International Journal of Science and Research Archive
eISSN: 2582-8185
Cross Ref DOI: 10.30574/ijsra
Journal homepage: https://ijsra.net/

(RESEARCH ARTICLE)

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Neem's promise: The way to a sustainable future and eco-friendly biopesticides

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International Journal of Science and Research Archive, 2024, 11(02), 1073–1082

Publication history: Received on 22 February 2024; revised on 29 March 2024; accepted on 01 April 2024

Article DOI: https://doi.org/10.30574/ijsra.2024.11.2.0532

Abstract

Modern agriculture must include pest management since pests can seriously harm crops and lower yields, resulting in considerable financial losses. Conventional chemical insecticides have been used as the main method of pest management, but their detrimental effects on the environment and human health have inspired the quest for new environmentally friendly options. In this situation, *Azadirachta indica* showed promise as a sustainable and eco-friendly biopesticide. This research shows many aspects for *Azadirachta indica* as an environment friendly biopesticide. Neem is well known for having antiviral, antiseptic, and antifungal characteristics, which make it a crucial component in remedies for many illnesses, skin disorders, and mouth care. It is also beneficial to the environment. When added to the soil, its seeds and leaves help increase the fertility of the soil and structure. Additionally, the tree's large root system helps stop soil erosion. *Azadirachta indica*, is a great asset in the field of pest control and agricultural sustainability due to its repellent and antifeedant qualities. These characteristics are a result of neem's bioactive substances, known as Azadirachtin which has been the subject of in-depth study and use because of its function as a natural repellent and antifeedant Azadirachtin is a potent natural insect growth regulator because it interferes with beetle feeding, molting, and reproduction. Furthermore, the eco-friendliness of azadirachtin and its safety for people and non-target animals highlight its essential function in sustainable pest management techniques, aiding in the advancement of environmentally friendly and healthier agricultural systems. The neem plant is a unique botanical gem that has enormous medicinal, farming, and cultural significance. Its adaptability and environmental friendliness make it an important resource for sustainable agriculture and human well-being. Three commercialized neem-based formulations were tested aphid, *Myzus persicae*, including Azatrol, Triple Action Neem Oil (70% neem oil), and Pure Neem Oil (100% neem oil) in greenhouse and laboratory settings. A bioassay using a leaf disc choice test indicated that of the established neem-based insecticides tested were effective against the aphid at the recommended concentrations. However, a doubling in the quantity of Azatrol and Triple Action Neem Oil resulted in a 50% decrease in the number of aphids landing on handled leaf tissue compared to untreated leaf tissue.

Keywords: Aphid control; *Azadirachta indica*; Azadirachtin; Azatrol; Biopesticide; Neem; Pest Management; Sustainable agriculture

1. Introduction

Eco-friendly pesticides offer a sustainable substitute for traditional chemical pesticides, which represents a significant paradigm change in contemporary agriculture. These eco-friendly formulations successfully control crop pests while placing a high priority on the wellbeing of humans, beneficial creatures, and ecosystems. The creation and application of environmentally friendly pesticides is in line with the overarching objective of lessening agriculture's environmental impact. Eco-friendly insecticides' decreased effect on non-target species is one of its main advantages. They are made to particularly target pests that pose a hazard to crops while sparing helpful insects and animals (Copping 2000). This methodical technique preserves the equilibrium and biodiversity of agricultural environments.

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Additionally, farmers are encouraged to use a comprehensive approach to pest control by encouraging the use of IPM (integrated pest management) techniques combined with environmentally benign insecticides. The need for chemical treatments is further diminished by integrating other strategies including the rotation of crops, bio controls, and habitat restoration. Sustainable farming methods, protecting human health, protecting the planet's sensitive ecosystems are all made possible by eco-friendly pesticides. These greener options will surely be crucial to the coming generations of agriculture as the desire for more ethical and environmentally friendly farming methods increases (Choudary 2011).

Environment friendly pesticides frequently include naturally occurring ingredients like the oil of Neem, diatomaceous earth, or advantageous nematodes. These bio-based treatments minimize environmental damage and lessen the chance that soil and water may become contaminated by pesticide residues. They breakdown more quickly, which reduces their environmental permanence (Devi 2023).

Azadirachta indica, the scientific name for the neem plant, is a unique tree that grown all over the world. It is a tree that can withstand drafts and grows well in sub-humid to sub-arid environments with an average annual precipitation of 400–800 mm. It consists of over 200 allelochemicals, which are present in different areas of the plant in varying amounts and have a range of pesticidal activities (Unsal 2019) .

The primary active component of the oil found in this tree's seeds, azadirachtin, accounts for 40% of the oil's composition and is primarily what gives neem its insecticidal properties. Additionally, the seed cake produced during neem oil manufacturing is an essential natural fertilizer utilized in standard agricultural methods. Neem leaves have also been used for ages because of their repelling qualities to combat pests that attack stored grains. The strong therapeutic qualities found in the Neem tree are among its best-known features (Cahill 2017). Since ancient times, the leaves, flowers, seeds, bark, and its oil have all been utilized in traditional medicine.

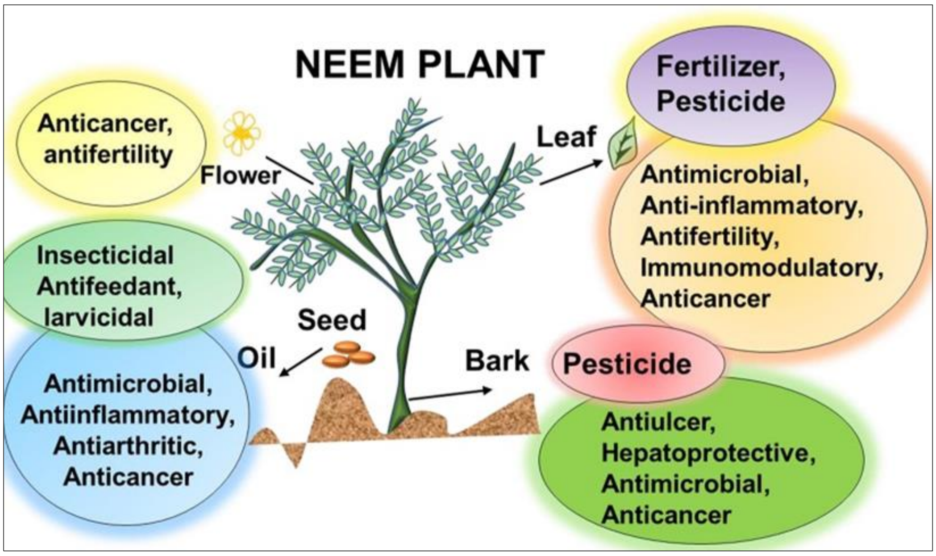

Figure 1 Schematic representation of *Azadirachta indica*

Neem leaf, bark, seed, and oil include active ingredients that have anti-inflammatory, antibacterial, cancer-preventing, hepatoprotective, anti-arthritic, and immune-modulating activities. Additionally, oil derived from neem seeds, bark, and leaves has insecticidal effects and is frequently used as a chemical pesticides, herbicide, fungicide, and weedicide. (A 2012) Neem leaves can also be utilized as a bio fertilizer because they can increase the vermicompost's yield.

1.1. Neem's Bioactive Components

Numerous bioactive substances with pesticidal activity can be found in neem that are very crucial for pest control and agriculture.

1.1.1. Azadirachtin

Azadirachtin, a bioactive substance present in neem, affects the life cycles of several pests in an efficient manner because of its intricate and diversified mechanism of action. It contains tetra nortriterpenoid limonoid with pesticidal and repulsive qualities. Azadirone and a C-ring opening are the first steps in the biosynthesis of triterpenoids which leads to the creation of azadirachtin. The active components in neem plant-based bio insecticides include azadirachtin and other related triterpenoids like azadirachtin B, salannin, and nimbin (A.J.Mordue 1993).

A strategy of action Azadirachtin shares structural similarities with "ecdysones," the insect hormones that cause metamorphosis. The brain inputs from the sensory detectors of the insects, such as the receptors for taste in the mouthparts, tarsi, and oral cavity, are necessary for the feeding behavior of insects. These sensors incorporate a "sensory code" that is transmitted to the brain. Azadirachtin causes antifeedancy to manifest by activating inhibitory cells in these chemical receptors and by inhibiting the stimulus of eating in insects by activating "sugar" receptor cells (Morgan 2009).

These compounds work by preventing insects from growing and developing as well as by preventing them from feeding. It inhibits molting, which prevents insects from losing their exoskeletons and moving on to the following developmental stage. This slowdown in growth ultimately lowers the number of pests (Biswas 2002). It serves as a potent antifeedant, deterring pests from devouring tissues from plants treated with azadirachtin. Pests' capacity to develop and reproduce is hampered since they consume less food. Azadirachtin interferes with reproduction by lowering the fecundity and fertility of pests. Further decreasing pest populations, it prevents egg-laying and hinders the growth of viable offspring.

1.1.2. Nimbolide

Nimbolide B and nimbic acid B are the primary components of neem, which exhibit herbicidal action. In a study, they were found to have allelopathic and phytotoxic effects by preventing the development of the lettuce, crabgrass, and Alfalfa, wild rice, and barnyard grass (Kato-Noguchi 2014). With an increase in active chemical concentration, the allelopathic activity rose, however the severity varied depending on the weed species.

1.1.3. Salannin

Neem contains salannin, an active ingredient that has insect growth-regulating and antifeedant properties. Salannin prevents eating, lengthens the larval stage, and delays molting. This produces lower pupal weight, which promotes larval and pupal death (Chattopadhyay 2002). Salannin promoted prolonged molting and nymphal death in early research on *Oxya fuscovittata*, demonstrating this.

1.2. Neem's Bio-Pesticidal Properties

The repelling properties of neem are extremely useful in insect control. It prevents insects from landing on treated plants, minimizing infestations and damage. This practice helps safeguard crops against a variety of pests, such as Aphids, mites, and caterpillars, as well as the growth of plant diseases that are frequently conveyed by these insects.

1.2.1. Bio-Pesticidal Properties of Neem Oil

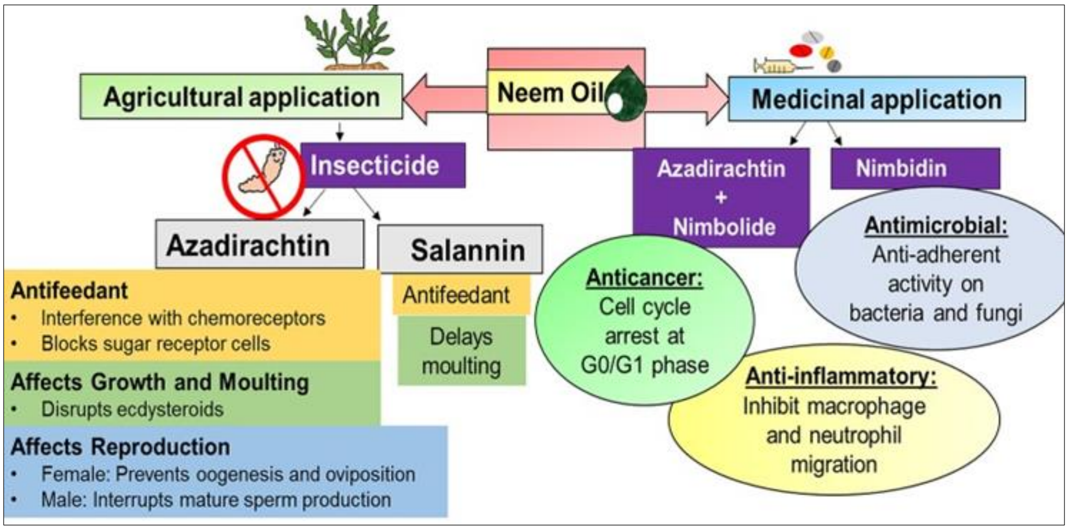

Figure 2 Uses of neem oil in agriculture and medicine

Neem oil, which is obtained by cold-pressing the plant's seed kernels, is very powerful against mites and soft-bodied insects. Neem oil's bioactivity is mostly attributed to the disulfide content. Although neem oil includes a variety of azadirachtin analogs, azadirachtin is primarily responsible for the insecticidal activity (Dua 2009). Nimbin, salannin, and related compounds are among the surviving triterpenoids, but they don't do much to increase effectiveness. Neem oil is interestingly non-toxic to mammals, birds, and fish, and because it has several modes of action for insects, it has lower chances of developing resistance (Isman 2006). Neem seed oil is used in numerous formulations that have ovicidal, larvicidal, growth regulating, and repelling properties.

1.2.2. Bio-Pesticidal Properties of Neem’s Leaf

Vermicompost made from neem leaves has fertilizing and pest-controlling qualities. Neem-fed vermireactors allow earthworms to develop and reproduce more quickly by adding neem leaves when vermicomposting with them. They can increase the yield by turning 7% of the meal into vermicompost each day. However, it is vital to take into account the intense nematicidal properties of neem, which might have a negative impact on annelids, when employing neem-fed vermireactors. It extends the lifespan of Mung bean grain by effectively preventing the pulse beetle, *Callosobruchus chinensis* (Grainge 1986). Neem leaf dust and boiler ash were recently found to considerably increase the capability of plants against infestation, demonstrating the effectiveness of neem leaves as an antifeedant and repellant.

1.2.3. Bio-Pesticidal Properties of Neem’s Bark

Since neem bark's pesticidal performance is lower than that of the neem tree's other parts, such as neem seed and leaves, in controlling insect pests, its usage as a bio-insecticide is restricted. However, it is known to have phytotoxic properties when added to soil to control pests, as was shown in a study where the bark and leaves of Neem inhibited the germination and growth of a variety of crops, including weeds and oats, carrots, beans, rice, radish, as well as sesame.

Neem-based products represent little to no harm to human health compared to chemical pesticides (Xuan 2004). They provide a safer alternative for pest management because they are harmless to humans and animals.

1.3. Remarkable Benefits of Neem as Eco-Friendly Pesticide

In contrast to chemical pesticides, neem-based remedies don't have any negative health effects. They are a sustainable option for pest management because they are also biodegradable and safe for the environment. Neem's specific mechanism of action and natural origin interrupt pests' biology without injuring unintended targets, protecting both humans and the ecology. This characteristic not only encourages safer working conditions for farmers but also protects helpful insects and wildlife, fostering more healthy and balanced agricultural ecology. A comprehensive method for pest control is provided by neem pesticides. They successfully combat a variety of pests, including as creatures such as insects, mites, and nematodes (Senthil-Nathan 2013). They offer thorough and dependable protection for crops by preventing pest growth and reproduction.

Pesticides made from neem have a negligible effect on the environment. They assist sustain a balanced ecosystem because they don't affect non-target species. Neem insecticides also don't leave any hazardous compounds in the ground or water, protecting the environment from long-term harm. Regular application of chemical insecticides frequently causes pest resistance. Neem-based pesticides work differently, altering the biology of pests in a way that lessens the possibility of resistance forming. This increases the pest management industry's long-term viability. Neem includes substances that improve soil. Neem has the added advantage of improving the fertility of the soil and microbial activity when applied as a pesticide (Ignacimuthu 2003). In addition to promoting plant development, this also strengthens the general heath of the agricultural ecosystem, which supports sustainable agriculture.

Pesticides made from neem do more than just keep pests away from crops. By promoting plant development, they increase crop yields. Farmers win from this dual function since it boosts their profitability and lessens their dependency on artificial fertilizers.

Pesticides made from neem offer enduring protection from vermin. Producers need fewer applications due to their capacity to repel and disrupt the life cycles of pests, which lowers the overall cost and labor of pest management. Application of neem-based pesticides has the potential to fundamentally alter rural communities (Verma 2015).

Neem tree farming and neem-based product manufacturing provide small-scale farmers with financial opportunities and support social and economic welfare in rural areas.

Neem provides a potent substitute for chemical insecticides, minimizing the need for these dangerous poisons. The switch to neem-based remedies is in line with the increasing global emphasis on lowering the use of chemicals in agriculture.

Pesticides made from neem have proven to improve crops' resistance to environmental stressors including drought and harsh weather (Gupta 2010). In light of the increasing difficulties that climate change presents for agriculture, this trait is particularly important. Neem insecticides support the maintenance of diversification in agro ecosystems by safeguarding beneficial insects.

1.4. Comparison of Chemical and Bio pesticides Based on Azadirachtin for Crop Protection

Azadirachtin is well known for its a variety of pests, including mites, caterpillars, and aphids. The complicated mode of action of Azadirachtin makes it harder for pests to build resistance, resulting in more effective and long-lasting pest control.

Chemical insecticides can provide quick and frequently effective pest control. However, based on the active component and the insect being targeted, its efficacy can vary. Chemical pesticides can become less effective over time, which calls for the creation of new formulations and substances (Buneri 2019). Multiple method of action, which interferes with insect molting, reproduction, and feeding

Azadirachtin has little effect on beneficial insects and non-target species, protecting biodiversity and the stability of ecosystems. It degrades more quickly in the environment, which lowers the possibility of soil and water contamination.

Chemical pesticides have the potential to harm non-target species, such as insects that are beneficial, pollinators, and wildlife, upsetting the ecosystems' delicate balance (Acharya 2017). A lot of chemical pesticides leave behind residues in the soil and water, and some of them linger there for a very long time, causing long-term environmental problems.

Azadirachtin is often not hazardous to people or animals. It is a less dangerous choice with regard to of human health because it provides little threat to farmworkers and customers. Due to hazardous remnants and exposure to pesticide drift, chemical pesticides can offer serious health concerns to farmworkers, communities close to agricultural areas, and consumers (Šunjka 2022). Azadirachtin is appropriate with a wide range of crops, including fruits, vegetables, and decorative plants. It is adaptable to many farming systems. Bio pesticides based on azadirachtin have demonstrated advantages in enhancing plant health and lowering the occurrence of specific plant diseases.

Chemical pesticides may require specialized formulations and administration techniques catered to various agricultural products that can be less adaptable. Specially, in the case of food crops, residual chemical pesticides might compromise crop quality and safety. Synthetic pesticide use has caused environmental problems, pest resistance, and poisoning to non-target creatures (Devip 2010).

It is essential to apply alternate methods because these manufactured pesticides have occasionally led to both acute and long-term poisoning in farmworkers, applicators, and even customers. Applying botanical pesticides, which are the most effective way to replace the widespread use of synthetic pesticides, is one of the important alternative tactics. Among them, plant-based biopesticides that control insects by utilizing plant oils and extracts have proven to be the most effective. These natural pesticides can be utilized as pesticides, chemical fumigants manures, urea coating agents, or soil conditioners, which helps increase agricultural productivity. Aphid, (*Myzus persicae*), one of the most significant polyphagous pests with a spread that spans across the globe (Zilberman 1991).

1.5. Various Neem-Based Biopesticide Applications

1.5.1. Management of the Rice leaf folder

Numerous substances with various chemical compositions and modes of action are categorized as insecticide of botanical origin. The major biologically active element of the complex limnoid neem plant is azadirachtin. The insect known as the rice leaf folder attacks rice (*Oryza sativa*). It has been demonstrated that insecticides made from neem and containing azadirachtin are crucial for crop protection. Azadirachtin has been tested alongside five other limnoids, and compared to the other limnoids, it has shown to be more successful against rice leaf folder. Azadirachtin has a strong antifeedant effect.

Neem greatly slowed these bugs' growth when it was introduced to their meal. (Huang 2004) It has been demonstrated that treating neem limnoids has a significant impact on the development and growth in *Cnaphalocrocis medinalis* larvae.

1.5.2. Root-Knot Nematode Management

Root-knot nematodes, or *Meloidogyne spp*., are the most significant nematode pest in both the tropical and subtropical regions of crop production. Nematodes, which are obligatory parasites of more than 2000 plant species, are having an impact on herbaceous and wood trees of mono and dicotyledons. The most common pathogens that harm field crops, vegetables, and fruit trees are *Hymenopellis incognita* and *Meloidogyne javanica*. Neem compounds, both raw and refined, have been tried against these nematodes. The unrefined form of neem is azadirachtin, whereas the crude form is a combination of leaves and oil cake. It has been researched that using these two formulations as nematicides decreases the quantity of eggs and egg bulk (Javed 2007). Azadirachtin 0.1% w/w treatment lessens the invasion of young nematodes. Azadirachtin has been shown to exhibit nematicide properties.

1.5.3. Plutella xylostella Management

Cabbage represents one of the world's most significant vegetable crops. One of the most significant insect pests of cabbage and various other significant Brassicae plants is *Plutella xylostella L*. The primary problem with long-term use of dangerous insecticides and the emergence of pests that are resistant to pesticides. Additionally, the usage of these synthetic pesticides is linked to adverse health effects and environmental concerns. Neem-based pesticides, however, have the potential to aid in the control of a plant pest. Insects seldom develop resistance to neem-based pesticides, and they are not hazardous to people.

1.5.4. Pine Species Management

Species of pine trees, spruce, fir, and cedar belong to the conifer family, which is highly sensitive to azadirachtin. Azadirachtin can make conifers phototoxic when exposed to sunshine. Leaf damage, chlorosis (leaf yellowing), and decreased growth are possible effects. The substance has the potential to interfere with photosynthesis, which would reduce the health and vitality of the tree as a whole.

In terms of pest control, azadirachtin's photosensitivity on conifers is a useful characteristic. When applied as a natural insecticide, azadirachtin can kill a variety of insects that harm conifers, including pests such as mites in particular and certain beetles. The pest populations are controlled by the light-sensitive effects on the pests, protecting the fir trees. On the other hand, it is essential to use azadirachtin-based products during times of reduced sunshine, such as over cloudy days or in the evening, to avoid unintended damage to conifers (McGinley 2003). With careful application, the conifer's health is preserved and any potential harm from photosensitivity is minimized.

2. Materials and Method

In the study, apterous species which were originally taken from a maintained culture were used to generate a population of aphids (*Myzus persicae*). The study of the biology and behavior of aphids was built on the initial population.

The aphids were kept on immature cabbage plants that were grown in plastic containers with potting soil inside that had a 16 cm diameter. These plants were tenderly cared for in a controlled greenhouse environment with a temperature of 25.3°C. In order to mirror the natural light cycle, a period of time of sixteen hours of daylight and eight hours of night (16:8 L:D) was also devised. The environment needed to support the aphids' growth and reproduction needed to meet these requirements.

The colony was developed inside cages to safeguard the aphids' health and to provide for their nutritional requirements. These cages had a hardwood frame that measured 60x60 by 100 cm as were covered in fine mesh above and on all sides. This layout allowed for optimum air flow and light penetration while preventing the aphids from fleeing. As additional cabbage plants were required, a consistent supply was given to the colony to support it and ensure that it continued to flourish.

The cabbage plant itself were created from seeds that underwent a three-day pre-germination process in glass Petri dishes with a 9 x 1.5 cm measurement. To generate a humid atmosphere ideal for germination, damp filter paper was used to coat the bottom of each of these plates. After the seeds germinated, 50 seedlings per tray were transferred onto plastic seedling trays that were 50 x 30 x 0.6 cm in size. Commercial potting soil was included in these trays to provide the young plants with a proper growing substrate.

The seedlings were cared for a further 10 days in a greenhouse after this initial growth period. The young plants were individually moved into wider plastic pots having a circumference of 16 cm and soil filling once they had developed their first set of leaves. These pots gave the plants plenty of room to grow and thrive. A constant temperature of 25 3°C was constantly monitored and maintained in the greenhouse. Additional grow lamps were employed to create a period of sunlight of sixteen hours of daylight and eight hours of darkness to augment the natural lighting conditions.

Another important aspect of the care given to these pepper plants was nutrition. They received regular fertilization using a water-soluble fertilizer with the balanced nutrient ratio 20-9-20 (N:P:K). The plants were guaranteed to acquire the essential nutrients for healthy growth thanks to this regular fertilization schedule. In order to promote the plants' overall health and maintain the right soil moisture levels, the plants were additionally irrigated as required.

2.1. Insecticides Based on Neem

Azatrol (1.2% azadirachtin), Impact Neem Oils (70% neem oil), and Absolute Neem Oils (100% neem oil) were three commercially accessible neem formulations that were employed.

To test the formulations' effects on *M. persicae* aphids, the suggested application concentrations for Azatrol, Three Action Neem Oil, and Pure Neem Oil were 31.5 ml/l, 7.5 ml/l, and 7.5 ml/l, respectively.

Three pesticides with neem bases were tested during in order to determine which ones were the most repellant. Products made from neem are well known for their ability to naturally repel insects and are frequently used in pest control. The goal of the study was to determine how well these neem-based pesticides worked in controlled environments to ward off aphid (*M. persicae*).

2.2. Experimental Bioassays

Researchers chose young leaves from non-infested plants that were the same maturity for the experiment. To ensure uniformity, these leaves were selected from the upper part of the plants. Then, one minute was spent dipping each of these chosen leaves into an extract of the neem-based solutions. These neem-based solutions' concentrations were generated at the levels that were stipulated in the experimental design.

For contrast, control leaves underwent slightly different treatment than those plants. These controls leaves were treated similarly to non-repellent treatments by being submerged in tap water rather than neem-based solutions.

After 15 minutes of air drying at room temperature, those with treatment as well as the control leaves were compared. The leaves were not extremely moist as aphids were introduced thanks to this drying interval, as too much moisture might have affected aphid behavior.

Each experimental and control leaf was separately placed within a plastic container with dimensions of 25 centimeters in size and 10 cm in height for the subsequent bioassays. To retain humidity and stop the leaves from drying out too quickly, damp tissue was used to coat a bottom of these pots. Then, secure lids were placed on the containers.

In this experiment, a test with multiple choices and two-choice examination were both used as bioassays.

The bottom of the container was split into four equal halves for the multiple-choice bioassay. One a leaf, which had been assigned at random to either the control or neem-based treatment, filled each of these spaces. Each leaf's lower surface, or abaxial surface, which is where aphids feed most frequently, was placed facing up inside the container. Aphid dispersal across the treatment and control leaves was made possible by this setup.

Two leaves were treated with the neem-based products and two leaves were left untreated as controls in the two-choice test paradigm. Within the container, the placement of the treated and untreated leaves was randomly distributed.

A synchronized aphid colony's 50 instar green peach aphid were randomly selected for use in both types of studies. Using a soft toothbrush, tiny aphids were softly released in the middle of each container. The aphids were put in to the containers and let to acclimate naturally over 24 hours.

Researchers were able to count and count the quantity of aphids on the handled and untreated leaves over the 24-hour exposure period. The distribution of aphids on leaves served as a proxy for the insects' preference or aversion, and this information shed light on the repellent properties of neem-based products.

To confirm the accuracy of the results, each exam (both the multiple-choice and the two-choice versions) was reproduced ten times. The experimental design was made more robust by replicating every procedure (neem-based products or control) three times.

All bioassays were conducted in a temperature-controlled environment with a constant temperature of 25°C, which is favorable for the green peach aphids' optimal performance. Additionally, a period of daylight of sixteen hours (L) and eight hours of darkness (D), which mimics a typical day-night cycle, was used for the tests.

2.3. Applications to the Entire Plant's Foliar

Young cabbage plants at the fourth true leaf stage were treated with mixtures comprising one of the neem formulations until runoff before the aphid release. Using a hand-held sprayer at the advised application. Only water was given to the control plants. Plants that had been sprayed were given two hours to dry outside in the shade. In a greenhouse set to 25°C and a 14:10 (L:D) h photoperiod, eight plants for each treatment were individually planted in a cage (60 x 60 x 60 cm) covered with a sheet from all sides and above.

Groups of 20 identically aged apterous adults (24 days old) were transplanted to the upper part of every treated and control plant, where they were free to forage and lay eggs. The medications were applied once more seven days after the aphid infestation. Live adult and offspring count per plant were at seven and fourteen days after application, respectively.

3. Results and Discussion

Young leaves from cabbage plants were offered to aphids by two types of experiment, either treated or untreated with each of three commercially available neem-based products.

There was no discernible difference between handled and untreated seedlings in the tests' propensity for settling. The settling tendency on the control vegetation with each of the three foliage treatments did not differ in the multiple-choice tests carried out with the approved neem concentrations. However, double the recommended field concentration of each neem-derived biopesticide resulted in considerably varied amounts of settling (repellency). In comparison to untreated plants, Triple Action Neem Oil and Azatrol recorded the fewest aphids after 24 hours of exposure, at 14 ml/l and 62 ml/l, respectively. As a result, even though several kinds of neem treatments showed the potential to be repellent, they were ineffective when used at the suggested dosages. Commercially available neem products showed some potential anti-aphid feeding effects, although to varying degrees.

Neem-based pesticides seem to provide an appealing option in pests' management systems given the concerns that synthetic biocides pose to human health and the environment. Since neem-based pesticides have no lasting effects on agricultural output, they are the perfect choice for pest management in a world where people are choosing green technologies. It has been proven through the current investigation that neem bio-pesticide are systematic and provide plants with long-term insect protection.

4. Conclusion

Neem-based pest control is extremely eco-friendly and sustainable due to its repellant and antifeedant characteristics. Neem and its preparations have demonstrated high efficiency against several harmful bacteria with regard to plant diseases. This mostly includes bacteria and fungus. Neem extracts have also been demonstrated to be effective in treating a number of other plant examination to determine the plant's value in combating phytopathogenic pests and microorganisms given the numerous studies on the biological effects of neem and its derivatives in plant control of diseases and pests. In addition to its potential as a biocide, neem also holds exciting promise for use in industries, medicine, and the environment

The purpose of this laboratory test was to systematically assess how well three neem-based insecticides repelled green peach aphids. The study's strict and controlled approach made sure that the findings were accurate and repeatable, illuminating the possible applications of these neem-based solutions in the control of aphid pests.

The National Farmer Policy of 2007 actively encouraged the development of biopesticides as a means of boosting agricultural output and maintaining both farmer and environmental health.

Additionally, it states that biopesticides will receive the same funding and promotion as chemical pesticides. Priority should be given to biological pest control method development and research, as well as education of the general public and agriculturalists in particular regarding the handling and application for these prevention measures. All of this will help people comprehend the advantages of biopesticides as a green alternative. IPM, INM, ICM, and GAP are needed today, nonetheless, and by putting them into practice, one may ensure a high level of life and health.

Compliance with ethical standards

Disclosure of conflict of interest

The authors declare no conflicts of interest regarding the publication of this paper.

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