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Research Article

Identification of Plant Extracts and Oils as Insect Repellents

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ABSTRACT

Introduction: Plant-based insect repellents have been used for many years in traditional practice as a personal protection measure against insects. Development of new plant-based insect repellent is a valuable resource for environmentally safe crop production. In recent years, plant-based insect repellents have gained importance among farmers, as these are considered "Safe" to the environment as compared to synthetic pesticides. To date, several bio pesticides have been identified as insect repellent, however there is no single plant based product that gives complete repellency. This emphasis the need for identification of plant based bio pesticides with high repellency. **Materials and Methods:** The current study evaluated the potency of 11 plant extract of both Indian and Irish origin for their repellency against the grey field slug species. Extracts of *Foeniculum vulgare* (Fennel), *Momordica charantia* (Bitter Gourd), *Trigonella foenum-graecum* seeds (Fenugreek), *Allium cepa* (Shallots), *Allium sativum* (Garlic), *Artocarpus heterophyllus* (Jack Fruit) leaves, *Phyllanthus emblica* (Amla), *Cymbopogon citrate* (Lemon grass), *Taraxacum officinale* (Dandelion), *Murraya koenigii* (Curry leaves) and *Curcuma longa* (Turmeric) were used in this experiment. Plant extracts was prepared by crushing 5g of the sample in 100ml of water using pestle and mortar. The extracts as filtered using household sieve to remove larger particles and used to test their potency against the slugs. **Results:** Out of 11 extracts tested, five extracts repelled the slugs to a greater extent and three extracts showed moderate effect. However, three extracts had no effect. **Conclusion:** The results of this current study strongly suggest the use of five plant extracts such as garlic, fenugreek, fennel, bitter gourd and shallots as an environmentally safe bio pesticide to control grey field slugs.

Key words: Natural product, Slugs, Repellents, Insects, Plant extracts, Home remedies.

INTRODUCTION

Slugs represent one of the most significant and unmanageable threats to sustainable agriculture.[1] They are persistent and widespread pests that wreak havoc in crops. The damage caused by slugs is most severe in countries of moist conditions such as Ireland and Britain. Slug damage depends on soil type, climate, distribution of slug species and practices and management of land. Slugs may kill seedlings of some crops by decreasing leaf area or destroying growing points or stems, which, therefore may lead to a decrease in yield or crop development.

Crops of the *Brassica* family are highly liable to attack from slugs. Young crops in the *Brassica* family are vulnerable to defoliation. Leafy vegetables are likewise susceptible to slug damage. Feeding marks left by the slugs renders the crop unsuitable for sale. Similarly, strawberries also fall prey to slugs. Tiny holes are gnawed by the slug which leaves the strawberry unfit for sale and encourages mold growth as well.[2-4]

The term slug refers to a gastropod with a reduced shell. The slug's body is primarily made up of water which results in its thin soft tissues being prone to desiccation. To deal with this, slugs must produce copious amounts of slime from skin glands to survive. This slime contains water, salts and mucus. In the mucus of slugs, there are mucins which are carbohydrates attached to protein. Slug slime is considered hygroscopic as it can absorb water. It is also able to change consistency when pressure is applied. The slime secreted from the lower surface of the slug allows the slug to stick on vertical surfaces, without slipping. Chemicals in the slug's slime can be detected by other slugs, which can assist the slug in finding a mate. However, this slime can also be identified by carnivorous slugs, who prey on other slugs. Slugs are most active at night, thus referred to as nocturnal. They may hibernate during winter months if too cold but may stay active during milder climates. Some slugs have a lifespan of around six years, though other species live only for a few months. Slugs are hermaphrodites as they have both male and female reproductive cells. Once a slug has located a mate, they encircle each other and exchange sperm through their protruded genitalia. Slugs can self-fertilise and do not need a mate to procreate.[5]

Slugs prey on a wide spectrum of organic materials, including mushrooms, strawberries and leaves from plants such as lettuce. Some slugs are carnivorous and prey on other slugs, for instance the Limus

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maximus (The leopard slug), which are known to pursue other slugs at rate of 15cm per hour. It is also detrivore as it eats dead plants and fungi. The leopard slug is known to eat young crops faster than they grow, so it is listed as agricultural pest.[6]

To control such pests, harsh chemicals such as metaldehyde is used. Metaldehyde is the active ingredient in most commercial slug pellets. The cells of the nucleus in the slug are damaged due to the molluscicide, thus causing the slug to produce excess slime, leaving it dehydrated. If not outright killed, metaldehyde leaves the slug immobile and unable to retreat.

Metaldehyde is also harmful to humans. Vapours of metaldehyde when inhaled causes severe irritation of the mucus membrane lining in the mouth, nose, sinuses and lungs. Ingestion of this molluscicide can cause irritation of the stomach and intestines and can cause liver and kidney damage. One to three hours after ingestion, symptoms such as nausea, vomiting, convulsion, fever, diarrhea, severe abdominal pain and coma may occur. Increased heart rate, panting, asthma attack, depression, drowsiness, high blood pressure, inability to control urine and faeces, excessive salivation and unconsciousness may also appear due to acute exposure. Birds who feed from areas treated by metaldehyde are killed. Symptoms such as muscle spasms, diarrhoea, tremors and rapid breathing was observed in poultry which were exposed to metaldehyde.[7]

Plant based alternatives may be used to replace the current chemical-based slug repellents as they are comprised of alkaloids which are biochemical compounds. For instance, extracts of garlic are commonly known for its repellent properties of deterring slug.[8] A survey was conducted at a local farmers market to measure the extent of damage caused by slugs. Through this survey it was found that slugs are a major pest for vegetable crops and sometimes the infestation of the slugs led to a total crop failure for the farmers. Therefore, this project aims to investigate the use of plants extracts as a bio pesticide against slugs. This project delineates to investigate the repellence potential of 11 plant extracts against the grey field slug species. This will be achieved through the following objectives:

1. Slug collection from fields and gardens.
2. Testing the efficacy of different plant extracts for their repellent qualities against grey filed slugs.
3. Analysing and generating the results.

MATERIALS AND METHOD

Farmers Survey

As a first step, a survey was conducted at a local farmers market to determine the damage caused by slugs. Through this survey, connections were established with the farmers and a farm visit was organised to study the slug damage and as well as to collect the slugs.

Slug Collection

First, the slugs were collected from the farm which was used for vegetable cultivation. About 50 slugs of different species were collected in the container. Small holes were made at the top of the lid to aid the air circulation and young lettuce leaves and strawberries were left inside the container as a feed for the slugs. The container was left outdoor under the shelter. However, due to heavy rain during the month of November, water seeped through the holes and few slugs were dead. Carefully the survived slugs were collected and transferred to a new container and this time, the slugs were kept indoors. Then, more slugs were gathered from gardens and lawns to make sufficient numbers to begin the experiment. In this study, light brown slugs from grey field species were used.

Preparation of the Plant Extract

5g of plant material was measured on an electronic balance. The plant material was placed in a pestle and mortar and was ground into a fine paste. 100ml of water was measured using an electronic balance and was added to the plant paste. This mixture was mixed thoroughly and then filtered into a plastic container using a strainer (Figure 1).

Preparation of the Board

On the edge of a canvas board, duct tape was stuck. The centre point of the board was marked and a circle was drawn using permanent marker. Pieces of string were coated in a paste made of salt and water. It was then tied around the inner side of the duct tape to ensure the slugs would not escape when the experiment was being done (Figure 2).

Experimental Method

A strawberry was then dipped into the plastic container containing the plant extract. The strawberry coated in the plant extract was the placed at the centre point of the board. A slug was picked from the container and placed on the strawberry. A timer was set for 5 mins and a photograph was taken at 0 mins. Lights were then turned off to ensure the best result. After 5 mins, the distance the slug moved from the centre point was measured using a ruler and recorded. A photograph at 5 mins was also taken. For each plant extract, the experiment was repeated twice. A strawberry dipped in water was used as a control (Figure 3).

RESULTS

Main Findings from Survey

The overall goal of the survey is to know the extent of damage by pest in the Cork region. The survey was conducted with 10 vegetable growers

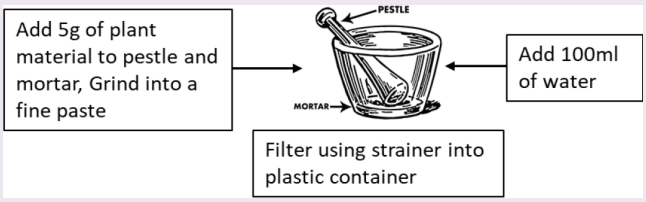

Figure 1: Preparation of the Plant Extract.

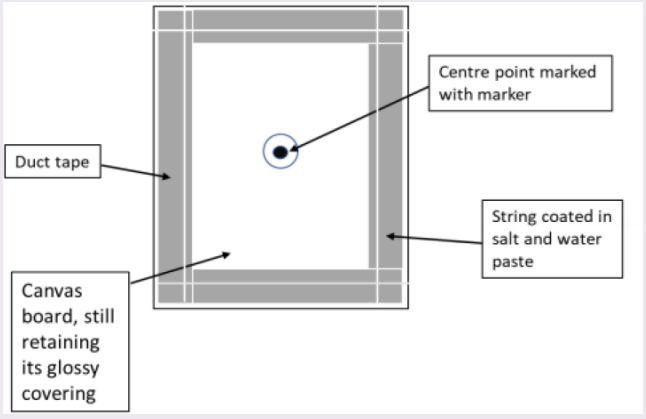

Figure 2: Preparation of the Board.

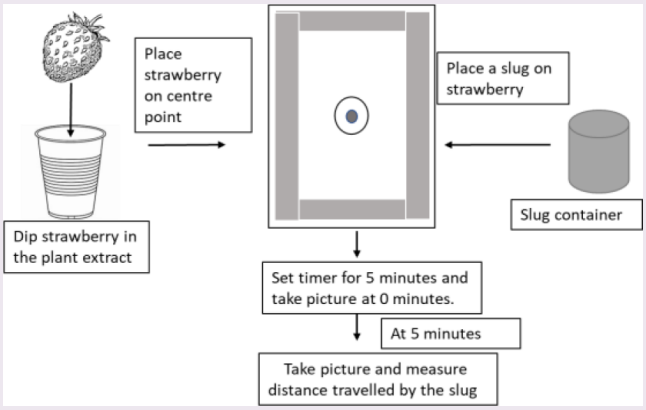

Figure 3: Experimental Method.

Figure 4: Slug Infestation on Potato.

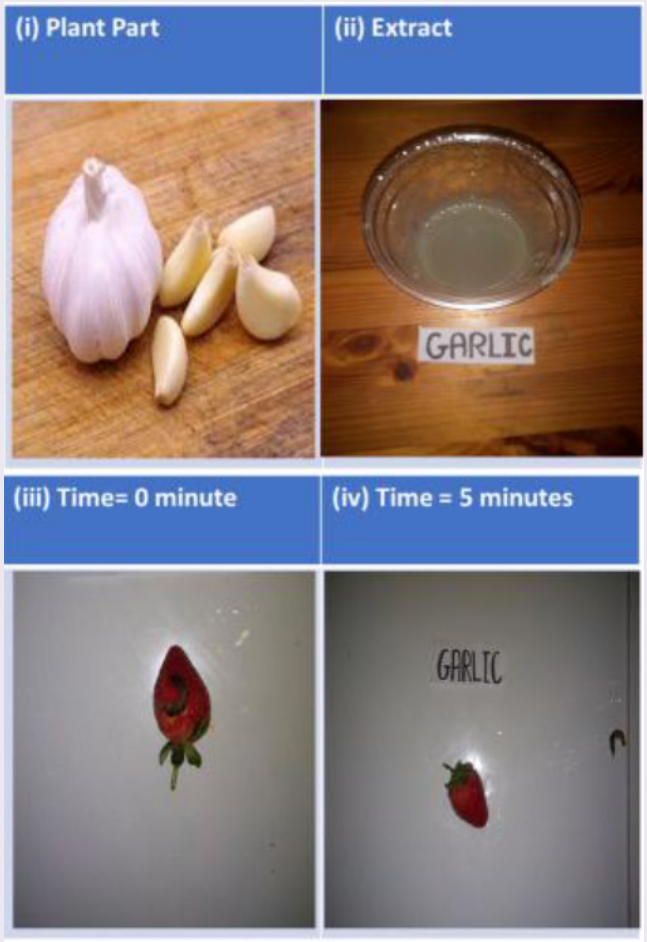

Figure 5: Results from Garlic Treatment.

in Cork region in Ireland. The survey results showed that the farmers faced a major problem with slugs. As the survey was mainly conducted with vegetable growers of small scale, they used natural methods such as mulching to save the crop from slug damage. In some instances, the slugs caused a total failure of the crop as well. (Figure 4).

Results from Plant Extracts

Results from Garlic treatment

The garlic extract had a yellow hue and the smell was quite pungent. Garlic proved to be one of the most effective in repelling slugs. In the first replicate the slug moved 24cm from the centre point and in the second 20cm from the centre point. As the slug reached the salt barrier within 30 sec, so the experiment was halted and recorded. The slug was very responsive to the treatment and moved away from the strawberry almost instantly (Figure 5, Figure 16 and Table 1).

Results from Bitter gourd Treatment

Bitter gourd is a fruit which has a distinctive bitter taste. The extract from the bitter gourd was bright green in colour and had a intense astringent smell and taste. Bitter gourd also proved to be quite effective in deterring slugs. Replicates of the experiments were performed and it was observed that during the first treatment the slug moved 20cm and in the second 15cm. Similar to the garlic, the slug was very responsive to this treatment, however moved a bit more sluggish compared to the garlic treatment (Figure 6, Figure 16 and Table 2).

Results from Lemongrass Treatment

Lemongrass is known for its lemon like scent and the taste is a mixture of lemon and lemon mint. Its extract had a light-yellow hue with a greenish tinge and had a tastes almost like a mix of lemon and lemon mint. The extract had a light-yellow hue and its scent was strong. Lemongrass was sufficient in repelling the slug as the slug moved an average of 5.5cm in five minutes (Figure 7, Figure 16 and Table 3).

Results from Fennel (Bulb) Treatment

Fennel is in the carrot family and is a flowering plant species indigenous to the Mediterranean. The extract acquired from the fennel was a light yellowish-green and was not strong in scent. For this treatment, the slug moved quickly, as it travelled around 15cm for both replicates and in under 2 mins and 30 secs. Fennel demonstrated to be efficient in repelling the slug (Figure 8, Figure 16 and Table 4).

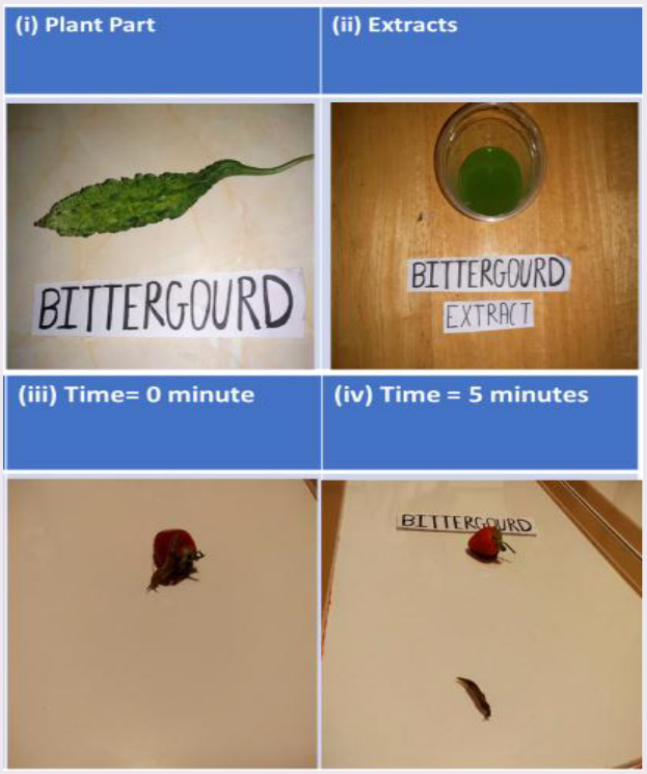

Figure 6: Results from Bitter Gourd Treatment.

Figure 7: Results from Bitter Gourd Treatment.

Results from Curry Leaves treatment

Curry leaves are of Indian origin. They are dark green in colour and their extract was also dark green. The extract had a very distinctive smell, so was assumed to have repellent qualities. However, the curry leaves were fruitless in deterring the slug as both replicates were one centimetre (Figure 9, Figure 16 and Table 5).

Results from Jackfruit Leaves Treatment

The leaves of the jackfruit tree are coarse and dark green. They are also edible. The extract yielded from the jackfruit leaves acquired dark green and its aroma was sweet with under laying notes of bitterness. The jackfruit leaves were sufficient in repelling the slugs. Each replicate were tested for 5 mins. During the first replicate the slug moved 4cm and for the second replicate it travelled 3cm (Figure 10, Figure 16 and Table 6).

Results from Dandelion Treatment

Dandelion leaves were used as one of the treatments. The extract produced by these leaves was a dark green. To this extract the slugs acted quickly and covered 12cm in 5 mins for the first replicate, however, the second replicate was not so fruitful as the slug did not move and proceeded to stay on the strawberry (Figure 11, Figure16 and Table 7).

Results from Amla Treatment

Amla or Indian gooseberry did not fair well in deterring slugs. The slug moved only 3cm in the first replicate and 2cm in the second replicate. Amla has a sweet, sour and bitter taste. Its scent is fairly sweet Figure 12, Figure 16 and Table 8).

Results from Fenugreek Seeds Treatment

Fenugreek is in the family Fabaceae. Fenugreek seeds were used as an extract for this experiment. The taste of these seeds is very bitter and so is its smell. Its extract was a light-yellow colour. For both replicates, the slug reached the end of the at around 15cms in 5mins. This treatment was effective and the slug was responsive (Figure 13, Figure 16 and Table 9).

Results from Shallots Treatment

Shallots are a variety of the allium family the same as garlic. Shallots are formed in cluster of offsets with a head composed of multiple cloves similar to garlic. The extract was a pale yellow. Its scent and taste were pungent and the slug was very responsive to this treatment and reacted quickly as it moved around 20cms for both treatments (Figure 14, Figure 16 and Table 10).

Results from Turmeric Treatment

In this experiment, turmeric powder was used as one of the treatments. Turmeric has a bitter taste and scent. The extract was a bright yellowish orange colour. The slug moved 1cm from the centre point for the first replicate and for the second, the slug did not move. However, after this treatment the slug was found dead. (Figure 15, Figure 16 and Table 11)

Eleven different plant extracts were screened for their slug repellent activity against the grey field slugs. When a slug was placed on the strawberry treated with plant extract, varying degree of repellent activity was exhibited by the plant extracts. The distance travelled by the slugs corresponds to the repellent potential of the plant extracts (Figure 5-15).

The graph above in figure is an average two replications and the repellent efficiency of eleven plant extracts was shown along with the control with no treatment. Treatments garlic, shallots, bitter gourd, fennel and fenugreek were very effective in repelling the slugs to a greater extent. Dandelion, lemongrass and jackfruit leaves extracts were sufficient to deter the slugs away. However, Turmeric and curry leaves extracts showed

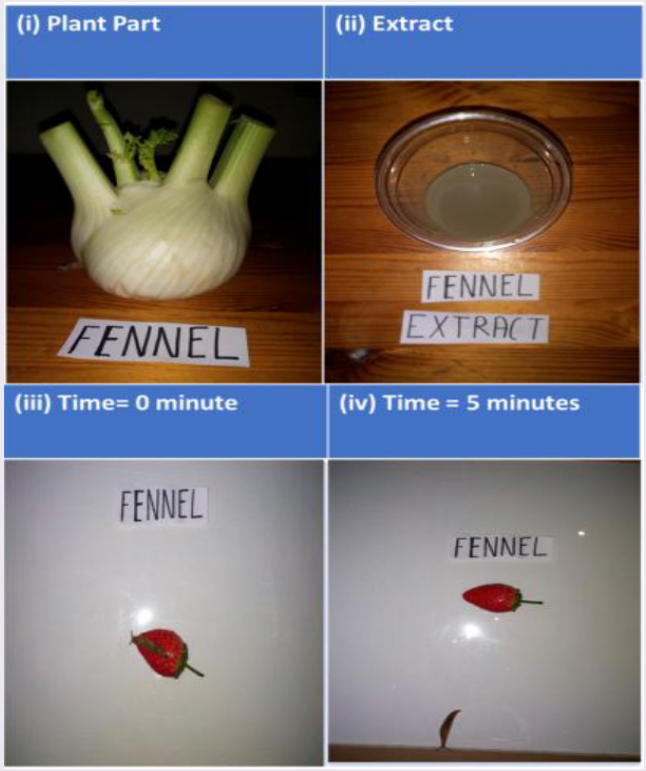

Figure 8: Results from Fennel (Bulb) Treatment.

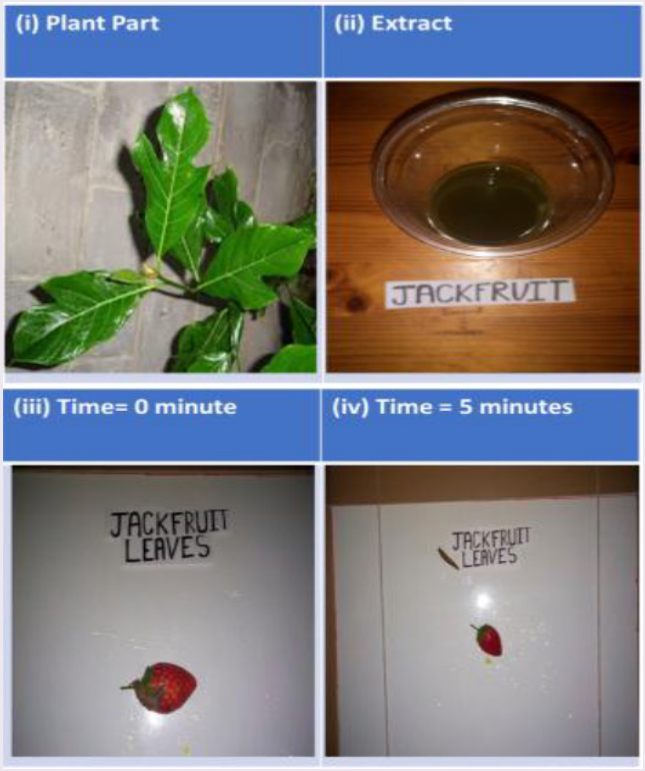

Figure 10: Results from Jackfruit Leaves Treatment.

Figure 9: Results from Curry Leaves Treatment.

Figure 11: Results from Dandelion Treatment.

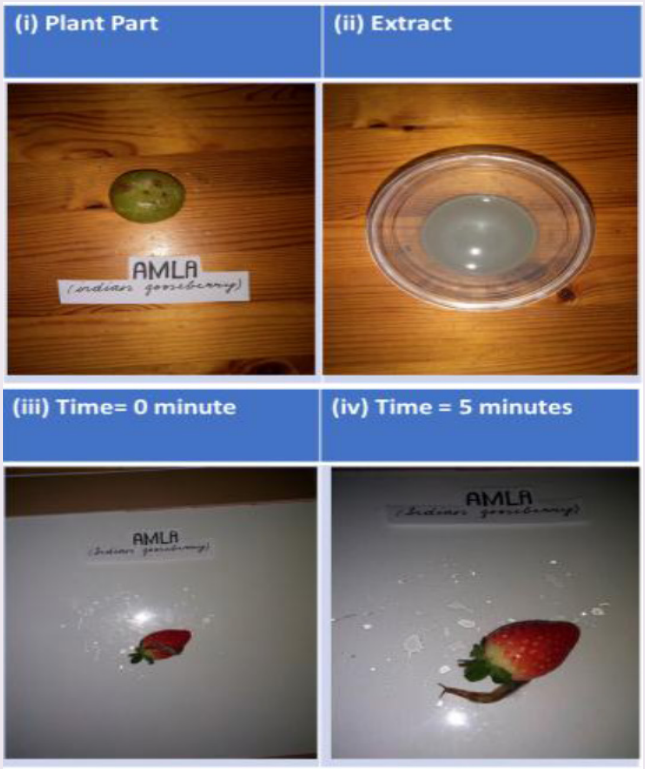

Figure 12: Results from Amla Treatment.

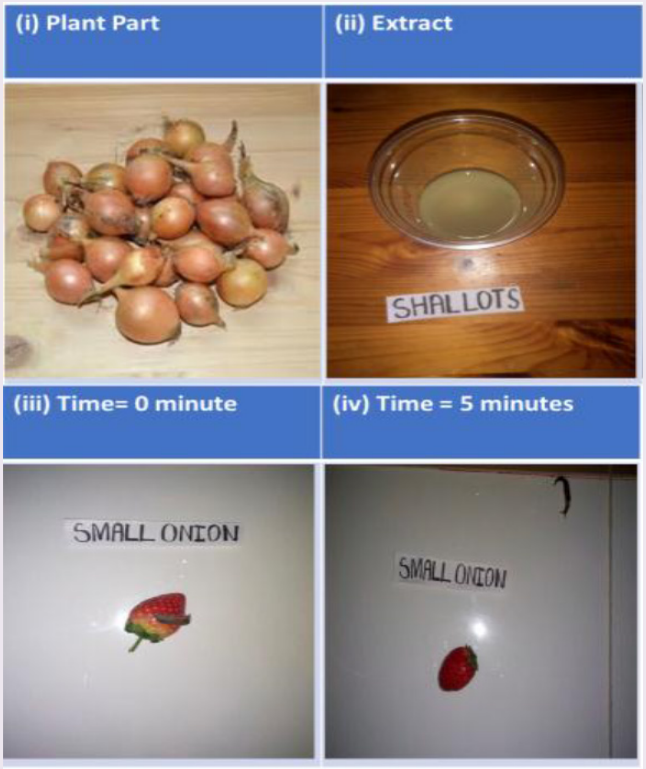

Figure 14: Results from Shallots Treatment.

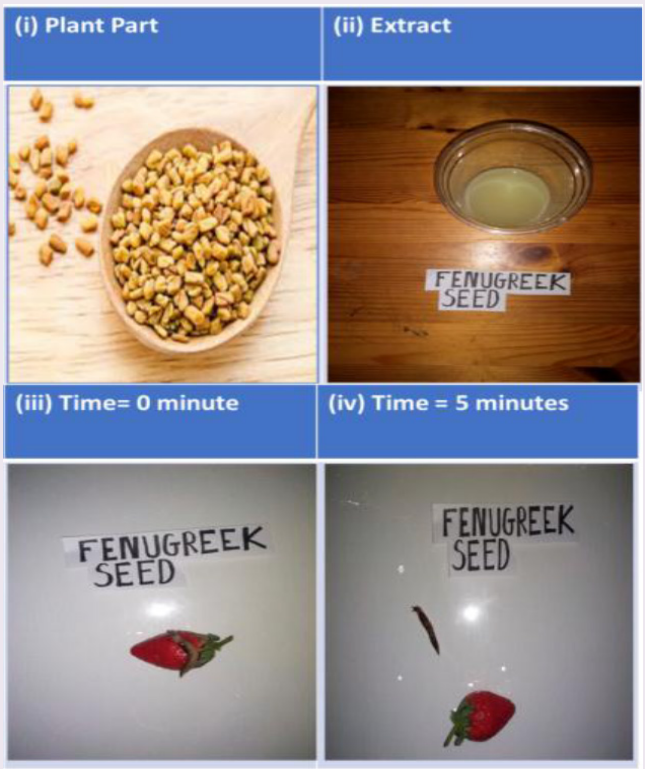

Figure 13: Results from Fenugreek Seeds Treatment.

Figure 15: Results from Turmeric Treatment.

no repellence against the slugs. For the control, the slug remained on the strawberry throughout the duration of the treatment. Used *t* test to find out the significant different between treatments. (*P* value: $P<0.05$ * $P<0.01$ ** $P<0.001$ ***).

DISCUSSION

In recent years, a search for insect repellents from plant sources has received more attention as it is safer to the environment as well as for human health. Several efforts have been made to identify compounds that can act as bio pesticides to replace chemical ones.[9] Numerous studies have been carried out to discover new insect repellent for slugs.[10] In the present study, eleven different plant materials were used in the present study as sources of natural insect repellents. These samples were tested against slugs for insecticidal activity. Bitter gourd, fennel, garlic, shallots and fenugreek exhibited a high percentage of repellent potential compared to other treatments. Therefore, these plant extracts can be developed as a repellent for slugs.

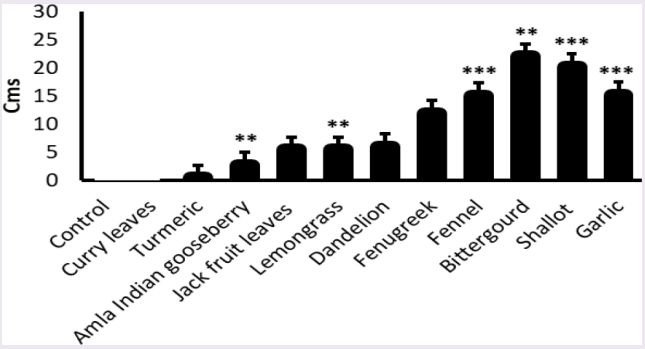

Figure 16: Average Distance Travelled by the Slugs in each Treatment.

Initially, a different method was planned to test these extracts. In the method that was proposed, a slug was supposed to be kept at one side of a box and feed coated in the treatment on the other end. This method is time consuming as there must be a starvation period so the slug will move toward the feed. Therefore, a slight change to the method was incorporated. In this method, we opted to place the slug directly on the feed, either treated or not. A canvas board still retaining its glossy packaging had its borders lined with duct tape and the inner boundary was lined with string coated in salt. This salt boundary was established as we did not wish for the slug to escape. Then a centre point was measured. This is where we placed the strawberry dipped in the plant extract and the slug. However, this method also had some flaws. As the board was rectangular the slugs could have moved diagonally, thus moving a greater distance compared to the slugs whom moved straight to the end. And when the slugs moved straight ahead, depending which direction was chosen, differences in distance moved occurred. Nevertheless, this was the most accurate idea proposed.

Many of the plant extracts used were of Indian origin. These, plants were used as they are recognized to have unpleasant taste and smell, so it was presumed that they would be effective in repelling slugs. Extracts of bitter gourd and fenugreek proved to be worthwhile as those extracts showed optimum performance in averting the slug from the strawberry. This may be because both fenugreek and bitter gourd have an astringent taste and smell, so therefore the slugs disliked the treatment and did not remain on the strawberry.

As garlic is an already known repellent for slugs, it was used as a positive control in this experiment.[8] Garlic functioned as expected and was quite effectual on the slug. Garlic contains an alkalide called acillin. Acillin is a compound produced when garlic is chopped or crushed. It is said that acillin attacks bacteria directly like antibiotics and can cause the bacteria to die or prevent them from proliferation (Zsolt). Slugs require probiotics to digest decaying matter and dead leaves. This may be the reason why the slugs reacted responsively and died within coming in contact with the garlic extract.[11] However, this could also react negatively to the

Table 12: Summary of the Results for all the Treatments.

Treatment	1st Replication (Cms)	2nd Replication (Cms)	Control	Time	Sent	Colour of extract	Taste	Effectiveness of treatment on the slug
Bitter gourd	24	20	0	2:30 mins	Bitter	Vivid green	Bitter	Reacted straight away
Lemongrass	5	6	0	5 mins	Citrusy and minty	Light yellow with a greenish tinge	Citrusy and lemon rind	Reacted slowly
Fennel	15	15.1	0	2:30 mins	Not a very strong scent	Light green/ yellow	sweet	Reacted straight away
Curry leaves	0	0	0	5 mins	Not very strong scent	Drank green	Bitter And savoury	Didn't react
Jackfruit leaves	4	7	0	5 mins	sweet	Dark green	Did not taste	Reacted slowly
Garlic	15	15.5	0	30 secs	Pungent	Pale yellow	Strong and spicy	Reacted quickly
Dandelion	12	0	0	5 mins	Not a very strong scent	Dark green	bitter	Reacted slowly
Amla Indian gooseberry	3	2.5	0	5 mins	Sweet	Yellow/ green	Sweet, sour and bitter	Not very responsive
Shallot	20.5	20	0	5 mins	Pungent	Pale yellow	Strong and pungent	Reacted quickly
Fenugreek	16	8	0	5 mins	bitter	Yellow	Bitter	Reacted well
Turmeric	1	0	0	5 mins	Orange or ginger	Yellow ochre	Pungent and bitter	Slug passed out

probiotics within the soil which keeps it healthy. As shallots are in the Allium family, similar to garlic, it was chosen for this experiment. Shallots also contain the alkaloid, acillin.[12] This alkaloid may be the reason why these extracts proved fruitful. However, this theory cannot be proved without further studies and research.

Bitter gourd was also effective in deterring slugs. Bitter gourd is comprised of momordicin which gives bitter its distinctive bitter taste and aroma.[13] This alkalide may be the reason that the slug reacted negatively to this treatment. However, the fennel bulb extract had no harsh smell or strong taste but proved to be quite effective in deterring slugs.

Curry leaves and Indian gooseberry (Amla) extracts prove to be futile as the slug did not move away from the strawberry. The Amlas sweet smell may be the reason the slug stayed on the strawberry. Curry leaves have a bitter taste and smell but proved to be unsuccessful in repelling slugs. Dandelion leaves and lemongrass were sufficient in repelling slugs. The citrus and minty scent of the lemongrass and the bittersweet nature of the dandelion leaves may have caused the slugs to move away from the strawberry. The turmeric was peculiar in deterring the slug. In the first replicate the slug only moved 1cm and in the second it did not move at all. After this treatment, the appeared to be dead. This may be because of the turmeric extract or the slug could be exhausted from the previous treatments and simply passed. Further investigation of this treatment is necessary to prove this theory.

Additional experiments with different concentrations could be applied, to procure a more feasible result which could be implemented by farmers regularly. This experiment could be conducted at different seasons and at different temperature to determine the effectiveness of these treatments throughout the year with different variations.

Further conduction of this experiment could investigate different mixtures of plant extracts for example, *Allium cepa* and *Trigonella foenum-graecum* to improve repellency. Certain compounds such as momordicin could be isolated and purified to develop a slug repellent. This experiment could be conducted at different seasons and at different temperatures to determine the effectiveness of these treatments with different variations. The alkaloids present in the plant extract could impact the efficiency. This higher proficiency in deterring slugs may also be due to the fact that the extracts were fresh and the sensory organs of the slugs worked well.

The current study has identified four non-toxic plant extracts (Shallots, Fenugreek, Fennel and Bitter gourd) as a potential repellent for grey field slugs. In order to use these plant extracts as effective repellent the biochemical compound from those plant extracts should be investigated to identify their mode of action. And also, more studies must be designed to determine if their combination have synergistic effects on repelling the slugs. Single dose of these plant extracts was tested on grey field slugs for their insect repellent efficacy. Further investigations are required to explore the repellent activity of these plant extracts against a wide range of slug species with varying concentrations to strengthen this finding. Results from this current study might be a foundation for the development of eco-friendly plant-based repellent that can be used as serious alternatives to chemical insecticides for grey field slug control.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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