint limiting food production in sub-Saharan Africa (Khosro et al., 2012). About 80% of farmers in this region are small-scale farmers (Zingore et al., 2008), who cannot afford to buy chemical fertilizers sold expensively beyond the global average (Ojha, 2003). Therefore, after a series of production, the soil loses all nutrients that support the growth of crops as the rate at which crops consume nutrients exceeds the rate at which the nutrients are replenished through fertilizer (Stoorvogel et al., 1993). This has resulted in a decline in yields and to make it worse population continues to increase worldwide and is expected to reach 9.3 billion by 2050 (Bloom, 2011). Majority of this population increase will be in Sub Saharan Africa. Food production needs to double to feed the growing population (Ray et al., 2013).

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Using chemical fertilizers to increase yields will leave environmental footprints that will be hard to reverse (Sharma and Singhvi, 2017). Research shows that chemical fertilizers pollute water bodies. When it rains, runoff drains into water bodies polluting water and resulting to Eutrophication and consequently death of marine life (Sharma and Chetani, 2017). Manufacturing synthetic fertilizers release nitrate oxide, a Green House Gas (GHG) that contributes to global warming hence climate change (Savci, 2012). Food security has been defined by World Food Program (WFP) as a situation that exists when all people at all times have physical and economic access to sufficient, nutritious and safe food that meets their dietary needs (Wiesmann et al., 2009). Research has shown that food produced using chemical fertilizers has chemical residues which pose health risks to consumers and has been associated with predisposing people to diseases such as cancer (Srivastav, 2020). For the use of organic fertilizer, though in the short run, the yields are lower than with chemical fertilizer as farmers continue applying manure, the soil structure improves; organic matter increases and yields increase in the long run (Muller et al., 2017). On the other hand, yields increase with chemical fertilizers in the short run, but decrease in the long run, as the chemicals alter the soil chemical and physical properties, such as lowering the soil pH making it acid and killing beneficial soil micro-organisms (Yang et al., 2015). Continued use of chemical fertilizer results in decline in yields and the situation gets worse to the point that farmers have to leave the land fallow to regain its properties.

Insects farming has increased (Ayieko et al., 2010; Banjo et al., 2006; Van Huis, 2015; Paul et al., 2021) and will continue to increase as farmers become aware of the numerous nutritional benefits of insects as feed for livestock and food fortification (Halloran et al., 2017). As the rearing of insects intensifies, there will be an accumulation of waste commonly known as frass. In this regard this experiment was conducted to see the effect frass has on the growth of crops. This research will provide recommendations on how to put frass to better use. The beneficiaries will be small-scale farmers keen to get an alternative affordable solution for fertilizing their soil. Farmers who have embarked on insect farming will also benefit by utilizing the waste from insect farming to create a circular economy in their farms.

Frass of mealworms and black soldier flies have been found to have positive effects on the growth of crops; however, the effects of cricket frass on the growth of crops, especially indigenous vegetables, which most households depend on for nourishment, has not been explored. Indigenous vegetables are rich in iron, plant protein and vitamins. Most households who earn less than 1 dollar a day cannot afford to buy animal protein and depend on indigenous vegetables. Despite these vegetables' critical role in household food and nutrition security, indigenous production has reduced and some are on the verge of becoming extinct. This research therefore, focused on the production of *Cleome gynandra*, commonly known as spider plant. *C. gynandra* is rich in iron, vitamins, proteins and fiber; it is also believed to have medicinal value. The experiment compared the results of using frass, cow manure, and a synthetic fertilizer Di-ammonium phosphate (DAP).

MATERIALS AND METHODS

The experiment was conducted between January to February 2021, in the horticultural farm of JOOUST Siaya campus, Kenya, which lies between latitude 0° 26' to 0° 18' north and longitude 33° 58' east and 34° 33' west. The climate of Siaya is semi-humid to semi-arid, with precipitation of between 600 and 1100 mm annually. The average temperature of Siaya is 22°C.

Cricket frass was collected from Jaramogi Oginga Odinga University of Science and Technology (JOOUST) insect farm. It was a mixture of house cricket and field cricket. The insects had been fed with chicken growers' marsh. The frass was sieved through a 2 mm sieve then left to decompose for three weeks.

Cow manure was collected from Joust dairy farm, sieved through a 2 mm sieve and left to decompose. The cows from which manure was collected had been fed with Napier grass and dairy meal.

Cow manure was collected from Joust dairy farm, sieved through a 2 mm sieve and left to decompose. The cows from which manure was collected had been fed with Napier grass and dairy meal. DAP was bought from a local agro-vet in Siaya. *C. gynandra* seeds were bought from local agro-vet in Siaya.

Two experiments were set, one in a greenhouse and another in the open field in JOOUST Siaya campus farm in January 2021. In the greenhouse, plastic planting bags with a diameter of 20 cm and depth of 30 cm were used. Each treatment was applied in 4 bags and replicated three times. In the open field, a plot that was previously fallow was cleared and dug, 30 experimental plots of 1 m^2 were demarcated with walking paths of 20 cm between plots. The 30 plots were ten treatments replicated three times. The treatments were frass 10 t/ha, frass 15 t/ha, and frass 20 t/ha. Cow manure 10 t/ha, cow manure 15 t/ha, cow manure 20 t/ha, DAP 100 kg/ha, DAP 150 kg/ha, DAP 200 kg/ha and a control (no fertilizer). The rate of application of DAP was lower than frass and cow manure because DAP has high levels of phosphorus and if a similar rate were used, it would burn crops increasing errors in the experiment.

The soil was collected from the experimental plot in the open field sieve through a 2 mm sieve and bulked into the plastic bags used in greenhouse experiment. A Completely Randomized Design (CRD) was used and treatments were applied accordingly. Two seeds were sown 2 cm deep in the planting bags at spacing of 10 cm and later after germination, thinned to 1. Watering was done twice daily and each plant received 500 ml of water per watering. In the open field, seeds were sown 2 cm deep and spaced at 20 cm between crops and 20 cm between rows. Hence, each plot had 25 plants. Watering was done twice daily, with each plant receiving 500 ml of water per watering. Seeds in the open field germinated faster than those in the greenhouse. On average in the open field, seeds took seven days, while in the greenhouse, they took 12 days. All cultural practices, such as weeding, were done promptly.

Data collection and analysis

Plant measurement

Data were recorded every seven days. In the greenhouse, all plants

Table 1. Physical and chemical characteristics of soil, frass and cow manure.

Variable	Soil	Frass (FR)	Cow manure (CM)	DAP
pH	6.15	9.8	7.44	3
Electrical conductivity (EC)	0.6	12.5	3	5
Nitrogen (N)	0.28%	1.16	0.96	18%
Organic carbon (OC)	2.25%	10.5	6.13	-
Calcium (Ca)	7.8 cmol/kg	4.5	15	-
Magnesium (Mg)	1.85 cmol/kg	4.05	2.35	-
Potassium (K)	2.17 cmol/kg	3.16	6.2	-
Manganese (Mn)	45.8 ppm	22.7	74	-
Sodium (Na)	0.38 cmol/kg	2.2	0.85	-
Phosphorus (P)	86.5 ppm	936	339	460000 (46%)
Zinc (Zn)	6.68 ppm	34.4	4.5	-
Iron (Fe)	65.5 ppm	132.5	161.3	-
Copper (Cu)	1.33 ppm	4	0.18	-

Source: LSD Test Results

were measured, while in the open field, data were collected from randomly selected and tagged plants to ensure consistency. Plant height was the distance between the shoots and apex. The number of leaves was recorded every 7 days and biomass weight data was recorded on day 30 after harvest. From planting to harvesting took 30 days.

Physical and chemical properties of treatments

Before experiments, soil used and treatments were analyzed in the Kenya Plants Health Inspectorate Service (KEPHIS) laboratory and the results are shown in the Table 1. Physical and chemical characteristics of DAP was obtained from secondary sources.

Statistical procedure

Data on plant height and the number of leaves was subjected to Analysis of Covariance (ANCOVA) to take into account the effect of time on the experiment since data was collected every 7 days and time could have a significant effect on the results. On the other hand, biomass weight, measured once at harvest, was subjected to Analysis of Variance (ANOVA). If data was found, significant post hoc using Least Significant Difference (LSD) was done.

RESULTS

Characteristic of experimental soil and treatments

Effects of frass on growth parameters

The parameters recorded were plant height, number of leaves, and biomass weight.

Effects of frass on plant height

Plant height data is shown in Table 2. All treatments with similar letters show that they are similar, different letters show that they are different. Frass at15t/ha, frass at 10t/ha, frass at 20t/ha and DAP at level 200kgs/ha had the same effect on plant height. Frass 15t/ha gave the highest mean height. There were similarities between Frass 20t/ha and DAP200kgs/ha on their effect on plant height. DAP 200kgs/ha, DAP150kgs/ha and DAP 100kgs/ ha had similar effect on plant height. DAP150kgs/ha, DAP 100kgs/ha, cow manure 20t/ha, cow manure10t/ha and cow manure 15t/ha did not have significant differences on their effect on plant height. Cow manure 10t/ha, cow manure 15t/ha and the control had similar effect on plant height and. Control, cow manure 15t/ha and cow manure 10t/ha gave the lowest mean height.

In the greenhouse, all treatments except DAP at level 200kgs/ha, DAP at level 100kgs/ha and the control had the same effect on plant height. Frass at level 15t/ha gave the highest mean height in both field and greenhouse experiment.

Effects of frass on number of leaves

Least Significant Difference test for number of leaves is shown in Table 3. Treatments with similar letter mean that they are similar and different letters are different. Post hoc using LSD was done. In the open field results showed that, the effect of frass 15t/ha, frass 10t/ha, Frass 20t/ha and DAP at 200kgs/ha on number of leaves are the same. Frass 10t/ha/ frass20t/ha, DAP 200kgs/ha, cow manure 20t/ha, cow manure 15t/ha, DAP 100kgs/ha and DAP150kgs/ha were statistically similar. DAP 200kgs/ha, cow manure 20t/ha, cow manure 10t/ha, cow manure 15t/ha, DAP100kgs/ha, DAP 150kgs/ha and the control has some similarities in their effects on number of leaves. In the greenhouse, frass 15t/ha, frass20t/ha, cow

Table 2. Effects of treatment in plant height (cm).

Variable	Treatment	Height (cm)
	FR15	39.44[a]
	FR10	37.33[a]
	FR20	36.63[ab]
	DAP 20	35.20[abc]
	DAP 15	31.83[bcd]
	DAP 10	30.28[cd]
Field	CM 20	29.89[d]
	CM10	28.11[de]
	CM15	27.97[de]
	CR0	23.71[e]
	FR15	7.83[a]
	FR20	7.28[ab]
	FR10	7.22[ab]
	DAP 15	6.83[abc]
	CM10	6.17[abc]
	CM15	6.00[abc]
Greenhouse	CM20	5.44[abc]
	DAP20	4.83[bc]
	DAP10	4.67[c]
	CR0	4.56[c]

Mean values in a column with different letters are significantly different values with similar letters are not significantly differerent at p<0.05. FR10=Frass10 t/ha, FR 15=frass 15 t/ha, FR20= Frass 20 t/ha, CM 10=Cow manure 10 t/ha, CM 15=Cow manure 15 t/ha, CM20=Cow manure 20 t/ha CR0=Control.
Source: LSD Test Results

manure 20t/ha, DAP 150kgs/ha, frass10t/ha and cow manure 10t/ha had the same effect on the number of leaves. Fass20t/ha, cow manure 20t/ha, DAP 15t/ha, frass10t/ha, cow manure 10t/ha, cow manure15t/ha and the control had some similarities on their effect on number of leaves. Cow manure20t/ha, DAP 150kgs/ha, fras10t/ha, cow manure 10t/ha, cow manure 15t/ha, control and DAP 100kgs/ha had similar effect on number of leaves. There were no statistical difference between cow manure 10t/ha, cow manure15t/ha, control, DAP 100kgs/ha and DAP 200kgs/ha.

Effect of frass on biomass weight

Biomass data is shown in Table 4. It is evident that all the treatments significantly influenced the biomass weight. The highest biomass weight in the field experiment was observed in plots treated with frass 15 t/ha and was statistically similar to DAP 150 and 200 kg/ha, and frass 10 and 20 t/ha. 15 t/ha displayed the highest biomass weight in the greenhouse experiment was statistically similar to frass 20 t/ha

The lowest biomass weight in the field experiment was observed in the control and in the greenhouse was with cow manure 15 t/ha and the control.

DISCUSSION

All treatments, including frass had higher plant heights than the control. This shows the availability of nutrients and effective uptake by crops and the control's inability to support the growth of *C. gynandra*. The study confirms previous studies that show nutrients in frass are easy to be absorbed by plants, as shown by the increase in the application of frass, resulting from an increase in yields. High organic carbon in frass could have stimulated the growth of frass microbes resulting in carbon and nitrogen mineralization.

Results observed by using frass at all levels were consistent and this confirms a study by Houben et al. (2021). They observed that frass released nutrients homogenously due to the uniform distribution of nutrients within the frass organic matter. The best results of plant growth with frass relative to cow manure and DAP, could be linked to the presence of plant growth promoters which have been found to be abundant in manures arising from insects (Poveda et al., 2019). The high number of leaves displayed in crops with frass 15 and

Table 3. Effects of frass on number of leaves.

Variable	Treatment	Group
Field	FR15	10^{a}
	FR10	9^{ab}
	FR20	9^{ab}
	DAP20	9^{abc}
	CM20	9^{bc}
	CM10	8^{bc}
	CM15	8^{bc}
	DAP10	8^{bc}
	DAP15	8^{bc}
	CR0	8^{bc}
Greenhouse	FR15	6^{a}
	FR20	6^{ab}
	CM20	5^{abc}
	DAP 15	5^{abc}
	FR10	5^{abc}
	CM10	5^{abcd}
	CM15	5^{bcd}
	CR0	5^{bcd}
	DAP10	5^{cd}
	DAP20	4^{d}

Mean values in a column with different letters are significantly different values with similar letters are not significantly different at $p < 0.05$.
Source: LSD Test Results

Table 4. Data on biomass weight.

Variable	Treatment	Biomass (Groups)
Field	FR 15	78.3^{a}
	DAP20	68.33^{ab}
	FR10	61.10^{abc}
	FR20	58.73^{abc}
	DAP15	49.43^{abcd}
	DAP10	43.87^{bcd}
	CM20	38.3^{bcd}
	CM15	37.2^{bcd}
	CM10	28.0^{cd}
	CR0	23.3^{d}
Greenhouse	FR15	20.17^{a}
	FR20	18.0^{a}
	FR10	13.17^{b}
	DAP20	11.83^{bc}
	DAP15	11.67^{bc}
	CM20	10.17^{bcd}
	DAP10	10^{bcd}
	CM10	7.67^{cd}
	CM15	6.67^{d}
	CR0	6.67^{d}

Source: LSD Test Results

frass 20 could be due to high nitrogen and phosphorus in frass (Hollinger, 1986) that promotes cell division resulting to the rapid growth of shoots. The high biomass weight observed with cricket frass could be due to sufficient nitrogen in the frass that promotes succulence in leaves of *C. gynandra* resulting in higher biomass weight. The findings are confirmed by Zahn and Quilliam, (2017), who studied crops treated with frass, had higher yields due to improved organic status and electrical conductivity. The control consistently displayed poor results in both experiments. This indicated the vital role nutrients play in boosting *C. gynandra* vegetative growth.

Conclusion

To bridge the knowledge gap about potential of cricket frass as an organic fertilizer, this experiment shows the potential of cricket frass to improve soil fertility and enhance the growth of *C. gynandra*. Cricket rearing requires less space, less water and food to rear compared to cow manure. To rear cows, a farmer need to allocate large tracks of land to grow fodder which many small scale farmers have no access to. Insect frass is therefore, an affordable fertilizer compared to cow manure and DAP. Frass 15 t/ha contributed to improved growth and yield of *C. gynandra*. The use of cricket frass improves the soil organic water hence water retention and increases available nitrogen in the soil resulting in improved vegetative growth. Integrated insect farming with livestock production and crop production will create a circular economy that will contribute positively to the fight against food insecurity. Future research work should focus on the possibility of utilizing frass to make liquid foliar fertilizers.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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