



Potential of Botanical Extracts in the Control of Kale Aphids (*Brevicoryne brassicaea*) and Their Effect on the Parasitic Wasp (*Aphidius ervi*)

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Authors' contributions

This work was carried out in collaboration between both authors. Author NWP designed the study, wrote the protocol and wrote the first draft of the manuscript. Author NWP reviewed the experimental design and all drafts of the manuscript. Authors NWP and JJK managed the analyses of the study. Authors NWP and JJK identified the plants. Authors NWP and JJK performed the statistical analysis. Both authors read and approved the final manuscript.

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ABSTRACT

The use of synthetic pesticides has made important impacts on aphid control. However, it has limitations due to the development of aphid resistance and negative effects on human health and the environment. In this research, we explore alternatives to pesticides by examining the effectiveness of plant extracts (Mexican marigold, Sodom apples, garlic and ginger) on reducing populations of the kale aphid while preserving its parasitoid, *Aphidius ervi*. Use of botanical plants would be of importance to small scale farmers due to their availability, affordability and environmental friendliness. The research was laid out in a Randomized Complete Block Design with three replications. Aphid numbers, mummified aphid numbers as well as parasitic wasps were counted; data was analyzed using Statistical Analysis Software (SAS) and mean separation done using Tukeys. Garlic extract was the most effective in control of aphids causing a reduction by 69.5%. Mexican marigold extract was the most effective as compared to garlic extract which controlled high percentage of kale aphids but was very lethal to the *Aphidius ervi*. Nonetheless, Mexican marigold extract was least effective in the control of aphids.

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1. INTRODUCTION

Kales are one of the most highly consumed vegetables in Kenya. They have high nutritional value and are well adapted to most climatic conditions. They are a source of income to both small and large scale growers. Despite their adaptability to a wide range of climatic conditions, kale production is affected by poor seed quality, pests and diseases, drought, poor market channels, poor transport to markets, lack of agronomic and utilization packages [1].

Major insect pest attacking kales include cutworms, aphids, diamond back moth, white grubs, and bugs. The kale aphids (*Brevicoryne brassicae* Linnaeus) are the most notorious pests of kales due to their ability to cause substantial plant and economic losses, and to develop resistance to a wide range of insecticides. Their feeding causes wilting, yellowing and stunted plant growth. They are also known to transmit viral diseases and secrete honey dew which attracts sooty mold and a number of insects [2]. Most farmers have continually used different types of synthetic pesticides that are systemic and broad spectrum to manage aphids, including methomyl, emamectine benzoate, pyrethroids, and neonicotinoids [3]. However, these insecticides have resulted in the development of pest resistance and in negative side effects on humans and the environment including beneficial insects [4]. Furthermore, they are of high costs which make them unaffordable to many farmers.

Botanical plants are readily accessible to small scale farmers and they have been found to be environmentally safe having low toxicity to mammals, fish and pollinators [5]. For these reasons, this study aims at evaluating botanical plant extracts in control of kale aphids and their effect on *Aphidius ervi* Haliday. This would help minimize the negative effects of synthetic pesticides.

2. MATERIALS AND METHODS

2.1 Experimental Site

The experiment was carried out at Chuka University farm, Tharaka Nithi County, Kenya. Chuka University lies at an altitude of 2000 m above sea level. The average rainfall received

ranges from 500 mm-2400 mm per annum, and the temperature range is of about 20°C.

2.2 Experimental Design and Linear Model

- 1) The experimental design was a completely randomized block design with 5 treatments replicated 3 times. The linear model being $y_{ij} = \mu + t_i + b_j + e_{ij}$. The experiment had 3 blocks each with 5 plots giving 15 plots and the plot size was $2 \times 1 \text{ m}^2$



Plate 1. Field layout of the research

2.3 Planting

Kale seedlings (Marrow Stem Variety) were planted in $2 \times 1 \text{ m}^2$ plots at spacing of 20 cm between plants and 30 cm between rows each experimental unit consisted of 15 plants.

2.4 Crop Maintenance

2 kg of manure was applied on each plot and incorporated into the soil using fork jembes. Watering was initially done twice daily, then once a week after the seedlings hardened.

Withered and damaged seedlings were gapped within the first week. Weeding was done as and when weed appeared, prevalent weeds were black jack and black night shades. Application of foliar fertilizer (Easy gro) was done on the second week after planting at a rate of 10 g per plot. This was to increase succulent leaves that would be attractive to aphids.

2.5 Preparation of Plant Extracts

Sodom apple fruits (*Calotropis procera*) and Mexican Marigold (*Tagetes erecta*) leaves were taken to the lab for drying. Sodom apple fruits were cut into small pieces to increase the surface area for drying. The Mexican marigold leaves and Sodom apple fruits were wrapped separately in aluminum foils and dried in an oven at 70°C. After 4 days, the temperatures were reduced to 50 degrees Celsius for uniform drying for three days.

The dried Sodom apple fruits and Mexican marigold leaves were ground using stones in the fields. 3 full table spoons of ground Sodom apple fruits and Mexican marigold leaves were soaked in 1 litre of water each separately a day before application.

Ginger and garlic were ground in their fresh form and 3 table spoons put in 1 litre of water and sprayed to the plots. A hand sprayer was used in the spraying of the experimental units at an interval of 7 days for four weeks.

2.6 Data Collection and Analysis

Data was collected in six randomly selected plants from each experimental unit, aphid, mummified aphid and parasitic wasp counts were done. Treatment application was done at an interval of 7 days. Data was subjected to

Analysis of Variance using SAS and mean separation done using Tukeys.

3. RESULTS

Before treatment application, all treatments had high numbers of aphids. After the first week of treatment, aphid numbers reduced significantly in plots and by the third week aphid mortality was highest in Garlic, Sodom apple, Ginger and Mexican marigold extracts respectively (Table 2). All the treatments reduced aphid numbers over time except the control. Garlic extract showed the highest mortality of aphids by the third week (Table 2).

Parasitic wasp (*Aphidius ervi*) populations were not significantly different ($p=0.05$) up to week three; however the populations decreased in all treatments except in the control. By week four, Garlic extract was most lethal to the parasitic wasps followed by Mexican marigold extract (Table 2).

Mummified aphids (pupal stage of the parasitic wasp) were highly affected by garlic extract causing highest mortality across the weeks. Sodom apple extract had highest numbers of the mummified aphids hence it was more friendly. However, with time, mummified aphids reduced in numbers across the treatments except in control. Nonetheless, by the fourth week, all the treatments were not significantly different ($p=0.05$) (Table 3).

Table 1. Aphid population over time across botanical plant extracts

Botanical plant extracts	Before treatment			
	Week 0	Week 1	Week 2	Week 3
Ginger	202a	149a	114ab	69ab
Garlic	118bc	85ab	51c	36c
Sodom apple	186ab	128ab	89b	62bc
Mexican marigold	108c	70b	65b	51bc
Control	100c	112ab	129a	101a

N/B treatments with the same letter are not significantly different according to Tukey's test

Table 2. Percent reduction in aphid populations after weekly sprays with botanical plant extracts for a period of three weeks

Botanical plant extracts	After treatment		
	Week 1	Week 2	Week 3
Ginger	26.2%	43.6%	65.8%
Garlic	27.9%	56.8%	69.5%
Sodom apple	31.2%	52.2%	66.7%
Mexican marigold	35.2%	39.8%	52.8%
Control	112%	129%	101%

Table 3. Populations of *Aphidius ervi* over time across treatments with botanical plant extracts

Botanical plant extracts	Before treatment		After treatment	
	Week 0	Week 1	Week 2	Week 3
Ginger	7a	6a	6a	6ab
Garlic	5a	3a	2a	1b
Sodom apple	8a	5a	5a	4ab
Mexican marigold	6a	4a	4a	2ab
Control	4a	5a	7a	7a

N/B treatments with the same letter are not significantly different according to Tukey's test

Table 4. Population of mummified aphids over time across treatments

Botanical plant extracts	Before treatment		After treatment	
	Week 0	Week 1	Week 2	Week 3
Ginger	14a	13ab	7b	2a
Garlic	9a	7b	5b	5a
Sodom apple	19a	18a	16a	12a
Mexican marigold	12a	12ab	6b	4a
Control	8a	13ab	10ab	9a

N/B treatments with the same letter are not significantly different according to Tukey's test

4. DISCUSSION

The populations of aphids, parasitic wasps and mummified aphids were high in week 0, before application of any treatments. This was because the kales had heavy succulent leaves that attracted the infestation and multiplication of aphids. After weekly spraying with botanical plant extracts for a period of three weeks, garlic extract was the most efficient in reducing aphid populations (69.5%). This was followed by extracts from Sodom apples (66.6%), Ginger (65.8) and Mexican Marigold (52.8%) extracts respectively.

After continuous application of treatments for 3 weeks garlic was found to be the most effective in aphid control. There was high mortality of aphids over time and aphid population was lowest in the last week of garlic application. Garlic extract has also been found to have Pesticidal effect on aphids (Chari *et al.*, [6]). Garlic extract is effective for control of small insects such as aphids because it has a strong pungent smell that insects find unpleasant. The odor may also mask the smells that pests use to find their hosts [7].

However, garlic extract was lethal to *Aphidius ervi* as it led to the reduction in the numbers of both the parasitic wasps and the mummified aphids. These results are in line with initial research work that proved garlic effectiveness in aphid control but very lethal to parasitoids [8].

Despite the effectiveness of plant extracts in reducing aphid populations, the tested water extracts resulted in damages on the kale leaves. The leaf edges of plants sprayed with garlic and Sodom apple extracts were burned. This is because the mode of action of botanical pesticides is mostly contact which has phytotoxic effect on plants especially when applied in high doses [8].

Sodom apple extract was the second most effective botanical extract after garlic extract in control of aphids. It was observed that aphid numbers had significant decrease over time. Initial work has also proved Sodom's effectiveness in control of aphids [9] Additionally, Sodom apple extract was found friendly to the parasitic wasps and mummified aphids because there was very low mortality rates of these parasitoids. Sodom apple extract is one of the medicinal plants that have been found effective in the control of pests without or with low negative impact on friendly insects [10].

Ginger extract was the third most effective in control of aphids. The mortality rate of aphids was moderately low as compared to other botanicals (Table 2) [11]. It was observed that ginger extract had an immediate burning or repellent effect on aphid as many of them fell off during application. The effect must have reduced over time and the aphid population rebuild up leading to lower effectiveness of ginger. Ginger extract was friendly to the parasitic wasps (Table 3) but showed lethal effects to their pupal stages

(mummified aphids) (Table 4). This could be because ginger extract resulted in an immediate burning effect on the cocoons and pupal stages [12].

Ginger extract has been used to control aphids in various infested plants of Brassica family. It has repellent mode of action against the aphids but no effect on non-target organisms e.g. parasitoids [13].

Mexican marigold extract was the least effective; however, it had 52.8% mortality of aphids by the third week (Table 2). This is in correlation with other studies showing that Indian Neem followed by Mexican marigold extract were the most effective in controlling mustard aphids [14].

Mexican marigold extract has also been combined with other botanicals e.g. tobacco and aloe vera and found very effective in control of aphid, other pests and even some diseases. The effectiveness of this water extract is related to its acrid smell, although, not as strong as that of garlic. Moreover, Mexican marigold extract had little effect on both the parasitic wasps and the mummified aphids. In fact, Mexican marigold is an indigenous weed with strong smell that repels most insect pests, but seems harmless or tolerated by beneficial natural enemies [15].

The aphid numbers in the control experiment increased over time due to favourable environment and availability of resources. When the aphid population peaked, some aphids developed winged and migrated to other plants; hence, the decrease in aphid number in the last week. It is known that aphids produce wings to find new resources under crowded conditions or decrease in food quality [16]. On the other hand, the number of parasitic wasps increased over time due to presence of favorable environment. The number of mummified aphids increased over time and reduced in the last treatment since the pupal stage developed into adult winged parasitic wasps.

5. CONCLUSION

The results showed that garlic extract was the most effective botanical pesticide against kale aphids with 69.5% reduction in aphid numbers.

Mexican marigold extract was viewed to be the most effective due to its friendliness to the beneficial insects (*Aphidius ervi*) as compared to garlic extract which controlled high percentage of kale aphid but was very lethal to the *Aphidius*

ervi. Mexican marigold extract was least effective and it resulted to least aphid mortality. Effectiveness of Sodom apple extract was relatively high with highest friendliness to *Aphidius ervi*. All botanical pesticides used in the experiment can be used in control of aphids. However, Mexican marigold extract should be used since they conserve *Aphidius ervi* and therefore they would be beneficial in the integrated management programs of the kale aphid.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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