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(RESEARCH ARTICLE)

The evaluation of the efficacy of natural (plant) insecticides in managing household insects against chemical insecticides

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Abstract

The current study was carried out to test the effectiveness of some plant-based insecticides in relation to a chemical insecticide against some household pests. Three different types of insects; *Periplaneta americana, Musca domestica, and Culex pipiens* were used. Plant extracts such as neem, garlic, chili, and peppermint were tested along with the chemical insecticide, cypermethrin, and their combined use.

The results showed significant differences among treatments ($P \leq 0.05$). The combined treatment achieved the highest mortality rates, followed by the chemical insecticide, while plant extracts exhibited moderate effectiveness. Among the plant-based treatments, peppermint oil showed the highest level of activity. Insect mortality increased over time, and susceptibility varied among the tested species.

These findings suggest that combining plant-based and chemical insecticides improves effectiveness and may provide a more sustainable approach for household insect control.

Keywords: Plant-based insecticides; Chemical insecticides; Integrated pest control; *Periplaneta americana*; *Musca domestica*; *Culex pipiens*; Neem extract

1. Introduction

Household insects have been viewed as a serious issue in urban settings because of the involvement of these organisms in the transmission of disease-causing microorganisms and being a nuisance to human beings. Insects like the American cockroach (*Periplaneta americana*), housefly (*Musca domestica*), and mosquito (*Culex pipiens)* are commonly found in many parts of the world and can cause a range of illnesses [1]. The occurrence of these insects is attributed to suitable environmental conditions, which include sources of food and water supply.

Insecticide chemicals have always been considered one of the most efficient ways of dealing with pests because they act fast and provide quick results.[2] Nevertheless, the use of chemicals in large amounts poses certain problems such as the development of insect resistance, environmental pollution, and health problems for humans and other living beings. As a result, more attention is being paid to the development of new strategies for pest control [3].

Natural insecticides have gained popularity owing to their source, biodegradable nature, and lower toxicity levels. Natural extracts from plants such as neem, garlic, chilies, and peppermint have bioactive components that serve as either repellants, poisons, or insect growth regulators [4]. Although these insecticides may not be as effective as chemical insecticides, they possess numerous benefits over them.

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The recent development in this area emphasizes the integration of plant and chemical pesticides for better efficiency without causing any harmful effects from the usage of chemicals. This type of integration could play an important role in achieving better insect pest control [5]. The objective of this research is to test the efficacy of certain plant-based insecticides against common house insects, compare the efficacy of these insecticides with that of an insecticide used conventionally, examine the effectiveness of their mixture, observe differences in susceptibility between various types of insects, and explore differences in mortality rates across periods of time.

2. Materials and Methods

2.1. Study Location and Environmental Conditions

The experiments took place in the laboratory to reduce the effect of the environment on the results of the study. The temperature was kept constant at (25±2) °C; this is appropriate because insects can be active under this condition. The relative humidity was regulated at (65±5) % because it affects the physiological performance of the insects and the efficiency of the insecticides. The photoperiod was regulated to (12h light/12h darkness).

2.2. Test Insects

Three of the most prevalent household insects were chosen for the study: *Periplaneta americana, Musca domestica, and Culex pipiens*. The insects were gathered from various localities in household settings and taken to the laboratory in well-ventilated boxes to ensure that they were alive when used for the experiment. These insects were then kept in the laboratory under controlled conditions for 7 days prior to the experiments. During the acclimatization period, proper nourishment was provided to each insect: cockroaches were given bread and water, flies were fed a 10% sugar solution, and mosquitoes were housed in an aquatic medium.

2.3. Tested Insecticides

Insecticides derived from plants known to be very efficient were chosen. The use of neem oil was based on the presence of an active substance known as azadirachtin, which works by disrupting the growth and reproduction of the insects. Garlic, which is made up of allicin, was also chosen because it acts as a poison and repellent. Chili peppers, which contain capsaicin, work by acting as an irritant to insects. Peppermint oil was also chosen based on the presence of menthol, which acts as a repellent. As a control, an insecticide made up of the chemical cypermethrin (a pyrethroid substance) was used. This insecticide works by disrupting the functioning of the insects' nervous system, causing them to become paralyzed and die within seconds.

2.4. Preparation of Plant Extracts

The plant extracts were made by simple processes to ensure that they contained bioactive ingredients. Garlic aqueous extract was made by grinding the garlic into a paste, adding distilled water to it, and then allowing the preparation to stay in the solution for 24 hours to enable extraction of the active compound. The extract was then filtered and kept in a dark glass bottle inside the refrigerator [7]. In the same way, the extract of chilies was obtained from fruits which were ground up, mixed with distilled water, left for 24 hours, and then filtered. Neem and peppermint oils were prepared at various concentrations (5% and 10%) using distilled water with the addition of an emulsifier such as liquid soap.

2.5. Experimental Design

The design that was employed in the study is the Completely Randomized Design (CRD). The design was chosen because it ensures even distribution of treatments and minimizes any form of bias. In the experiment, each insect species was grouped into the control (no treatment applied), different treatments of plant extract application, application of chemical insecticide, and an additional treatment group where both plant and chemical were used. Each treatment had 20 insects replicated three times, thus making a total of 60 insects in each treatment group.

2.6. Application Method

The insecticides were applied through direct spraying with the use of hand-held sprayer within petri dishes or cage. This was done using the same amount for each treatment, which was about 2-3 mL[8]. The treatments were done individually to prevent contamination while keeping the environment the same for all groups.

Figure 1 Experimental setup and insect treatment groups under laboratory conditions

2.7. Measured Parameters

2.7.1. Mortality Rate

The number of dead insects was recorded at specific time intervals (1, 6, 24, and 48 hours), and mortality percentage was calculated using the formula:

Mortality (%) = (Number of dead insects / Total number of insects) × 100[9]

2.7.2. Knockdown Time

The duration taken for immobilization of 50 percent of the insects (KT50) was noted to establish the comparative rate of effectiveness of plant and synthetic insecticides.

2.7.3. Residual Activity

The residual activity of the insecticide was determined at 24 and 48 hours using the insect's activity and mortality rate.

2.8. Statistical Analysis

Data were analyzed using SPSS. One-way ANOVA was used to compare groups, and Tukey's test identified differences between them. Results were considered significant at $P \leq 0.05$.

2.9. Safety Measures

In this experiment, the laboratory safety protocol was adhered to, whereby gloves and masks were worn, ventilation was maintained, there was no direct contact with chemical insecticides, and waste was disposed of following laboratory safety protocols.

3. Results

3.1. Effect of Insecticide Type, Insect Species, and Time on Mortality Rate

A significant difference was noted for insecticide type, insect species, and time of exposure, as well as for their interaction ($P \leq 0.05$). There was an increasing mortality rate over time, where the highest values were recorded in chemical and combined insecticides than in plant insecticides.

3.1.1. American Cockroach (Periplaneta americana)

The effects of varying treatments at different periods are provided in Table (1). There is a progressive rise in mortality rates with an increase in contact period for all treatments used. Combined treatment, which involves the plant and chemical compounds, was found to be the most effective, followed by Cypermethrin chemical insecticide.

Plant extract had moderate results, where neem and peppermint oils outperformed garlic and chili pepper. The resistance of the cockroach increased for the first hour when compared to other times such as after 24 and 48 hours.

Table 1 Mortality rate (%) of *Periplaneta americana* at different time intervals

Treatment	**1 h**	**6 h**	**24 h**	**48 h**
Control	0	2 ± 1	5 ± 1	5 ± 1
Neem	20 ± 2	45 ± 3	78 ± 3	80 ± 2
Garlic	15 ± 2	40 ± 3	72 ± 4	75 ± 3
Chili	10 ± 2	35 ± 3	65 ± 3	68 ± 2
Peppermint	25 ± 2	50 ± 2	70 ± 2	73 ± 2
Cypermethrin	70 ± 3	90 ± 2	95 ± 2	90 ± 2
Combined	80 ± 2	95 ± 1	97 ± 1	95 ± 1

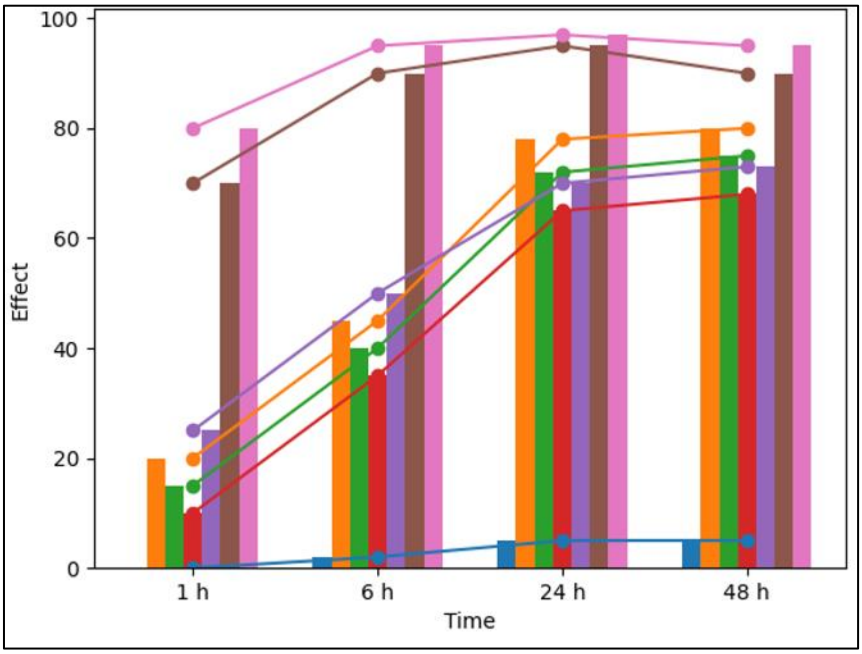

Figure 2 Comparative Time-Dependent Efficacy of Chemical and Plant-Based Insecticides Against Household Insects

3.1.2. Housefly (Musca domestica)

Table (2) shows the effect of various treatments on houseflies. The results show that houseflies react faster with greater sensitivity than the cockroach. The combination treatment produced the highest mortality rate at all the time frames, followed by the chemical insecticide, which proved highly effective in just one hour of exposure.

The plant extracts also proved very effective, especially the peppermint oil and neem extracts, which proved highly lethal after some time. Houseflies were more sensitive to these treatments, producing higher mortality rates within less time.

Table 2 Mortality rate (%) of *Musca domestica* at different time intervals

Treatment	1 h	6 h	24 h	48 h
Control	0	1 ± 1	3 ± 1	3 ± 1
Neem	30 ± 2	60 ± 2	85 ± 2	87 ± 2
Garlic	25 ± 2	55 ± 3	80 ± 3	82 ± 2
Chili	20 ± 2	50 ± 2	75 ± 2	78 ± 2
Peppermint	35 ± 2	65 ± 2	88 ± 2	90 ± 2
Cypermethrin	85 ± 2	95 ± 1	98 ± 1	95 ± 1
Combined	90 ± 1	97 ± 1	99 ± 1	97 ± 1

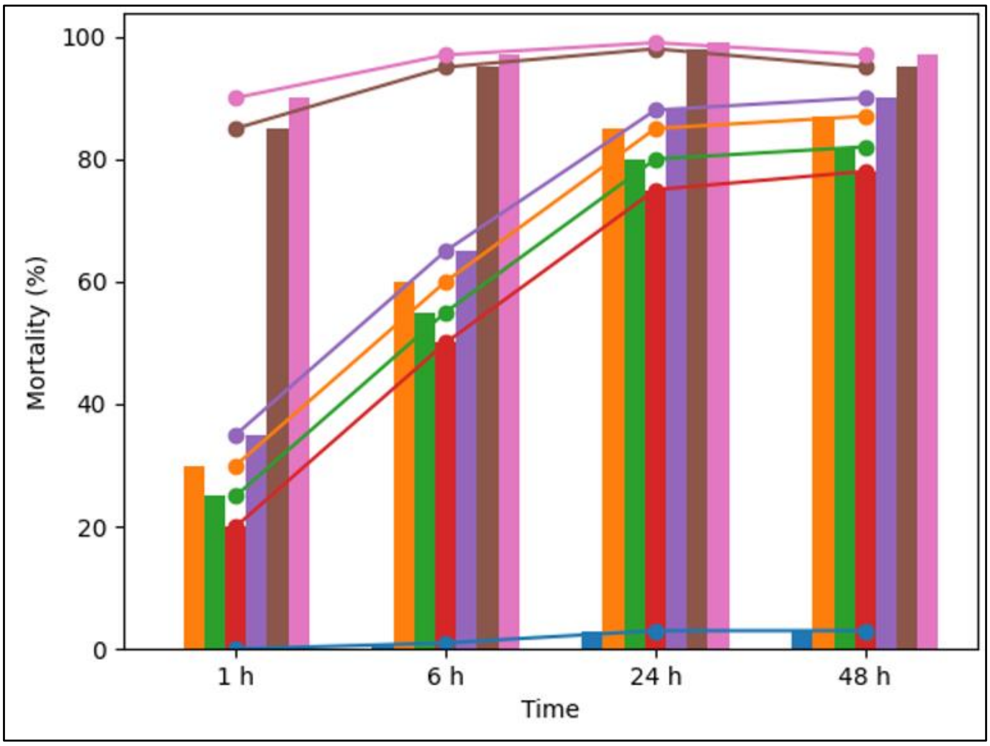

Figure 3 Comparative Time-Course Evaluation of Mortality Induced by Chemical and Plant-Based Insecticides Alone and in Synergistic Combination

3.1.3. Mosquito (Culex pipiens)

Table (3) displays the impact of treatments on mosquito mortality rate. The mosquito was the most vulnerable of all the species examined. The compound treatment had the highest mortality rates at all time durations compared to the other insecticides.

From the plant extracts, the peppermint oil had the highest efficacy, especially for shorter exposure periods. There is a notable enhancement in mortality rate with an increase in time.

Table 3 Mortality rate (%) of *Culex pipiens* at different time intervals

Treatment	1 h	6 h	24 h	48 h
Control	0	2 ± 1	4 ± 1	4 ± 1
Neem	35 ± 2	65 ± 3	82 ± 3	85 ± 2
Garlic	30 ± 2	60 ± 2	76 ± 2	80 ± 2
Chili	25 ± 2	55 ± 2	70 ± 3	73 ± 2
Peppermint	40 ± 2	70 ± 2	90 ± 2	92 ± 2
Cypermethrin	88 ± 2	96 ± 1	97 ± 1	95 ± 1
Combined	92 ± 1	98 ± 1	99 ± 1	97 ± 1

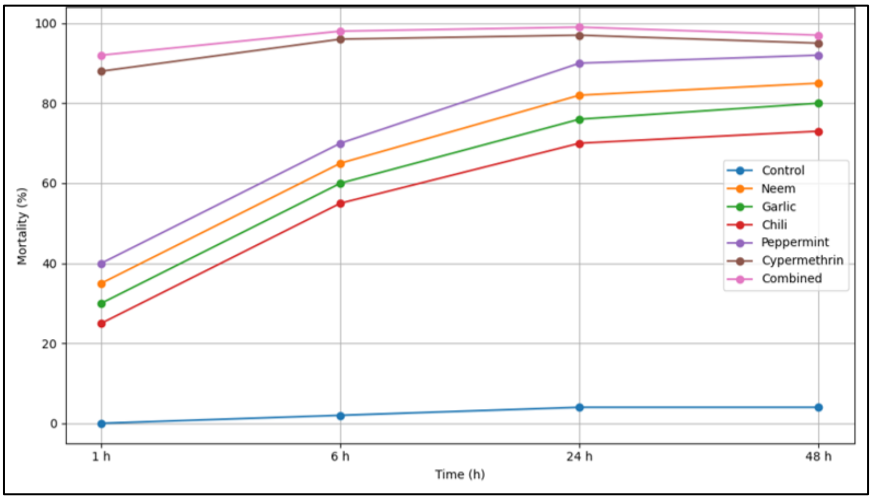

Figure 4 Time-course mortality (%) of different treatments

3.2. Knockdown Time (KT50)

Table (4) shows the knockdown time (KT50) for each treatment, which is defined as the time taken to incapacitate 50% of the insect population. The study shows considerable variations among the treatments in terms of effectiveness.

The joint application of plants and chemicals gave the shortest KT50, making it the most effective treatment in terms of speed of action, followed by the use of chemical insecticide (cypermethrin).

Among the plant extracts, the peppermint oil was the most rapid in action, while the chili extract was the least effective.

Table 4 Knockdown Time (KT50) of different treatments

Treatment	KT50 (min)
Neem	35 ± 2
Garlic	42 ± 3
Chili	50 ± 3
Peppermint	30 ± 2
Cypermethrin	10 ± 1
Combined	**8 ± 1**

3.3. Residual Effect (After 48 Hours)

Table (5) depicts the residual effectiveness of the different treatments after 48 hours of application. The residual effectiveness was found to be higher in the plant + chemical insecticide combination (90% to 95%) and in the chemical insecticide itself (Cypermethrin) (85% to 90%). It is clear from this observation that chemicals play a vital role in providing long-lasting insecticidal activity. On the other hand, plant-based pesticides demonstrated moderate residual efficiency, where the residual efficacy of peppermint oil was the highest among all, then came neem extract, garlic extract, and chilli extract. The lower residual activity of plant-based pesticides is explained by their faster degradation rate in the environment. To conclude, the outcomes indicate that mixing plants and chemicals improves the efficiency of pesticides.

Table 5 Residual Effect (%) after 48 hours

Treatment	**Effectiveness (%)**
Neem	60–65
Garlic	55–60
Chili	50–55
Peppermint	65–70
Cypermethrin	85–90
Combined	90–95

3.4. Effect of Variables

The statistical analysis revealed the following:

3.4.1. Effect of Insecticide Type

The combination of both plant and chemical as well as the chemical insecticide resulted in significantly high mortality than the plant alone ($P \leq 0.05$).

- Efficacy Against Insect Type

Mosquitoes proved to be the least resistant insects, followed by houseflies, while cockroaches were found to be relatively more resistant**.**

- Efficacy Over Time

Mortality gradually rose over time under all treatment conditions, suggesting that time is an important factor in insecticide efficacy**.**

- Interaction Effect of Independent Variables

Table 6 An interaction effect (Insect × Treatment × Time) was noted ($P \leq 0.05$)

Source of Variation	**F-value**	**P-value**
Insecticide Type	High	≤ 0.05
Insect Species	High	≤ 0.05
Time	High	≤ 0.05
Insect × Treatment	Significant	≤ 0.05
Treatment × Time	Significant	≤ 0.05
Insect × Treatment × Time	Significant	≤ 0.05

4. Discussion

It was evident from the findings in the current study that there were notable differences in the performance of plant extracts and chemical insecticides when dealing with insects in a house [10]. The increase in the mortality rate observed in the case of Cypermethrin is as a result of the neurotoxicity that this chemical causes [11].

The treatment combination of the plant along with the insecticide exhibited better effectiveness than any other combination [12]. It can be attributed to the synergic reaction between the biologically active compounds derived from the plant, such as azadirachtin, menthol, and allicin, along with the synthetic insecticide used [14]. The plant-derived insecticides had significant efficacy. Among those, peppermint oil was the most effective because of its high concentration of menthol, an effective repellent that is highly toxic[15]. Another insecticide derived from plants with significant efficacy is neem extract; this extract affects the reproductive capabilities of insects [16].

The variations in insect sensitivity were observed [17]. The mosquitoes turned out to be highly susceptible due to their small body size and cuticle thinness, while cockroaches displayed some level of tolerance owing to their thick cuticle and detoxification system [18]. The rise in mortality rate with time proves that time exposure is an important parameter in defining insecticidal efficacy, particularly for plants extracts because the contact time should be higher [19]. In summary, the findings show that the study agrees with other researches that plant insecticides are safe but less persistent and chemical insecticides are effective but harmful [20].

5. Conclusion

This research clearly shows that chemical insecticides (Cypermethrin) are highly efficacious and fast acting on domestic insects. Plant insecticides proved to be moderately efficacious and took more exposure periods before providing satisfactory outcomes. Combined use of both plant and chemical insecticides provided maximum efficiency, suggesting a potential synergy between the two insecticides. Additionally, the data suggests variation in sensitivity among different insect types, where mosquitoes are found to be highly susceptible while cockroaches are found to be more resistant. It is also clear from the findings that exposure period has a considerable impact on insect death; efficiency increases with an increase in exposure period.

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