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Assessing the suppressive effects of mineral oil on aphid populations in a controlled environment

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Abstract
Experiments were carried out in a laboratory setting to examine how mineral oils affect the production rates of aphid nymphs. Five distinct mineral oils were evaluated at a concentration of 0.10ml/100ml, with each treatment and the control group having five replicates. The analysis focused on average reproduction rates and standard deviations. The findings reveal that treatments with mineral oils resulted in either an initial rise followed by a decline in nymph production or an overall reduction when compared to the control group. This research sheds light on the potential application of mineral oils for controlling aphids in agriculture, emphasizing the intricate effects these substances have on aphid reproduction. Additional studies are necessary to fully comprehend the mechanisms driving these changes and to refine mineral oil usage for effective pest management strategies.

Keywords: Mineral oil, aphid reproduction rate, integrated pest management

Introduction

Aphids are a major agricultural pest, notorious for their fast reproduction and the harm they inflict on crops. These tiny insects lead to significant crop yield reductions annually by directly damaging plants and transmitting destructive plant viruses (Yu *et al*., 2016, Venkateswarlu *et al*., 2016, Sridhar *et al*., 2020, Sridhar *et al*., 2021a) [17, 19, 23, 24]. Cereal crops, in particular, frequently fall victim to various aphid species, either one after another or at the same time, which greatly diminishes both the quality and quantity of the grain harvested (Luo *et al*., 2022, Sridhar *et al*., 2021b, Sridhar *et al*., 2022) [10, 17, 18]. To tackle this pressing agricultural issue, numerous control methods have been devised and examined. These methods include chemical control, the use of cultivars with single-gene-based antibiosis resistance, and more sustainable techniques like plant-mediated RNA interference (RNAi) and the integration of aphid-resistant wheat cultivars with agricultural management practices (Luo *et al*., 2022; Yu *et al*., 2016) [10, 24]. Nonetheless, developing effective and eco-friendly pest management strategies remains essential for mitigating aphid damage in agricultural ecosystems.

The earlier research primarily examines plant-based essential oils and other phytochemicals as insect repellents and pest management solutions, rather than focusing on mineral oils. Essential oils derived from plants and other secondary metabolites have been proven to exhibit antifeedant, insecticidal, and reproductive impacts on a variety of insect pests (Kanda *et al*., 2016; Regnault-Roger, 1997; Sharma., *et al* 2025) [6, 13, 15]. For instance, compounds like thymol, carvacrol, eugenol, and trans-anethole have shown toxicity towards pests that infest stored grains, while linalool has been identified as a feeding deterrent (Kanda *et al*., 2016) [6]. Phytoestrogens, which imitate reproductive hormones, are suggested to influence the fertility of vertebrate herbivores as a plant defence strategy (Hughes, 1988) [5]. Although plant-based compounds and essential oils are considered potential alternatives to synthetic pesticides, there is no evidence provided to support the claim that mineral oils affect insect reproduction. The study emphasizes phytochemicals and their varied mechanisms of action against insect pests, including toxicity, feeding deterrence, and effects on growth and reproduction (Koul, 2008; Regnault-Roger, 1997) [8, 13].

Numerous studies have explored how various factors impact aphid reproduction and feeding habits. For example, Gul *et al*. (2023) [3] investigated the sublethal impacts of flonicamid, a systemic insecticide, on the biological characteristics and feeding patterns of *Schizaphis graminum* (greenbug). Their research revealed that sublethal doses of flonicamid led to reduced lifespan, fertility, and essential demographic metrics in aphids (Gul *et al*., 2023) [3]. Furthermore, electrical penetration graph (EPG) recordings indicated that flonicamid shortened the duration of phloem sap consumption and simultaneous salivation in both parent and offspring generations of aphids. Regarding feeding behaviour, Ramírez and Niemeyer (2000) [12] showed that prior exposure to a host plant and physiological conditions (such as hunger) can influence aphid feeding behaviour. Their findings indicated that aphids previously exposed to wheat exhibited longer pathway activities and spent less time on mechanical stylet work compared to those with oat experience (Ramírez & Niemeyer, 2000) [12]. Although these studies do not specifically examine the effects of mineral oil on aphids, they underscore the significance of considering various factors that can affect aphid reproduction and feeding behaviour. Additional research focusing specifically on mineral oil is needed to ascertain its impact on these aspects of aphid biology.

Exploring the impact of different pest control methods can significantly contribute to developing more precise and sustainable strategies for managing aphids. Studies have demonstrated that integrated pest management (IPM) techniques, which encompass cultural, genetic, economic, and chemical controls, are successful in controlling soybean aphids (Hodgson *et al*., 2012) [4]. These methods not only safeguard crop yields but also postpone the development of genetic resistance to insecticides. Notably, the peach-potato aphid, *Myzus persicae*, has acquired resistance to a greater number of insecticides than any other herbivorous insect pest, emphasizing the necessity for alternative control measures (Ali *et al*., 2023) [1]. This resistance highlights the critical need for sustainable pest management strategies, such as biocontrol agents, entomopathogens, natural plant-derived substances, and cultural practices. Ultimately, there is an urgent need to transition to a comprehensive system approach for crop protection to tackle the growing economic and environmental challenges posed by agricultural pests (Lewis *et al*., 1997) [9]. This strategy focuses on maximizing the inherent preventive capabilities within ecosystems, with therapeutic measures acting as supplementary options. By combining various management tools, including host plant resistance, sampling methods, and the timely use of foliar insecticides, it is feasible to lower overall production costs, reduce adverse environmental impacts, and achieve more sustainable and effective pest control (Hodgson *et al*., 2012; Lewis *et al*., 1997) [4, 9].

Aphid reproduction and feeding behaviour are affected by several factors, including the quality of the host plant, the plant's developmental stage, and its anatomical features (Simon *et al*., 2017; Stadler *et al*., 1994) [16, 21]. For instance, aphids that feed on the shooting stage of high-quality plants tend to have elevated reproductive rates (Stadler *et al*., 1994) [21]. The feeding behaviour of aphids is shaped by the plant's physical and chemical characteristics, such as structural features like trichomes and its nutritional makeup (Nalam *et al*., 2021) [11]. The accessibility and quality of the phloem composition are crucial for aphid performance on particular plant locations. This study primarily aims to assess the effect of mineral oil on aphid reproduction rates and its antifeedant properties. We propose that mineral oil will decrease aphid reproduction rates and demonstrate notable antifeedant effects.

Methodology

1. Sample Collection

Aphid samples are gathered from several potato fields located across different areas of Himachal Pradesh. - This comprehensive collection ensures a representative sample of the aphid population in the region.

2. Expert Identification

The collected samples are identified by entomologists from two institutions: a) Central Potato Research Institute (CPRI), Shimla b) Dr. YS Parmar University of Horticulture and Forestry - This dual-expert approach guarantees accurate species identification and classification.

3. Subculture Maintenance

Experimental insects are maintained in subcultures within a controlled glasshouse environment. - Chinese cabbage plants are used as hosts for these subcultures. - This controlled setting provides stable conditions for ongoing research and experimentation. Parthenogenetic females are chosen for the experiment to prevent any potential issues. These females are identified by observing the developing nymph inside the aphid's abdomen under a microscope. They are then gently transferred into vials using a soft brush to avoid damaging their stylets. Their feeding behaviour is monitored, and any aphids that do not feed are promptly removed from the vials. Additionally, the impact of mineral oil on the aphid's antifeedant properties will be examined. A number of aphids are placed in vials, with triplicates for each concentration and a control group. On the day of result observation, nymphs are counted and removed, and the experiment continues until either aphid mortality is observed or the leaves completely dry out.

Selection of mineral oil

Five mineral oils were selected for the experiment with concentration 0.1ml/100ml

Results

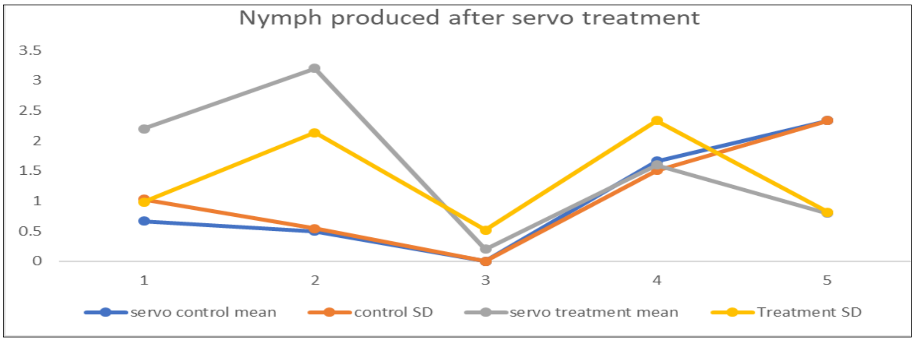
The process of planting Chinese cabbage in a glass house experiments begins with sowing seeds in pots and placing them in the controlled environment of the glass house. Over the course of several days, the seeds will germinate and grow into young plants under carefully maintained conditions (Figure A). These conditions include appropriate temperature, humidity, and light levels to ensure optimal growth. Once the Chinese cabbage plants reach a suitable size and stage of development, they will be ready for use in the experiments. This method of cultivation in a glass house provides a standardized and controlled setting, which is crucial for maintaining consistency in plant growth and minimizing external variables that could potentially influence the results of subsequent bioassay studies

Fig 1: Maintenance of aphid culture in controlled conditions

After the servo treatment was administered, a distinct pattern in nymph production was noted (graph 1): 1. Initial surge: Nymph production initially increased when compared to the control group following the servo treatment. 2. Subsequent decline: This initial rise was followed by a reduction in nymph production. 3. Control comparison: The reduction in nymph production resulted in levels falling below those of the untreated control group. This pattern indicates that the servo treatment initially stimulated nymph production, but later had a suppressive effect. Possible reasons for this occurrence might include: 1. A short-term stress response that boosts reproduction 2. Delayed adverse effects of the treatment on reproductive ability 3. Resource depletion due to the initial overproduction

Fig 2: Nymph production on leaf disc

Fig 3: Aphid mortality on leaf disc



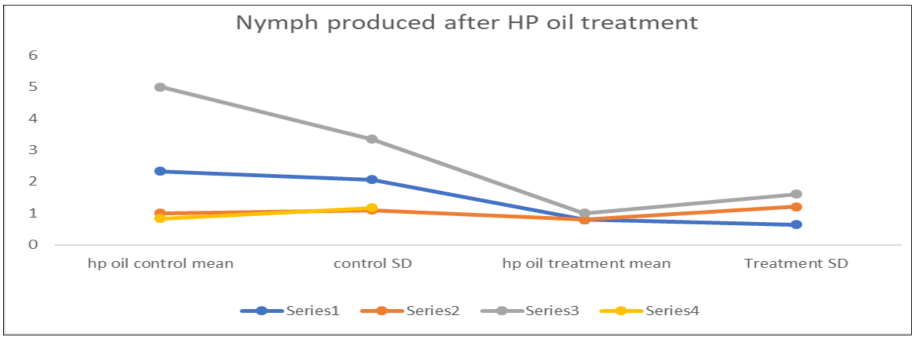
Graph 1: Details of nymph produced in servo treatment in comparison to control. (Mean±SD)

Statistical analysis was performed to evaluate the rates of nymph production in both treated and control groups (Graph 2). The findings highlighted several important points: 1. Temporal pattern: Following hp oil treatment, there was an initial rise in nymph production, which was later followed by a decline. 2. Consistent trend: Throughout the duration of the study, the group treated with hp oil consistently showed higher nymph production than the control group. 3. Longitudinal assessment: Nymph production was assessed at various time intervals to monitor changes throughout the study (Figure 4 and 5), providing a thorough understanding of the treatment's effects over time. 4. Significant change: A significant alteration in nymph production was noted after hp oil treatment, indicating a distinct impact of the treatment. 5. Visual representation: Graph 2 offers a comparison of nymph production rates between the treated and control groups, aiding in the interpretation of the results. 6. Sustained effect: The group treated with hp oil maintained elevated nymph production throughout the study, suggesting a lasting effect of the treatment. 7. Positive association:

A positive correlation was found between hp oil treatment and increased nymph production, suggesting a potential causal link. 8. Initial stimulation hypothesis: The initial rise in nymph production might be due to the stimulatory effects of hp oil, though further investigation is needed. 9. Future research directions: Additional studies are required to clarify the long-term effects of hp oil treatment on nymph production and to understand the underlying mechanisms. These findings offer valuable insights into the effects of hp oil treatment on nymph production, highlighting both immediate and lasting impacts. The results suggest a complex relationship between hp oil treatment and nymph production, with initial stimulation followed by a decrease. This complexity emphasizes the need for further research to fully comprehend the long-term implications and potential applications of hp oil treatment in managing nymph production.

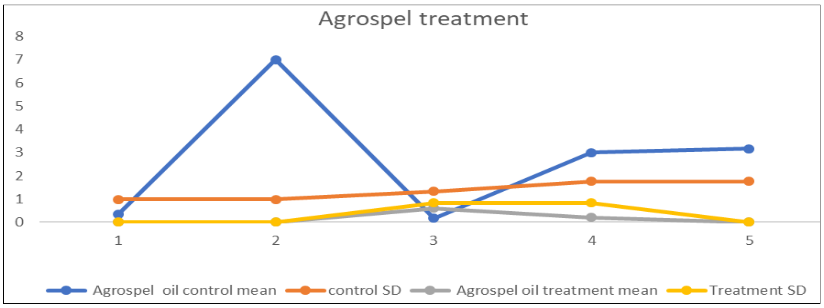
Fig 4: Nymph production on leaf disc

Fig 5: Aphid mortality on leaf disc



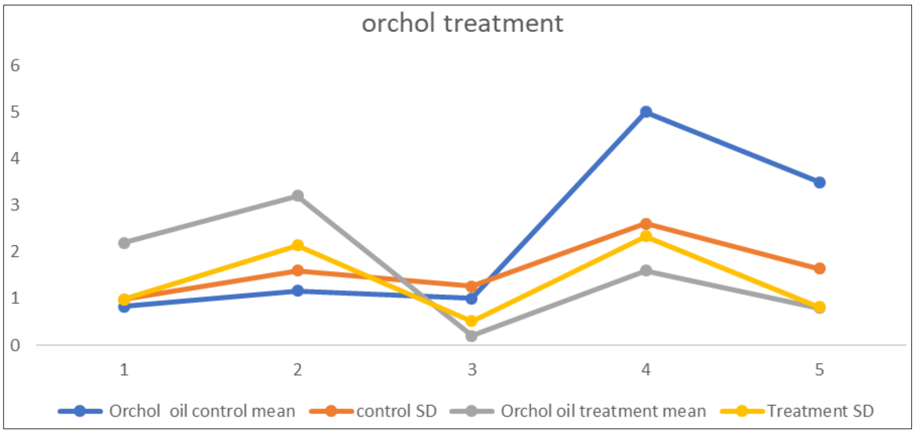
Graph 2: Details of nymph produced in hp oil treatment in comparison to control. (Mean±SD)

1. Nymph production: This term describes the quantity of young insects (nymphs) generated by adult insects. 2. Comparison to control: The control group consists of untreated subjects, providing a standard for comparison (graph3). 3. Decreased production: The treatment resulted in a reduction in the number of nymphs produced. 4. Potential implications: - Agrospel may influence insect reproduction or survival rates - The treatment might be effective in controlling insect populations - There could be effects on the insect's life cycle or development 5. Further analysis needed: - Measure the degree of the decrease - Determine if the reduction is statistically significant - Explore the mechanism by which Agrospel impacts nymph production - Evaluate potential long-term effects on insect populations and ecosystem balance This observation could be significant for pest management strategies, especially if the target insects are agricultural pests. However, it is crucial to consider potential ecological impacts and unintended consequences of reduced nymph production.



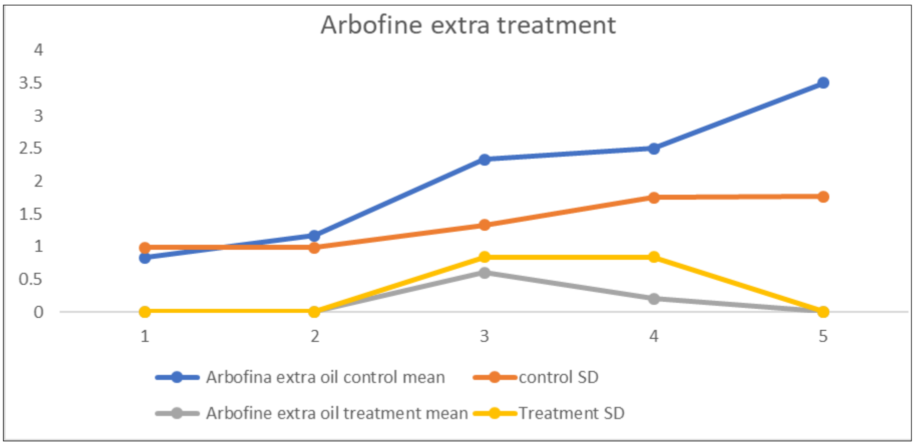
Graph 3: Details of nymph produced in Agrospel treatment in comparison to control. (Mean±SD)

The pattern of nymph production following orchol treatment initially rises and then falls when compared to the control group. This two-phase response indicates (Graph 4): 1. Initial stimulation: The treatment might have initially enhanced reproductive output. 2. Subsequent suppression: Extended exposure or delayed effects of orchol resulted in decreased nymph production. 3. Temporal dynamics: The treatment's influence on reproduction varies over time. 4. Potential mechanisms: - Hormonal disruption affecting reproductive cycles - Physiological stress responses - Alterations in adult insect behaviour or mating patterns.



Graph 4: Details of nymph produced in orchol treatment in comparison to control. (Mean±SD)

The decrease in nymph production of aphids after arbofine treatment compared to the control group indicates a significant impact of this treatment on aphid reproduction. Arbofine, appears to interfere with the aphids' reproductive processes. Key points to consider (graph 5): 1. Reproductive inhibition: Arbofine may disrupt hormonal pathways or physiological processes crucial for nymph production in aphids. 2. Comparison to control: The observed decrease is relative to untreated aphids, highlighting the specific effect of arbofine. 3. Potential mechanisms: Arbofine could affect aphid fecundity by: - Reducing overall fitness and energy available for reproduction - Interfering with egg development or embryogenesis - Disrupting mating behaviors or pheromone production 4. Implications for pest management: This effect suggests arbofine's potential as an effective aphid control method in agricultural settings. 5. Dose-dependency: The extent of decrease in nymph production may vary based on arbofine concentration or exposure duration. 6. Long-term effects: Consider whether the reduction in nymph production is temporary or persists over multiple generations. 7. Species-specificity: The effect may vary among different aphid species or populations. 8. Environmental factors: Interactions between arbofine treatment and environmental conditions (temperature, humidity) could influence the observed decrease. Further investigation into the precise mechanisms of arbofine's action and its broader ecological impacts would be valuable for understanding and optimizing its use in aphid control strategies.



Discussion

The primary aim of this study was to investigate the effects of various mineral oils on the nymph production of aphids. Our observations indicated that aphid nymph production initially increased and then decreased after treatment with mineral oils, or showed a total decrease compared to the control group. Several studies have investigated the effects of various substances on aphid reproduction and nymph production. For instance, neem seed extracts were found to significantly reduce the fecundity of *Aphis gossypii*. At high concentrations (1,410.0 mg/100 mL), the net reproductive rate dropped to 0 nymphs/female compared to 35.0 nymphs/female in the control group (Santos *et al*., 2004) [14]. Similarly, essential oil volatiles from *Tagetes minuta L.* (Mexican marigold) reduced aphid reproduction by up to 100% after 5 days of exposure, with the effect varying based on the quantity of oil used and the aphid species tested (Tomova *et al*., 2005) [22]. Interestingly, some studies have shown contradictory results regarding the effects of different substances on aphid reproduction. For example, while entomopathogenic fungi like *Lecanicillium attenuatum* CS625 reduced the total fecundity of cotton aphids (Kim, 2007) [7], endophytic colonization by fungi such as *Beauveria bassiana* and *Metarhizium brunneum* did not result in an overall decrease in aphid population, despite affecting the rate of nymph production (González-Mas *et al*., 2019) [2]. In conclusion, while the specific effects of mineral oils on aphid nymph production are not directly addressed in the provided context, various substances have been shown to impact aphid reproduction and nymph production. The effects can range from significant reductions in fecundity to more complex interactions that may not result in overall population decreases. Further research specifically focusing on mineral oils would be necessary to draw definitive conclusions about their impact on aphid nymph production.

Conclusion

The research uncovers notable changes in the patterns of nymph production among aphids exposed to mineral oils compared to those in the control group. Unlike earlier studies, the results indicate that mineral oils can have both stimulating and suppressing effects on aphid reproduction. These findings, backed by stringent experimental controls and statistical evaluations, offer important insights into the use of mineral oils for pest management and their potential effects on aphid populations. The dual impact of mineral oils on aphid reproduction highlights the necessity for careful consideration in pest control strategies. By comprehending these intricate interactions, agricultural professionals might develop more efficient and targeted methods to manage aphid populations in crop fields, which could lead to enhanced agricultural productivity and sustainability.

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