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Effects of *Moringa oleifera* leaf extract on morphological and physiological growth of cassava and its efficacy in controlling *Zonocerus variegatus*

Uchenna Mabel Ndubuaku[1*], Theophilus Chinyere Nkasiobi Ndubuaku[2], Emmanuel Ike[1] and Peter Ikemefuna Ezeaku[3]

[1]Department of Crop Science, Faculty of Agriculture, University of Nigeria, Nsukka, Nigeria.
[2]Department of Pest Management Technology, College of Agriculture, National Root Crop Research Institute, Umudike, Abia State, Nigeria.
[3]Department of Soil Science, Faculty of Agriculture, University of Nigeria, Nsukka, Nigeria.

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***Zonocerus variegatus* infestation has been found to cause a lot of devastation in the production of cassava crop plants in tropical and subtropical areas. Understanding the efficacy of *Moringa oleifera* leaf extract on controlling *Z. variegatus* is desired. The present study was conducted in the Department of Crop Science experimental site, Faculty of Agriculture, University of Nigeria, Nsukka to investigate the effects of *M. oleifera* leaf extract (MLE) on the morphological and physiological growth characteristics of cassava (*Manihot utilissima* Pohl.); and its efficacy as organic insecticide for controlling *Z. variegatus* infestation. *M. oleifera* leaf extract diluted in water at the volume to volume (v/v) ratios of 1:10, 1:20, 1:30 and 1:40 were applied weekly while "Uppercut (R)" (30 g dimethoate plus 250 g cypermethrin), used as water emulsifiable concentrate, was applied at the rate of 0.2 a.i./ha at three-weekly interval for two months. Result shows that *M. oleifera* leaf extract (MLE) dilution at the ratio of 1:30 MLE in water gave the highest percentage stem height difference (%SHD) at 32 weeks after planting with a value of 20.5% followed by 1:20 (17.8%), 1:10 (10.56%), dimethoate plus cypermethrin (8.98%) and 1:40 (8.05%). The control had the least %SHD and %LND. Dimethoate plus cypermethrin treatment was more efficacious as it eradicated the insects and caused significant ($p < 0.05$) increase in the number of leaves and reduction in the percentage leaf abscission especially from the thirtieth week after planting. However a combined use of Dimethoate plus cypermethrin and *M. oleifera* leaf extract may give a better result and as such recommended than a single treatment application.**

Key words: Moringa extract, dimethoate plus cypermethrin insecticide, cassava hybrid, *Zonocerus variegatus* infestation.

INTRODUCTION

Cassava (*Manihot utilissima* Pohl.) belongs to the *Euphorbiaceae* family, and it is one of the most important root crops in the tropics especially Nigeria. Four African countries including Mozambique, Nigeria, Tanzania and Zaire, were among the 10 largest producers of cassava in the world by 2005 (Anikwe et al., 2005). All the cultivars of cassava belong to the species *Manihot esculenta* Crantz and *M. utilissima* Pohl. These species can be differentiated based on many factors such as shape of their leaves, plant height, petiole color, leaf size, etc.

(Anikwe et al., 2005). Cassava can be used in various ways such as cassava pellets, cassava chips, cassava flakes and fermented cassava. Some of the pests of cassava include termites, mites, mealybugs such as *Phenacoccus manihotis,* and grasshopper such as *Zonocerus variegatus. Z. variegatus* can defoliate the leaves and reduce the photosynthetic capacity of a plant. Some other plants attacked by *Z. variegatus* include cowpea, maize, soybean, sweet potato etc. *Z. variegatus* infestation has been found to cause a lot of devastation in the production of these crop plants.

Some botanicals such as neem (*Azadirachta indica*) seed extract and scent leaf (*Ocimum gratissimum*) extract are used as insect-repellent liquids (Silva et al., 2010). *Moringa oleifera* leaves have been found to possess some antibacterial and antifungal characteristics (Rao et al., 2007; Arya et al., 2010). Moringa is an all-purpose plant. It is a native of India but is widely cultivated in some sub-Saharan African countries like Zimbabwe, Madagascar, Zanzibar, South Africa, Tanzania, Malawi, Benin, Burkina Faso, Cameroon, Chad, Gambia, Ghana, Guinea, Kenya, Liberia, Mali, Mauritania, Nigeria, Niger, Sierra Leone, Sudan, Ethiopia, Somalia, Zaire, Togo, Uganda and Senegal (Amaglo, 2010; Annenber, 2010; Fuglie and Sreeja, 2011). Every part of the plant can be used for one thing or the other. The leaves have very high nutritional value. They are good sources of protein, minerals, vitamins, beta-carotene, amino acids and various phenolic compounds. They provide a rich and rare combination of zeatin, quercetin, beta-sitosterol, caffeoylquinic acid and kaempferol (Moyo et al., 2011). The seed is eaten like a peanut in Malaysia. The thickened root is used as substitute for horseradish. The foliage is eaten as green garnish in salads, in vegetable curries, as pickles, and it can also be used for seasoning.

Moringa is very important for its many impressive ranges of medicinal uses. Various parts of this plant such as the leaves, roots, seeds, fruits, flowers and immature pods act as cardiac and circulatory stimulants. They possess antitumor, antipyretic, antiepileptic, anti-inflammatory, antiulcer, antispasmodic, diuretic, antihypertensive, antidiabetic, hepatoprotective, antibacterial and anti-fungal, cholesterol lowering properties and some antioxidants (Fuglie and Sreeja, 2011; Moyo et al., 2011; Oz, 2014). The leaves are ground and used for scrubbing utensils and for cleaning walls. Its seeds yield about 40% of non-drying oil, known as Ben or Oleic oil, used for cooking, lubricating watches and other delicate machinery, soap and cream making etc. The oil is clear, sweet and odorless, and it is useful in the manufacture of perfumes and weave-on oil in hairdressing. The oil compares favorably with olive oil (Moyo et al., 2011; Oz, 2013). Moringa wood yields a blue dye. The leaves and young branches are eaten by livestock. It is planted as a living fence tree. The bark can serve for tanning; its mature seeds can also be used to purify water. The flowers which are present throughout the year, are good sources of nectar for honey producing bees, thus its presence enhances production in other crops due to increase in pollination activities by bees (Fuglie and Sreeja, 2011). Incorporation of the green leaves of *M. oleifera* into the soil had been successfully used in preventing damping off disease caused by *Pythium debaryanum* in seedlings of okra plant (Rao et al., 2007; Arya et al., 2010). Little or no information had been given on the use of *M. oleifera* leaves or the extract as organic pesticide. The main objectives of this work were to determine the effect of *M. oleifera* leaf extract application at various concentrations on some morphological and physiological characteristics of cassava, and also study the efficacy of *M. oleifera* leaf extract in controlling *Z. variegatus* infestation on cassava.

MATERIALS AND METHODS

The experiment was carried out in the experimental plot (crop garden) of the Department of Crop Science, Faculty of Agriculture, University of Nigeria, Nsukka (UNN). The treatments involved the use of different concentrations of *M. oleifera* leaf extract (as organic insecticide) and dimethoate plus cypermethrin at the rate of 0.2 a.i./ha (as inorganic insecticide) to control *Z. variegatus* in cassava. The dimethoate plus cypermethrin was collected from the Entomology Unit of the Department of Crop Science, UNN. The moringa leaf liquid extraction was done by pounding the freshly harvested leaves in a clean mortar and squeezing out the liquid through a filter paper into a container. Lower mature leaves (6^{th} leaf and below) were used for the experiment because of their high composition of phytochemicals (Ndubuaku et al., 2014). The different concentrations of the moringa leaf extract (MLE) were made by mixing the extract with water at the following v/v ratios: 1:10, 1:20, 1:30 and 1:40. The untreated plot was the control. The *M. oleifera* leaf extract (MLE) was applied to the cassava plants weekly while the dimethoate plus cypermethrin was applied tri-weekly using a hand sprayer to avoid drift. The spraying was done for eight weeks between April and June at the onset of regular rainfall when the *Zonocerus* infestation was heavy relative to other pests. During this period, the cassava plants were between four and six months old (16 weeks before and 24 weeks after spraying). The cassava cultivar used in this study was a hybrid, CR1247 and the cuttings were planted at the spacing of 1 × 1 m. The experiment was laid out in a randomized complete block design (RCBD) with four replications. The four replicates constituted the blocks.

The morphological characteristics studied included the

*Corresponding author. E-mail: uchemay@yahoo.com. Tel: +2348056128876.

Abbreviations: MLE, *Moringa oleifera* leaf extract; **RCBD,** randomized complete block design; **SPSS,** statistical package for social sciences; **SHD,** stem height difference; **WAP,** weeks after planting; **IPM,** integrated pest management.

Table 1. Effect of *Moringa oleifera* leaf extract (MLE) and dimethoate plus cypermethrin on mean population of *Zonocerus variegatus* in a cassava plot between 1 and 7 weeks after spraying (WAS).

Concentration (MLE : Water)	Weeks after spraying (WAS)								Treatment mean
	Before spaying	1 WAS	2 WAS	3 WAS	4 WAS	5 WAS	6 WAS	7 WAS	
1:10	2.12	2.35	2.12	1.87	2.35	2.74	2.92	3.09	2.45
1:20	1.87	2.12	2.35	1.87	2.12	2.55	2.92	2.74	2.32
1:30	2.35	2.35	2.12	2.12	2.12	2.35	2.74	2.92	2.38
1:40	2.12	1.87	2.12	1.87	2.12	2.35	3.24	3.24	2.37
Dimethoate plus cypermethrin	2.35	1.87	1.58	1.22	1.22	1.22	0.71	0.71	1.36
Control	2.35	2.55	2.12	2.35	2.12	2.74	3.39	3.39	2.63
Mean	2.19	2.07	2.07	1.88	2.01	2.33	2.65	2.68	
F-$LSD_{0.05}$	NS	NS	NS	NS	NS	NS	1.39	1.40	

NS means not significant.

percentage stem height difference (% SHD). The stem height was measured with a meter ruler and the percentage of the differences over the different periods of observation was calculated. The number of leaves was determined by the total number of leaves on the plant in each sampling period and the percentage difference (% LND) calculated as the difference in the number of leaves at two consecutive periods. The physiological growth characteristics included the rate of leaf fall (% leaf abscission),

$$\% \text{ Leaf abscission} = \frac{(T_2 - T_1)\ (L_1 - L_2 - nf)}{L_1\ (T_2 - T_1)} \times \frac{100}{1}$$

Where, L_1 = Number of leaves at the periods T_1, L_2 = Number of leaves at the period T_2, nf = the number of new leaves (leaf flushes), and the rate of leaf appearance (leaf flushing),

$$\% \text{ Leaf appearance} \quad \frac{(T_2 - T_1)\ (L_1 - L_2)}{L_1\ (T_2 - T_1)} \times \frac{100}{1}$$

Where, L_1 = Number of leaves at the periods T_1, L_2 = Number of leaves at the period T_2

The insect population was determined by counting the number of insects on the plants at each period of observation and transforming the data collected into indexed values as shown below using linear additive model, Statistical Package for Social Sciences (SPSS) Release 7.22 Edition 3 (Obi, 2002):

$$Y^2 = X + 0.5$$

Where, Y = insect population (indexed), X = number of insects on the plants.

Data collected were presented in percentages. The transformed data were analyzed using analysis of variance (ANOVA) and significant means separated using Fisher's least significant difference at 5% probability.

RESULTS

The percentage stem height difference (% SHD) in the cassava plants treated with 1:10, 1:20, and 1:30 of *M. oleifera* leaf extract (MLE) in water increased with time as shown in Table 1. The 1:40 MLE in water increased the % SHD from 28 weeks after planting (WAP). There was a decreasing effect of Dimethoate plus Cypermethrin treatment on the percentage stem height difference (% SHD) 26 WAP, after which the value increased steadily from 28 to 32 WAP. The % SHD of the control plants decreased at 30 WAP. The plants treated with 1:30 MLE in water showed the highest % SHD (20.5%) on the 32 WAP followed by those treated with 1:20 MLE in water with the highest value (18.43%) on the 30 week. There were significant differences ($p < 0.05$) in the % SHD of the plants treated with the different ratios of MLE in water from the 26 to 32 weeks after planting (Figure 1). With the exception of the plants treated with dimethoate plus cypermethrin, the percentage difference in the number of leaves (%LND) in the MLE-treated plants, including the control, decreased with time. The 1:10 MLE in water treatment caused a reduction in the % LND at 32 week while in the other treatments, with the exception of dimethoate plus cypermethrin treated plants, the reduction started from 30 weeks (Figure 2). There were significant differences ($p < 0.05$) across the treatments from 26 to 32 weeks after planting.

The percentage leaf abscission (% LA) in all the treatments, except dimethoate plus cypermethrin, increased from 30 weeks with the initial decrease at 26 weeks after planting. The % LA in the dimethoate plus cypermethrin treated plants decreased consistently from the 26 to 32 week after planting. The highest % LA (30%) showed in the control plants at 32 weeks after treatment (Figure 3). There were significant differences ($p < 0.05$) in the % LA of the plants across the treatments from 26 to 32 week after planting. The treatment effect on percentage leaf appearance (leaf flushing) is shown in Figure 4. It increased progressively and consistently in all the treatments, including the control, from the 26 to 32 week after planting. However, 1:40 MLE in water gave

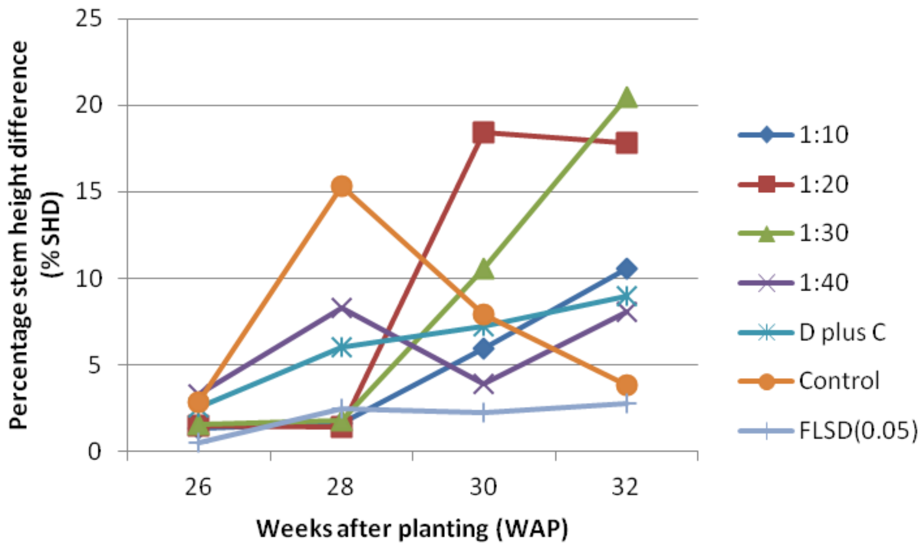

Figure 1. Effect of different concentrations of *Moringa oleifera* leaf extract (MLE) and dimethoate plus cypermethrin on percentage stem height difference (%SHD) of cassava between 26 and 32 weeks after planting (WAP), D plus C = dimethoate plus cypermethrin.

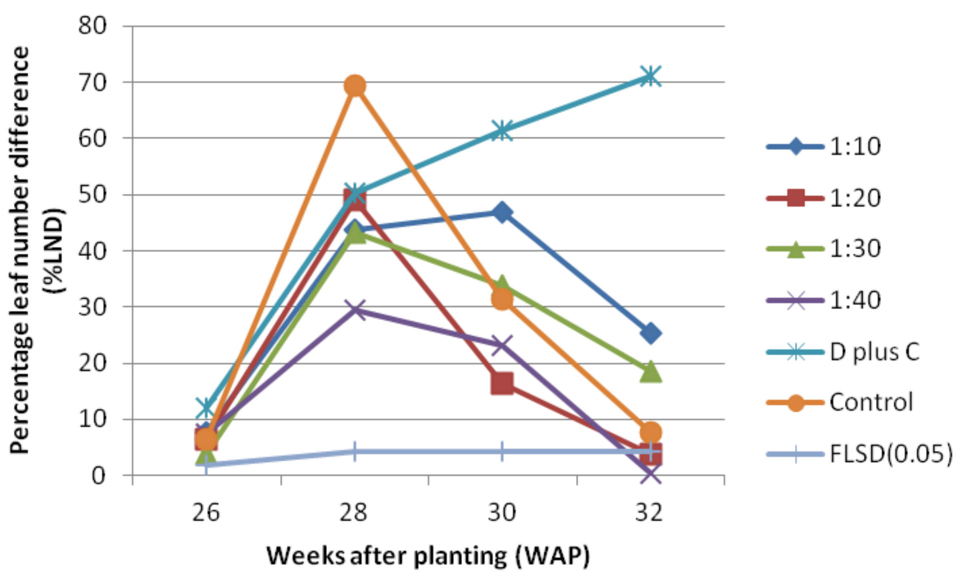

Figure 2. Effect of different concentrations of *Moringa oleifera* leaf extract (MLE) and dimethoate plus cypermethrin on percentage leaf number difference (% LND) of cassava plants between 26 and 32 weeks after planting (WAP), D plus C = dimethoate plus cypermethrin.

the highest percentage leaf appearance at the thirty second week after planting followed by 1:30, 1:20, 1:10, dimethoate plus cypermethrin and control in that order (31, 29, 28, 26, 20 and 17%, respectively). There were no significant differences ($p > 0.05$) across the various treatments in the first two weeks of treatment but there were significant differences ($p < 0.05$) between twenty eighth and thirty second week after planting (Figure 4).

Data comparing the effects of *M. oleifera* leaf extract (MLE) and dimethoate plus cypermethrin on *Z. variegatus* population are shown in Table 1. The population of the insect in the plot treated with dimethoate plus cypermethrin decreased progressively from 1 to 7 weeks after spraying. There was an increase in the insect population in all the *M. oleifera* leaf extract-treated plants, as well as the control, from the fifth week after spraying.

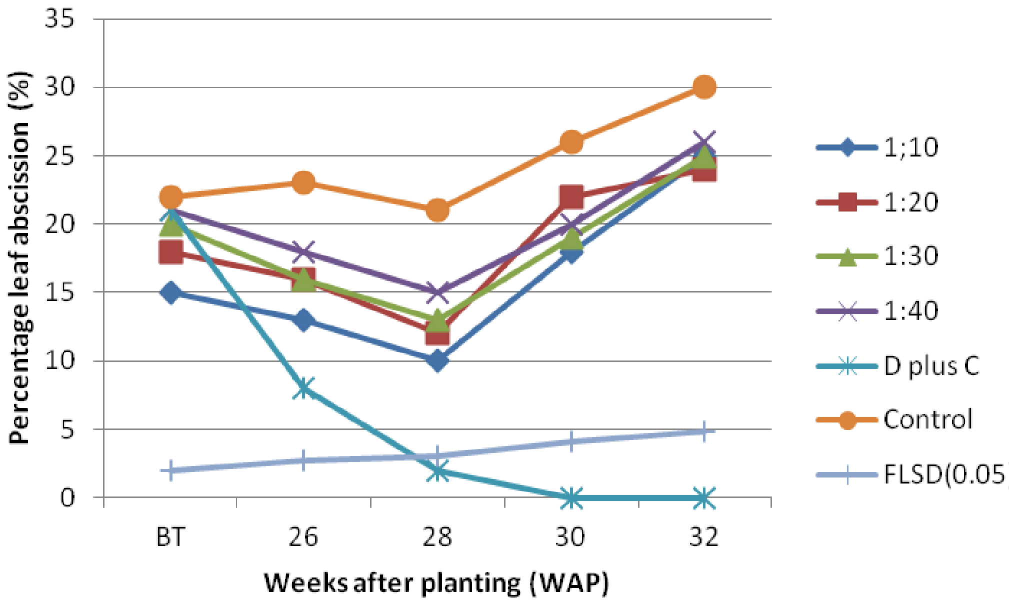

Figure 3. Effect of different concentrations of *Moringa oleifera* leaf extract (MLE) and dimethoate plus cypermethrin on percentage leaf abscission (%LA) in cassava between 26 and 32 weeks after planting (WAP), D plus C = dimethoate plus cypermethrin, BT = before treatment.

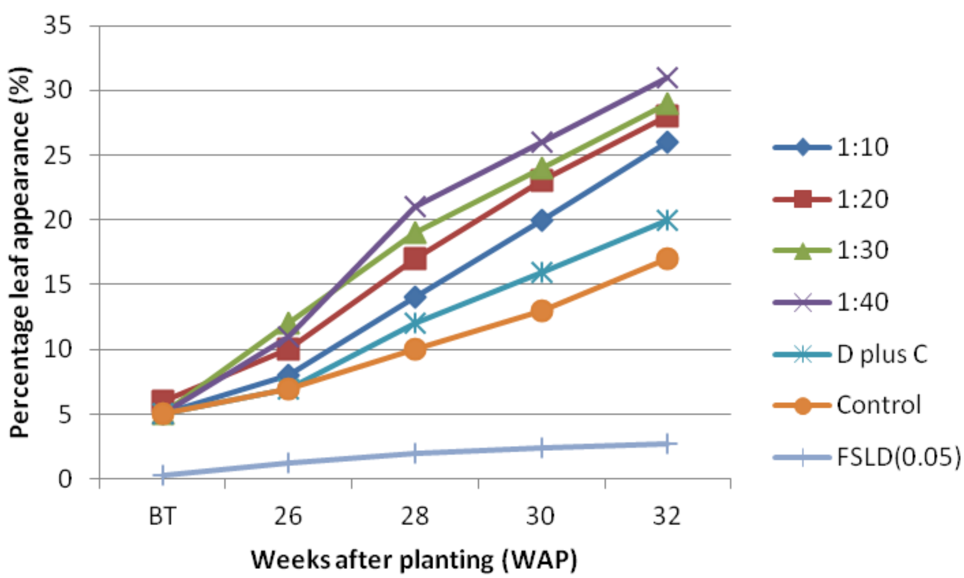

Figure 4. Percentage leaf appearance (flushing) in cassava weeks after treated with different concentrations of *Moringa oleifera* leaf extract (MLE) and dimethoate plus cypermethrin between 26 and 32 weeks after planting (WAP), D plus C = dimethoate plus cypermethrin, BT = before treatment.

The control plants had the highest insect population (2.63) followed by the plants treated with 1:10, 1:30, 1:40 and 1:20 MLE in water in that order (2.44, 2.38, 2.37 and 2.32, respectively). There were significant differences ($p < 0.05$) in the insect population across the treatments from the 6 to 7 week after spraying.

DICUSSION

The high values of percentage stem height difference (% SHD) obtained in 1:10, 1:20 and 1:30 MLE in water especially at the thirty second week after planting could be attributed to the high nutritional values of the extract at these concentrations. Fuglie and Sreeja (2011) observed that 1:32 MLE in water increased the growth and yield of maize and other crops by 30%. The dimethoate plus cypermethrin treatment gave the highest percentage leaf number difference (70.99) at the 32 weeks after planting and the value increased consistently from 28 to 32 week after planting. This could be ascribed to the total eradication of the insect especially at the 6 and 7 week after spraying, thus, reducing the level of defoliation (leaf abscission) and increasing the total number of leaves mostly with the new flushes emerging over the period. The high nutritional qualities of *M. oleifera* leaf extract further increased the general growth of the plants and enhanced the rate of leaf appearance on the MLE treated plants as earlier reported by Fuglie and Sreeja (2011). Ndubuaku et al. (2006) observed that increase in the number of leaves as a result of leaf flushing enhanced the photosynthetic capacity of cocoa plants, increased the photosynthate accumulation and total yield. The fluctuations in the percentage leaf number especially in the MLE-treated plants could also be due to high percentage leaf abscission obtained in the plants as shown in the result which might not be commensurate with the rate of leaf flushing (percentage leaf appearance). The variations in the %SHD, %LND, %LA and percentage leaf appearance measured fortnightly (biweekly) showed the marginal differences in the growth traits which could also reflect in the weekly measurements. Rain is a major constraint in foliar pesticide/fertilizer application to plants because much of the applied chemical can be washed off after immediate rain following application thus, reducing the amount actually absorbed by the plant. However, in all the applications of the MLE and dimethoate plus cypermethrin, there were no immediate rains before and after applications. Hand sprayer was used for application to reduce wind-drift and ensure direct contact with the plants.

At all the concentrations of *M. oleifera* leaf extract and the control, the insect population increased from the fifth week of treatment application which coincided with the period of heavy rain (around May/June). Fuglie and Sreeja (2011) reported that *M. oleifera* leaves and young shoots could be used for animal feed because of their high nutrient contents. Thus, the leaf extract, instead of acting as organic insecticide, could have been a source of nutrition for the insect to increase its strength and destructive abilities. This reflected in the high rate of defoliation/ leaf abscission recorded in MLE treated plants from 6 week of treatment when the level of insect infestation on the plants increased. Dimethoate plus cypermethrin controlled the insect population better than *M. oleifera* leaf extract. This was evident in the high reduction in the population of the insect in the dimethoate plus cypermethrin -treated plants all through the period of observation. This ultimately enhanced the morphological growth (stem height and number of leaves) of the plants treated with dimethoate plus cypermethrin because they were not prone to much destruction by the insect attack. However, this does not suggest that the organic pesticide cannot be used in a good integrated pest management (IPM) program. Higher concentrations and the undiluted form of the *M. oleifera* leaf extract should be tried in further experiments to ascertain the level that can be toxic to the insect. Efforts to isolate the active ingredients in the leaf extract are important to know if *M. oleifera* leaf extract had any insecticidal quality.

Conclusion

Dimethoate plus cypermethrin controlled the insect population in the plot better than *M. oleifera* leaf extract. This was evident in the high reduction in the population of the insect in the dimethoate plus cypermethrin -treated plants all through the period of observation. This ultimately enhanced the morphological growth (stem height and number of leaves) of the plants treated with dimethoate plus cypermethrin because they were not prone to much destruction by the insect attack. However a combined use of Dimethoate plus cypermethrin and *M. oleifera* leaf extract may give a better result and as such recommended than a single treatment application.

Conflict of interests

The authors did not declare any conflict of interest.

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