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Research Article

Efficacy of Aqueous and Alcoholic Extracts of *Piper nigrum* against *Aphis gossypii* and Associated Pest Population Dynamics on Cucumber

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ABSTRACT

Cucumber (*Cucumis sativus* L.) cultivation is significantly threatened by various insect pests that reduce yield and quality. This study investigated the population dynamics of major cucumber pests during the spring season and evaluated the efficacy of black pepper (*Piper nigrum*) extracts against aphid nymphs under laboratory conditions. Monitoring of pest populations from March to May 2023 revealed fluctuating densities of whitefly nymphs (*Bemisia tabaci*), two-spotted spider mite nymphs (*Tetranychus urticae*), cotton leaf-worm larvae, and cotton aphid nymphs (*Aphis gossypii*). All pests exhibited peak densities early in the season, with the highest counts recorded between 1 to 8 March, and a gradual decline toward the end of the season (24 May). The maximum population densities observed were 79 whitefly nymphs, 80 spider mite nymphs, 10 leaf-worm punctures, and 78 aphid nymphs per leaf. A bioassay was conducted to assess the insecticidal potential of aqueous and alcoholic black pepper extracts against cotton aphid nymphs. Results indicated a concentration- and time-dependent increase in aphid mortality. At a 2 mg/L concentration, the highest mortality rates on day 7 were 18% (aqueous extract) and 29.83% (alcoholic extract), while the lowest mortality occurred on day 1 at 1 mg/L concentration (3.33% and 6.33%, respectively). The alcoholic extract was more effective than the aqueous form across all treatment levels. In conclusion, the findings highlight the temporal dynamics of key cucumber pests and demonstrate the promising potential of black pepper extracts, especially alcoholic formulations, as eco-friendly botanical insecticides for aphid management.

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Introduction

Cucumber (*Cucumis sativus* L.) is one of the most important vegetable crops due to its wide cultivation and significant economic value. It is believed that India and Africa are the original centers of origin for cucumber (Schaffer and Paris, 2016). Although the fruit is composed predominantly of water, cucumber possesses notable nutritional value and medicinal importance due to its content of calcium, potassium, proteins, carbohydrates, and vitamins C, B1, B2, and niacin (Javid et al., 2024).

In Iraq, cucumber is cultivated in open fields during the spring and autumn seasons, as well as in protected environments such as greenhouses. However, the crop is highly susceptible to various insect pests, including the

cotton leafworm (*Spodoptera littoralis*), whitefly (*Bemisia tabaci*), thrips species (*Thrips tabaci*, *T. palmi*), the two-spotted spider mite (*Tetranychus urticae*), the leaf miner (*Liriomyza sativae*), and several aphid species (*Aphis* spp.) (Flaih, 2014).

The cotton leafworm is among the most destructive pests affecting a wide range of agricultural crops. The larvae are polyphagous and cause significant economic damage by feeding on the lower (epidermal) surface of leaves. Under favorable conditions, *S. littoralis* can complete 4-6 generations annually (Ozcalici and Alaserhat, 2025).

The whitefly is a major pest with a host range exceeding 500 plant species, including vegetables, fruits, and ornamentals. It is prevalent throughout the year in both protected and open-field environments and is a key pest in tropical and subtropical regions across Asia, Africa, the Mediterranean, and parts of Europe (Idan et al., 2018). Whiteflies cause direct damage by feeding on phloem sap and indirect damage through honeydew secretion, which leads to leaf stickiness, sooty mold growth, impaired photosynthesis, and overall reduction in crop yield and quality. Moreover, *B. tabaci* is a vector of 128 plant viruses, resulting in symptoms such as leaf yellowing, defoliation, and stunted growth.

The cotton aphid is a polyphagous pest that infests both cultivated crops and ornamental plants (Ebert and Cartwright, 1997). It damages plants by extracting sap and is an efficient vector of numerous economically important plant viruses (Chan et al., 1991). Aphid infestation results in honeydew accumulation on leaf surfaces, which disrupts physiological functions such as photosynthesis, respiration, and transpiration, while also promoting the growth of sooty mold fungi (Nietupski et al., 2022). *A. gossypii* is particularly significant due to its broad host range, affecting crops like watermelon, cucumber, cotton, okra, sesame, sugar beet, asparagus, garlic, and maize (Imenes et al., 2002). It can reproduce asexually throughout the year; however, low temperatures can suppress its reproduction rate.

The two-spotted spider mite is another important pest, infesting a wide variety of crops and causing substantial reductions in yield and quality (Wilson, 1993).

Due to the adverse environmental and health effects associated with chemical pesticides, there is increasing interest in alternative pest control strategies, particularly those derived from plant-based sources. Many plants contain bioactive compounds with insecticidal properties, such as growth regulators, anti-feedants, repellents, or toxicants, making them suitable candidates for eco-friendly pest management (Rao et al., 2005; Souto et al., 2021).

Black pepper (*Piper nigrum*), one of the oldest cultivated spices originating from India, has been distributed globally (Daba et al., 2017). It contains a range of biologically active compounds, including piperyline, piperettine, essential oils, phenolic compounds, β-carotene, lauric acid, myristic acid, and piperine, many of which exhibit insecticidal and repellent activities (Aljoboory, 2017). Black pepper has shown high repellent activity against several insect pests (Ahmed et al., 2012).

The objective of this study, therefore, was to evaluate and identify insect pests infesting cucumber crops in Baghdad, Iraq, and to assess the toxicity of aqueous and alcoholic extracts of *P. nigrum* against the cotton aphid.

Materials and Methods

The experiment was conducted in a 500 m^2 greenhouse located at the Department of Plant Protection, College of Agricultural Engineering Sciences, University of Baghdad, during the spring season of 2023. Prior to planting, the greenhouse soil was prepared by plowing and the application of organic fertilizer. Five plots were established, each measuring 36 × 0.5 m, with 1 m spacing between plots and a 0.75 m buffer zone on each side. Cucumber seedlings (F1 hybrid "Al-Mustaqbal") were transplanted at 50 cm spacing between plants. No insecticides were applied, and plants were left to be naturally infested by pests.

The experiment was arranged in a randomized complete block design (RCBD) with three blocks. Five cucumber plants were randomly selected from each plot, and three leaves were collected from each plant weekly. Leaf samples were taken to the laboratory and examined under a dissecting microscope to count the larval or nymphal stages of insect pests.

Preparation of aqueous extract of black pepper

Fifty grams of black pepper powder were soaked in 300 ml of distilled water in a flask and stirred for 1 h. The mixture was then stored in a refrigerator for 24 h. Afterward, the extract was filtered through multiple layers of gauze, followed by filtration through Whatman No. 1 filter paper. The filtrate was lyophilized to obtain a dry powder, which was stored in a clean, dry container in the refrigerator until use (Riose et al., 1987).

Preparation of alcoholic extract of black pepper

Alcoholic extraction was carried out at the Central

Laboratory Unit, College of Agricultural Engineering Sciences, University of Baghdad. Dried black pepper fruits were purchased from local markets and ground using an electric grinder (JFSD-100 Pulverizer). A total of 20 g of the ground powder was subjected to Soxhlet extraction using 400 ml of 97% ethanol. The mixture was stirred for 30 min and then kept at room temperature for 24 h. It was subsequently filtered through multiple layers of gauze and again through Whatman No. 1 filter paper. The solvent was evaporated in an oven at 45°C. The resulting dry powder was stored in a clean, dry container in the refrigerator (Harborne, 1984).

Bioassay procedure

Three concentrations (1.0, 1.5, and 2.0 mg/L) of both aqueous and alcoholic extracts were prepared. Each treatment was replicated three times. For each replicate, three cucumber leaves naturally infested with aphids were placed in Petri dishes lined with moist filter paper. Leaves were sprayed with the respective extract concentrations using a hand sprayer held 15 cm above the surface. Control treatments were sprayed with distilled water. Before spraying, aphid nymphs on each leaf were counted. Petri dishes were maintained at 25°C and 65 ± 5% relative humidity. Each treatment was applied once, and aphid mortality was recorded at 24, 48, and 72 h post-treatment. Mortality percentages were corrected using Abbott's formula (Abbott, 1925):

$$\text{Correct percent of mortality} = \frac{T - C}{100 - C} \times 100$$

Where

T = Percentage mortality in the treatment

C = Percentage mortality in the control

Statistical Analysis

Data were analyzed using a completely randomized design in a factorial arrangement. Treatment means were compared using the Least Significant Difference test at the 0.05 significance level. Statistical analysis was performed using GenStat version 12.

Results and Discussion

Population density of cucumber pests during the spring season

Figure 1 illustrates the population density of cucumber pests during the spring season, where multiple pests were identified, including whitefly nymphs (*Bemisia tabaci*), two-spotted spider mite nymphs (*Tetranychus urticae*), cotton leaf-worm larvae, and cotton aphid nymphs (*Aphis gossypii*). The figure also shows that the density of all pests was highest at the beginning of the growing season and lowest at the end. It can be observed that pest densities varied throughout the cucumber growing season, with several peaks recorded.

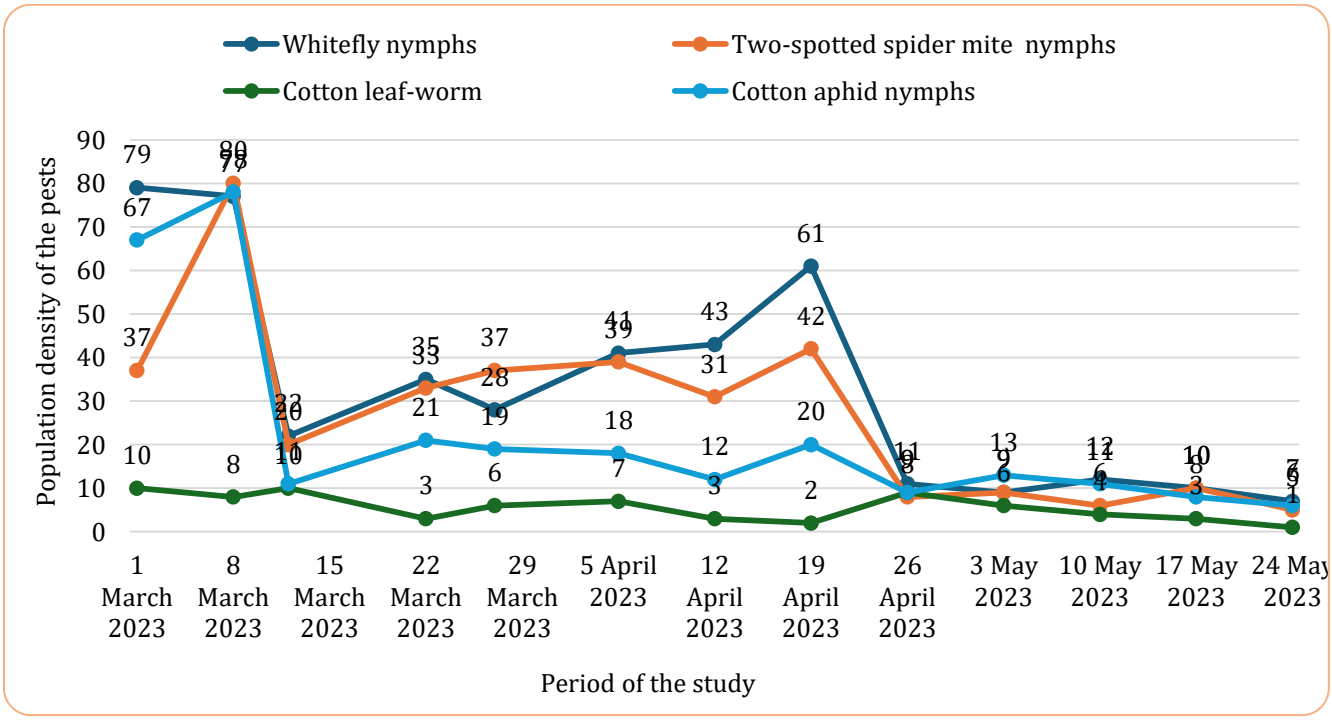


Figure 1. Population densities of the pests of cucumber crop.

The highest density of whitefly nymphs was 79 nymphs per leaf at the beginning of the season (1 March 2023), while the lowest was 7 nymphs per leaf at the end of the season (24 May 2023). The two-spotted mite showed a higher population density, reaching 80 mites per leaf on 8 March 2023, and the lowest was 5 mites per leaf on 24 May 2023.

The highest number of cotton leaf-worm punctures was recorded at 10 punctures per leaf on 1 March 2023, while the lowest was 2 punctures per leaf on 24 May 2023. Moreover, the highest population density of cotton aphids was recorded at 78 nymphs per leaf on 7 March 2023, whereas the lowest was 6 nymphs per leaf on 24 May 2023.

In Egypt, results showed significant differences in the weekly mean number of pests on the winter plantation of cucumber during the 2019 and 2020 seasons under greenhouse conditions. The study also indicated that whitefly was the most common pest found in cucumber plants during both seasons (Ammar et al., 2021). The population density of pests was also recorded on potato during two planting seasons (fall and spring) in Baghdad, Iraq, including black bean aphid (*A. fabae*), Egyptian cotton leafworm (*Spodoptera littoralis*), whitefly, and two-spotted mite (Kathiar et al., 2019).

Effect of alcoholic and aqueous extracts of black pepper on the mortality rate of aphid nymphs

The efficacy of aqueous and alcoholic extracts of black pepper on the mortality rate of aphid nymphs was evaluated on cucumber plants under laboratory conditions. The results (Table 1 and Table 2) revealed significant differences between the effects of different concentrations. Statistical analysis indicated significant differences based on both the concentration and the duration of treatment. The mortality rate of aphid nymphs increased with higher extract concentrations and longer exposure durations, indicating that the extract has a prolonged toxic effect, persisting for up to seven days.

Table 1. Effect of aqueous extract of black pepper on the mortality rate of aphid nymphs.

Treatments Concentrations (mg/L)	Mortality rate %				LSD
	1st day	2nd day	3rd day	7th day	
1	3.33	5	9	13	4.59*
1.5	4.33	7.33	13.33	17.33	5.62*
2	5.33	10.67	14.33	18	4.81*
LSD	2.38 NS	3.08*	3.15*	4.02*	--

* (P≤0.05)

Table 2. Effect of alcoholic extract of black pepper on the mortality rate of aphid nymphs.

Treatments Concentrations (mg/L)	Mortality rate %				LSD
	1st day	2nd day	3rd day	7th day	
1	6.33	9.47	17	21.8	10.08*
1.5	8.40	13	22.35	27	5.283*
2	7.20	12.20	22.33	29.83	8.37*
LSD	2.926 NS	4.07 NS	4.825*	5.963*	--

* (P≤0.05)

The highest mortality rates of aphid nymphs were 18% and 29.83% on the seventh day of the experiment at a 2 mg/L concentration for the aqueous and alcoholic extracts, respectively. In contrast, the lowest mortality rates were 3.33% and 6.33% on the first day after treatment with a 1 mg/L concentration for the aqueous and alcoholic extracts, respectively.

The results of the current study showed that both aqueous and alcoholic extracts of black pepper had significant effects on aphid mortality rates, with effectiveness increasing with concentration. This effect may be attributed to disruption of the insect nervous system, leading to poisoning and death (Muthr-Krishnan and Pushpalatha, 2001). The neurotoxic effect of black pepper extract is attributed to the presence of amides such as pyrolidine amide and piperine in high concentrations (Elliott et al., 1986).

Many studies have shown that secondary metabolites in plant extracts play a vital role in insect control, thus reducing the need for synthetic pesticides, which can

negatively impact the environment (Nisar et al., 2022; Fatma, 2023). The mortality percentage of adult rice weevils reached 100% at a 2.5% (w/w) concentration after 21 days of treatment with the etheric extract of *P. nigrum* (Hussein et al., 2017). Ethanol extracts of black pepper also had a significant effect on the mortality rate of adult *Tribolium castaneum* after 24 h of treatment, with mortality reaching 100% after 7 days at a 2% concentration (Ismail and El-Delimy, 2017).

Conclusion

The findings of this study demonstrate that the population densities of key cucumber pests, *B. tabaci*, *T. urticae*, cotton leaf-worm, and *A. gossypii,* were highest at the beginning of the spring growing season and progressively declined toward its end. This trend suggests that early-season monitoring and intervention are crucial for effective pest management. Furthermore, laboratory evaluation of black pepper extracts revealed that both aqueous and alcoholic formulations exhibit insecticidal activity against aphid nymphs, with the alcoholic extract showing significantly higher mortality rates. The mortality effect was positively correlated with both concentration and duration of exposure, indicating that black pepper extracts possess sustained bioactivity and could serve as potential alternatives to synthetic insecticides.

Recommendations

Based on the observed pest population trends, it is recommended to initiate pest surveillance and control measures early in the cucumber growing season to prevent significant crop damage. The integration of botanical insecticides such as black pepper extracts, particularly in alcoholic form, should be considered as part of an eco-friendly pest management strategy. Further field trials are recommended to validate the laboratory results under natural conditions and to optimize application methods and concentrations. Furthermore, promoting the use of botanical extracts could reduce reliance on chemical pesticides, supporting sustainable agriculture and reducing environmental risks.

Authors' Contributions

AAQ and SA designed the study; SK prepared the materials, collected and analyzed the data; IJD helped in disease scoring. AAQ and SD supervised the studies; AAQ and SK wrote the manuscript; All the authors proofread and approved the final manuscript.

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Conflict of Interest

The authors declare no conflict of interest.

Sustainable Development Goals Targeted

SDG 2: Zero Hunger
SDG 12: Responsible Consumption and Production
SDG 15: Life on Land

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