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Using Natural Enemies to Control Greenhouse Pests

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Abstract: Biological pest control, often known as biological pest control or biocontrol, is a sustainable and ecologically friendly method of pest management in agriculture. It entails using living organisms including predators, parasitoids and diseases to control pest populations and reduce agricultural loss. In this research study, the researcher used certain natural enemies (ladybirds, lacewings and trichogramma evanescens) to test their effects on protecting tomato and cucumber crops in greenhouses from harmful pests in the Sultanate of Oman. The results revealed that Green lacewing and Ladybirds played significant roles in eliminating whiteflies in both tomato and cucumber crops by effectively controlling their populations.

Keywords: Natural Enemies, Greenhouse Pests, Control, Sultanate of Oman

Introduction

Natural enemies have a long history of being used as biological control agents against agricultural pests throughout the world. With varied degrees of effectiveness, predatory insects, mites, parasitic wasps, pathogenic bacteria, fungi, and viruses have been utilized against these pests. This process is called "biological control" (Riddick, 2022; Dreistadt, 2014). The preservation of natural enemies is widely acknowledged as the most crucial biological control technique (Cortez-Madrigal and Gutiérrez-Cárdenas, 2023). Biological pest control techniques are widely used in the production of vegetables to protect human health and the environment (Türkten, 2017). This might be attributed to the fact that it reduces the need for pesticides, which in turn causes fewer risks to the environment and human health (Yilmaz and Tanc, 2019).

This method fits with organic and ecological methods and lessens the need for pesticides. However, research on different aspects of insect pest management in greenhouses is still limited. Biological control has been demonstrated as just an effective chemical control and is quite inexpensive, particularly when compared to some of the more recent pesticides (Parrella and Lewis, 2018). Effective biological pest management necessitates biological and ecological understanding of the host plants, host insects, biological control agents and the places where the biological control agent will be deployed (Al-Kindi *et al*., 2017).

Crops grown in greenhouses are susceptible to pests and diseases (Pottorff and Panter, 2009). The surrounding environment of greenhouses provides homes, refuges, shelters, or food sources for insects, which poses the danger of crop colonization by insect pests (Doehler *et al*., 2023). Biological control in greenhouse crops is achieved by the periodic release of natural enemies. In these situations, the introduction of predators or parasitoids aims to create the population needed for control over a considerable amount of time (Perdikis *et al*., 2008).

Natural enemies such as ladybirds, Lacewings, and Trichogramma Evanescens can help reduce the negative effects of pests in greenhouses. Many researchers (Leman *et al*., 2014; Snyder *et al*., 2004) confirm that biological control in greenhouses can have many positive effects with the aid of natural enemies such as green lacewing It is recommended to utilize ladybirds to assist in managing aphids in greenhouses (Riddick, 2017). Trichogramma evanescens can also be used in greenhouses for biological control (Keçeci and Öztop, 2017).

Statement of the Problem

Greenhouse tomato production accounts for around 2-5% of total Oman tomato production, whereas greenhouse cucumber production accounts for approximately 61-73% of total Oman cucumber production. Tomatoes are cultivated in greenhouses two to three times a year, while green-house cucumber is planted three to four times each year. There are several threats to the Sultanate's tomato and cucumber crops (Ishag and Al Rawahy, 2018). Infested tomatoes are common in various agricultural areas around Sultanate of Oman (Al-Maawali *et al*., 2021). Cucumber agriculture in the Sultanate is also plagued by several pests (Mkook *et al*., 2020). Keeping in mind that chemical control initiatives in Oman have had minimal success as they provide only short-

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term solutions (Al-Kindi *et al*., 2018; Al-Kindi *et al*., 2017). Given the fact that native and habitat-specific antagonistic microorganisms, which may be more adaptable to the prevailing local climatic conditions in Oman, may be suitable for use as biocontrol agents for the management of pre-and post-harvest diseases of vegetables (Al-Maawali *et al*., 2021). The researcher aimed to identify the statement of the problem to revolve around identifying the effectiveness of using natural enemies to control greenhouse pests in tomato and cucumber crops within the Sultanate of Oman.

Questions of the Study

The main question of the current study is: How can natural enemies contribute to controlling greenhouse pests? Many sub-questions can be derived as follows:

1. How does the use of biological control agents (Ladybirds) contribute to protecting tomato and cucumber crops
2. How does the use of biological control agents (Green Lacewing) contribute to protecting tomato and cucumber crops

Significance of the Study

Overuse of pesticides in suppressing damaging pests can lead to insecticide resistance and have many negative effects on the environment and human health. Biological control of insect pests has long been acknowledged as a natural pest control strategy. Pest control in greenhouses can be difficult, but natural enemies like Ladybirds (Coccinellidae), Lacewings (Neuroptera), and Trichogramma Evanescens can help reduce pest numbers in greenhouse crops. The significance of the study stems from the fact that biological control by natural enemies can be more cost-effective than chemical control approaches.

While synthetic pesticides require constant application, natural enemies can provide continual pest control once established in an agricultural region. Omani farmers can save money in the long run by minimizing the costs of acquiring and applying chemical pesticides. In addition, Omani farmers can maintain a healthy ecology and reduce crop loss caused by pests by depending on natural enemies.

Limitations of the Study

The limitations of the current study can be reviewed as follows:

- Objective limitations: The current study is limited to discussing the role of natural enemies in controlling greenhouse pests
- Time limitations: This study has been conducted for three seasons during the period from 2019-2021
- Place limitations: This study has been conducted in the general directorate of agricultural and livestock research in Al-Rumais, Sultanate of Oman

Literature Review

Background

The main economic movers in developing nations are their economies and agriculture is their backbone. Human health, plant soils, and the environment are all at risk due to the growing use of chemical fertilizers and hazardous pesticides. To preserve crops, microbial insecticides have been used recently. As an alternative to managing pests and pathogens, biological agents for pest control have drawn increased attention in the last year. It helps to reduce the overuse of hazardous compounds and offers a sustainable method of managing plant health. The antagonistic bacteria are classified into six distinct phyla: Actinomycetota, bacteroidota, pseudomonadota, bacillota, and mucoromycota. Various techniques have been used to produce microbial pesticides, such as the extraction of pure cultures and efficacy bioassays conducted in both controlled and uncontrolled environments. It is widely acknowledged that the most advanced technology for ecologically friendly agriculture is biological control agents or BCAs.

There have been reports of several beneficial BCAs for managing plant health, but standardizing bioformulation and gaining effective acceptance was necessary (Negi *et al*., 2023).

In this sense, because of the protected habitat that separates them from their range of natural enemies and pathogens, certain pests can become more problematic in greenhouses than they are outdoors (Veronesi, 2022). In addition, In greenhouse systems, the frequent mass introduction of natural enemies has been a common biological control technique when the resident population of natural enemies is not large enough to control the pests. An even more cost-effective and efficient approach would be to assist in the formation and population growth of beneficials. One of the most important factors in the success of biological control programs nowadays is the proactive development of parasitoids and predators before the advent of pests. In both Conservation Biological Control (CBC) and Inoculative Biological Control (IBC), the"predators and parasitoids-in-first" approach is employed (Pijnakker *et al*., 2020).

Moreover, insect pests that damage crops frequently represent a serious risk to farmers. The ecology in the area, chemical control methods, and biological control strategies that use living things must all be vividly coordinated for pest management to be implemented successfully. Once desired modifications have been made at the genome level, natural enemies can be incorporated into the pest management system. Therefore, molecular interventions are required for the efficient modulation of natural enemies (Remya and Nisha, 2020). Thus, by using biocontrol agents against pests, biological control aims to reduce the harmful effects of synthetic pesticides on the environment. Biological control is based on three fundamental concepts: Importation, augmentation, and conservation. To achieve an effective outcome, biocontrol agents are imported through the process of importation (Dey, 2020).

Natural Enemies

Under sheltered conditions, the natural enemies that manage pests outdoors are absent. These factors lead to the development of insect problems indoors more frequently and more severely than outdoors. Pests such as nematodes, mites, and insects cause enormous losses in greenhouse vegetable and flower harvests. Effective management of these pests is crucial in preventing crop losses and boosting yields in protected vegetable and flower farming. Growers that implement effective pest management technology should anticipate receiving higher and more compensation for producing high-quality horticultural crops grown under protected cultivation (Mani, 2022).

In this context, preservation biological control refers to the process of improving the natural enemies that already reside within crops. This can be accomplished by planting cover crops, which serve as insectary plantings and give natural enemies food and shelter (such as pollen and nectar) (Veronesi, 2022). Additionally, the main places where natural enemies can find a home are the boundaries of fields where crops and edge vegetation converge. In addition to taking into account the ideal field sizes, number of edges, and management techniques at and around edges, conservation and improvement of natural enemies may involve modifying plant species and arrangement, particularly at these edges. Combining the advantages of windbreak and agricultural systems is a viable strategy for managing field edges that also provides extra benefits related to wind protection (Mani, 2022). There are several types of natural enemies as follows:

i. Green lacewing: The green lacewing is a highly efficient and practical general pest hunter in many types of crops and greenhouses. This is because insecticides like lufenuron, novaluron, and lambda-cyhalothrin are widely used in commercial products (Alsendi *et al*., 2023). A possible predator of the Neuropterean insect known as the chrysopid (green lacewing) has been discovered. It is commonly referred to as the "green eye bug." Growing interest in incorporating beneficial predators into integrated pest management plans for horticultural and field crops has been observed lately, as producers look for chemical substitutes for controlling insect pests (Timke *et al*., 2020)
ii. Ladybird: Exotic ladybird examples have been widely employed to control economically significant herbivorous insects. Recent instances of commercially significant bugs introducing themselves biologically have highlighted the necessity to carefully assess whether the anticipated advantages of pest management outweigh any potential environmental hazards (Rondoni *et al*., 2021). A valuable biological pest management agent in all terrestrial landscapes, including agroecosystems, is the ladybird beetle. These pest predators are declining because of agricultural intensification, primarily because of pesticide use, habitat loss, and decreased food availability (Hussain *et al*., 2022)
iii. Trichogramma evanescens: Trichogramma species are tiny endoparasitoids of insect eggs that play a crucial role in controlling lepidopteran pests, making them one of nature's most effective foes. Trichogramma females' lifespan, capacity for searching, fertility, and capacity to locate their hosts are all influenced by their body size (Taha *et al*., 2022)

Greenhouse Cultivation

In both natural and artificial environments, beneficial insects provide biological control and pollination. High-value fruits and vegetables, especially those cultivated in greenhouses, require these Ecosystem Services (ES) in particular. Since its adults pollinate crops and its larvae feed on aphid pests, the hoverfly Eupeodes corolla provides both ES. In this study, we examined the dual function of *E. corollae* in three greenhouse-grown horticultural crops strawberry, melon, and tomato that are pollinated by insects and impacted by aphids (Li *et al*., 2023). In this sense, in greenhouses, many forms of biological control, which are characterized by using the population of one organism to lower the population of another organism are employed. In nations where greenhouse structures are frequently partially open, such as the Mediterranean basin, the tropics, and the semi-tropics, natural biological control, or NatBC is observed. NatBCis the process by which natural enemies reside in the environment to lower pest populations. Enhancing natural biological control can be achieved by cultivating plants close to greenhouses that offer natural enemies shelter, pollen, or nectar, or by growing such plants inside the greenhouse. Conservation biological control is the result of human activities that safeguard and enhance the activity of naturally occurring natural enemies (Van Lenteren *et al*., 2020).

Biological Pest Control

In agricultural settings, biocontrol agents are considered a more environmentally friendly substitute for pesticides. To adopt more environmentally friendly methods, farmers use natural enemies as a biocontrol to eradicate aphids from crops; the harlequin ladybird (Harmonia axyridis) is not yet regarded as toxic. Aphid management in crops may be better achieved by employing an augmentative or conservation biological control technique that uses native coccinellid species found in the area rather than the invasive harlequin ladybird (Camacho-Cervantes *et al*., 2021). In a related context, in field crops, orchards, and forests, biological control can be crucial in lowering the total number of pests. Trichogramma spp. are true egg parasitoids that are regarded as the most commonly utilized natural enemies in the world (Shawer *et al*., 2021). This is partly because they are easy to produce in large quantities and may target a wide range of major insect agricultural pests, particularly lepidopterous ones in their early stages (their eggs). It is quite helpful to store natural enemies so they are ready for use when needed (Shawer *et al*., 2021). In addition, ecosystems have a significant role in flowers and intentionally selecting plant species based on their floral architecture is one way to support ecosystem services, including pest management and biodiversity in agricultural settings. The field of sustainable agriculture holds immense importance and it emphasizes how important it is to integrate ecological interactions between natural predators, prey, and floral resources into pest-management strategies (Hyder *et al*., 2023).

Materials

A variety of tools and techniques were used to breed ladybugs and green lacewings, with the tools varying according to different environments and agricultural seasons. The tools used included:

1. Plastic containers: Used for mass rearing beneficial predators
2. Brushes: For meticulously cleaning insects
3. Insect vacuum collector: This device is designed specifically for capturing insects without causing harm. It typically consists of a handheld vacuum with a soft nozzle that allows for gentle suction
4. Glass tubes: For storing and transporting insects
5. Artifacial diet: To provide food for the beneficial insects during the mass rearing process
6. Tissues (Kleenex): To cover containers, secured with rubber bands
7. Cotton and honey: For various uses during the mass rearing process
8. Pens: For recording observations and data
9. Trays: For distributing and organizing samples
10. Labels: For identifying and documenting samples
11. Cages: Including large cages measuring 20* 20* 20* cm and small plastic cages, to provide different environments for the mass rearing process

The tools were carefully assembled to provide a suitable environment for conducting research, which contributes to the success of the mass rearing process and the achievement of the desired goals.

Where (R1), for example, refers to the value that represents all the repetitions of (line1), indicating (the date of the experiment) when the number of agricultural pests is measured at different times after applying the intervention, which is (3, 6, 10 days).

Methods

The study seeks to answer the following main question: How does the use of biological control agents contribute to protecting tomato and cucumber crops? From there, the following sub-questions arise:

1. How does the use of biological control agents (ladybirds) contribute to protecting tomato and cucumber crops
2. How does the use of biological control agents (Green lacewing) contribute to protecting tomato and cucumber crops

The Experiment

The experiment was conducted in the Al Batinah South Governorate in Barka in a period extended for three seasons from 2019-2021, on tomato and cucumber crops. The researcher observed widespread complaints among farmers regarding crop loss and excessive pesticide spraying. Through monitoring production quantities, the researcher discovered that harvested crops fell short of expected levels. Utilizing television imaging technology facilitated this analysis. Consequently, the researcher initiated the study before disseminating the findings to farmers. After the first season, the experiment was extended to be applied to Al Sharqiyah Governorate in the north. In the second season, the Ad Dakhiliyah Governorate was included. In the third season, Al Batinah North Governorate in the north was included. The current experiment was conducted on two crops, cucumber and tomatoes due to their nature which is considered resistant to environmental factors. The crops were treated against the following insects (thrips, whiteflies, mites). Biological control was implemented using Green lacewing and Ladybird. The SPSS program was relied upon and the study's results are presented in the following Table 1.

Table 1: Illustrates the effect of Green lacewing on insect pests in (R1)

	Number of whiteflies	Number of thrips	Number of mites
R1	186	28	23
3 days	160	27	21
6 days	147	23	19
10 days	17	6	3

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Green Lacewing

As shown in the previous Table 2, it is evident that there is a positive effect of Green lacewing. Green lacewing insects play a crucial role in controlling agricultural pests, as the percentage of thrips decreased after (10) days of using Green lacewing. Additionally, mites were significantly affected, with their count reaching (3) on the day (10).

As shown in the previous Table 3, there is an effect of Green lacewing in reducing the number of harmful insects, including whiteflies, thrips, and mites. Whitefly was eliminated on the tenth day, while the count of thrips decreased to 2 and mites decreased to 1. This can be attributed to the role of Green lacewing in controlling and eliminating whiteflies, especially in the early stage of their life cycle, without causing any harmful side effects on plants.

From the previous Table 4, it is evident that there was an effect of Green lacewing on day 10, as both mites and thrips were eliminated. This can be attributed to the reliance on Green lacewing, which is an essential part of the pest control program, as thrips cause plant damage and weaken them.

From the previous Table 5, it is evident that mites were completely eliminated on the tenth day, in addition to a decrease in the number of thrips to 2 and a decrease in whiteflies to 8. This can be attributed to the effect of Green lacewing, which helped reduce the number of harmful insects. Whiteflies cause a significant decrease in tomato yields, so relying on Green lacewing and other active predatory insects, including Ladybirds, is crucial as they feed on other small insects, including whiteflies, thrips, mites, and aphids.

Ladybird

From the previous Table 6, a decrease in the number of pests (mites, whiteflies) to 2 and a decrease in thrips to 3 on the tenth day is evident. This can be attributed to the effect of Ladybirds on crops, as Ladybirds is an active predator that feeds on small insects, thus protecting plants from harmful pests. According to what Rondoni *et al*. (2021) have indicated, Exoticladybirds examples have been widely employed to control economically significant herbivorous insects. Recent instances of commercially significant bugs introducing themselves biologically have highlighted the necessity to carefully assess whether the anticipated advantages of pest management outweigh any potential environmental hazards.

Table 2: Illustrates the impact of Green lacewing on pests causing plant damage in (R2)

	Number of whiteflies	Number of thrips	Number of mites
R2	181	20	17
3 days	155	15	14
6 days	89	6	3
10 days	0	2	1

Table 3: Illustrates the impact of Green lacewing on pests causing plant damage in (R3)

	Number of whiteflies	Number of thrips	Number of mites
R3	159	22	19
3 days	139	17	16
6 days	88	8	5
10 days	10	0	0

Table 4: Demonstrates the impact of Green lacewing on pests causing plant damage in (R4)

	Number of whiteflies	Number of thrips	Number of mites
R4	188	30	14
3 days	169	26	11
6 days	60	12	9
10 days	8	2	0

Table 5: Illustrates the impact of Ladybirds on pests causing plant damage in R1

	Number of whiteflies	Number of thrips	Number of mites
R1	177	27	19
3 days	155	20	23
6 days	21	8	4
10 days	2	3	2

Table 6: Illustrates the impact of Ladybirds on pests causing plant damage in (R2)

	Number of whiteflies	Number of thrips	Number of mites
R2	191	29	20
3 days	155	31	22
6 days	11	13	14
10 days	0	3	6

It is evident from the previous Table 7 that Ladybird was able to eliminate whitefly on the tenth day. This can be attributed to its ability to protect plants from agricultural pests and harmful insects.

This aligned with what Hussain *et al*. (2022) have indicated, they stated that a valuable biological pest management agent in all terrestrial landscapes, including agroecosystems, is the ladybird beetle. These pest predators are declining because of agricultural intensification, primarily because of pesticide use, habitat loss and decreased food availability.

The previous Table 8 demonstrates the impact of ladybirds on harmful pests, as mites were completely eliminated on the tenth day. This can be attributed to the effectiveness of ladybirds in controlling agricultural pests. They are safe to use and do not produce any harmful side effects on plants.

It is evident from the previous Table 8 that mites were completely eliminated on the 10^{th} day. This can be attributed to the important role played by ladybirds in maintaining ecological balance. They help control the population of harmful insects, protecting plants and preventing significant damage.

It is evident from Tables 9-10 that both Green lacewing and ladybirds were highly efficient in eliminating harmful pests such as mites, thrips and whiteflies. However, Green lacewing had a greater impact in completely eliminating mites, thrips and whiteflies on the 10^{th} day. This can be attributed to the ability of Green lacewing to target and eliminate harmful insects that cause significant crop damage. Additionally, Green lacewing is larger in size compared to ladybirds, allowing them to consume a greater number of harmful insects in a day. They are also more aggressive than ladybirds, making them more effective in eliminating and controlling harmful pests. This aligns with what Li *et al*. (2023) who examined the dual function of *E. corollae* in three greenhouse-grown horticultural crops strawberry, melon and tomato that are pollinated by insects and impacted by aphids.

Table 7: Illustrates the impact of Ladybirds on pests causing plant damage in (R3)

	Number of whiteflies	Number of thrips	Number of mites
R3	149	28	25
3 days	161	23	9
6 days	40	15	4
10 days	4	5	0

Table 8: Illustrates the impact of ladybirds on pests causing plant damage in (R4)

	Number of whiteflies	Number of thrips	Number of mites
R4	188	30	14
3 days	144	21	5
6 days	50	11	2
10 days	10	4	0

Table 9: Green lacewing

	Efficiency of whitefly				Efficiency of thrips				Efficiency of mite			
	R1	R2	R3	R4	R1	R2	R3	R4	R1	R2	R3	R4
3 days	14.0	14.36	12.58	10.11	3.57	25	22.7	13.3	8.7	17.65	15.79	21.43
6 days	21.0	50.83	44.65	68.09	17.86	70	63.6	60.0	17.4	82.35	73.68	35.71
10 days	90.9	100	93.71	95.74	78.57	90	100	93.3	87.0	94.12	100	100

Table 10: Ladybird

	Efficiency of whitefly				Efficiency of thrips				Efficiency of mite			
	R1	R2	R3	R4	R1	R2	R3	R4	R1	R2	R3	R4
3 days	12.4	18.85	-8.05	23.4	25.93	-7.0	17.9	30.0	-21.1	-10.00	64.00	64.29
6 days	88.1	92.90	75.2	56.3	60.00	58.1	34.8	47.6	82.6	36.36	55.56	60.00
10 days	98.7	100	90.0	80.0	62.50	76.9	66.7	63.6	50.0	57.15	100	100

Results

The study yielded the following results:

- Green lacewing played a significant role in eliminating whiteflies in both tomato and cucumber crops by effectively controlling their populations. It also had an important role in eliminating both thrips and mites in both crops
- Ladybirds also contributed to the elimination of a large number of whiteflies by consuming substantial amounts of them. It was capable of eliminating 50 whiteflies in a single day
- Ladybirds also helped in reducing thrips populations significantly
- Additionally, both Green lacewing and Ladybird safely and naturally eliminated mites

Discussion

- The results indicate that the green lacewing plays a significant role in controlling whiteflies in both tomato and cucumber crops. It has demonstrated its effectiveness in managing whitefly populations, reflecting its high efficiency in eliminating these pests. Additionally, ladybugs have proven their ability to control thrips and mites in both crops, highlighting their value in pest management strategies and their contribution to sustainable agriculture
- Ladybugs have also shown high efficiency in controlling whiteflies, with the ability to significantly reduce their numbers, thereby improving crop quality and increasing productivity. Furthermore, ladybugs have contributed to reducing thrips populations, highlighting their pest control capabilities
- Studies have also shown that both green lacewings and ladybugs can naturally and safely control mites on crops. This indicates that both insects are capable of eliminating a large number of agricultural pests, making them key instruments in pest management

Conclusion

Omani farmers rely on natural enemies to promote sustainable agriculture and pest management. Natural enemies control pest populations by preying on them or their eggs. They function as biological pesticides, minimizing the need for chemical pesticides, which contributes to the preservation of a balanced ecosystem. Omani farmers can lessen their reliance on chemical pesticides by relying on natural enemies for pest management. This provides several advantages, including economic savings, fewer chemical residues on crops, and a lower likelihood of pesticide resistance among target pests. Future researchers can concentrate on investigating the effect of natural enemies on other crops or using other enemies rather than those employed in the current study to measure their effectiveness in protecting vegetables from harmful pests.

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Ethics

The researcher adhered to all ethics of scientific research while conducting this study.

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