Life Science Journal

Websites:
http://www.lifesciencesite.com
http://www.sciencepub.net

Emails:
editor@sciencepub.net
sciencepub@gmail.com

MARSLAND PRESS
Multidisciplinary Academic Journal Publisher

A REVIEW ON LIFE CYCLE OF RICE LEAF FOLDER ITS BIOLOGICAL CONTROL AND STRATEGIES FOR EFFECTIVE MANAGEMENT

*Usama bilal[1], Muhammad Imran[1], Muhammad Usman[1], Abdul Khaliq[2].

[1]Department of Zoology, GC University, Faisalabad
[2] Sugarcane Research Institute, AARI, Faisalabad
*Corresponding Author: usama.202300108@gcuf.edu.pk

Abstract: The rice leaf folder (Cnaphalocrocis medinalis) is a significant pest affecting rice cultivation worldwide, c ausing considerable yield losses and economic damage. This review provides a comprehensive examination of the lif e cycle of the rice leaf folder, highlighting the developmental stages from egg to adult and the factors influencing its population dynamics. Emphasis is placed on understanding the biology and ecology of this pest to inform effective m anagement strategies. Biological control methods, including the use of natural predators, parasitoids, and entomopath ogenic organisms, are critically evaluated for their efficacy and sustainability. Additionally, integrated pest managem ent (IPM) strategies combining biological, cultural, and chemical controls are discussed, offering a holistic approach to mitigating the impact of rice leaf folder infestations. The review underscores the importance of continuous monito ring, farmer education, and the adoption of environmentally friendly practices to achieve sustainable pest manageme nt. Future research directions are proposed to address current knowledge gaps and improve control measures, ultimat ely enhancing rice production and food security.

[Usama bilal, Muhammad Imran, Muhammad Usman, Abdul Khaliq, **A REVIEW ON LIFE CYCLE OF RICE LEAF FOLDER ITS BIOLOGICAL CONTROL AND STRATEGIES FOR EFFECTIVE MANAGEMENT**. *Life Sci J* 2024;21(7):14-27]. ISSN 1097-8135 (print); ISSN 2372-613X (online). http://www.lifesciencesite.com. 02. doi:10.7537/marslsj210724.02.

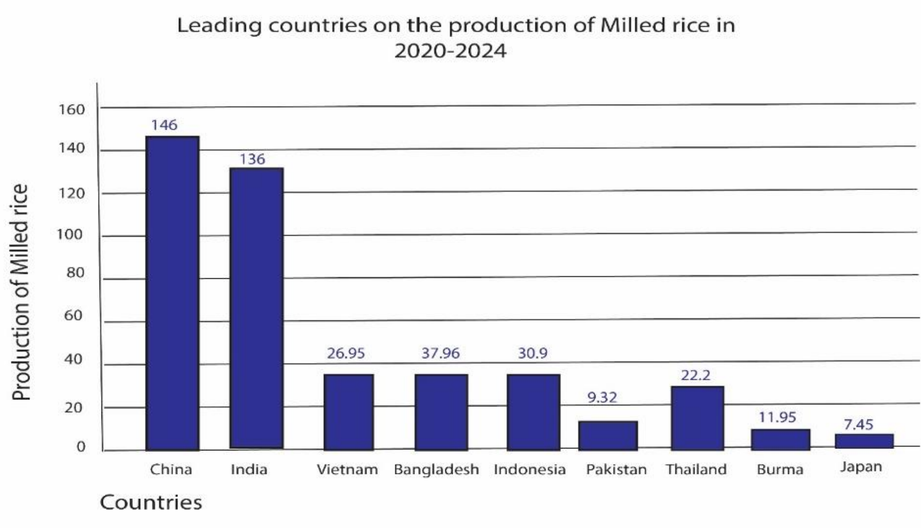
Keywords: Cnaphalocrocis medinalis, Integrated pest management, Rice leaf folder, Sustainable Agriculture,

1-Introduction:

Rice is one of the most important cereal_crop and staple food for about half of the world's population. It is grown in about 114 countries, mostly developing nations in Asia and Africa. Rice production plays a vital role in the economy of these countries and any hazard that reduces the yield of the product significantly influence their economy (Babendreier *et al.,*2022). Rice is categorized under the grass family Poaceae. It's a major source of nutrition around the world, especially in African countries like Ethiopia. Around 50% of the world's population, including more than 2 billion Asians eats it as a staple diet. It is predominantly a subsistence crop because half of it is consumed where it is grown (Arun *et al.,*2023). The cultivation of rice holds immense economic significance for these nations, and any potential risks impacting its output greatly affect their economies. In response to the ever-increasing demand for higher rice grain production, farmers worldwide are intensifying their cultivation methods, leading to a rise in pest infestations (Reddy *et al.,2023).* Consequently, insecticides and herbicides have often been excessively applied, resulting in adverse environmental and economic repercussions. In Pakistan, fine rice varieties, particularly basmati rice, are renowned worldwide for their unique aroma (Chandio *et al.,*2020). They make a substantial contribution to Pakistan's economy, accounting for 3.5% of the added value in agriculture and 0.7%. In 2021, Pakistan cultivated rice on 3.335 million hectares and produced 8.419 million tons (Naseer, *et al.,*2020). Pakistan is the 10th largest producer of rice in the world and the fourth-largest exporter (Abbas *et al.,*2021). According to the USDA, Rice was planted on 3.3 million hectares of land in 2020-21. About 70% of our farmers are cultivating paddy and the production is about 104.32 million tonnes and productivity being 2404 kg/ha (McClung *et al.,*2020). The production of rice in India was 74.68 MTs in 1991- 1992 increased to 124.1 MTs in 2022 – 2023. Rice provides up to 50% of the dietary caloric supply and a substantial part of the protein intake for about 520 million people living in poverty in Asia (Surendran *et al.,*2021). Nearly 90% of the world rice is obtained from Asia (nearly 640 million tons), with China and India as the major contributors (Fahad *et al.,*2019). Roughly, 75% of the world's rice is obtained from 85 to 90 M ha of paddy lowland areas, where rice can be grown on a same field up to three times in a year. Rice is currently grown in over a hundred countries that produce more than 715 million tons of paddy rice annually (480 million tons of milled rice) (Zhou *et al.,*2020). Fifteen countries account for 90% of the world's rice harvest.13 China and India alone account for 50% of the rice grown. More than 120,000 rice varieties are grown worldwide, cultivated in various growing conditions like irrigated rain-fed low-lands and up-lands (Sarwar *et al.,*2022).

1.1-Share of rice in agriculture and GDP:

Pakistan produced 7,410 million tons of rice according to the financial year survey. Pakistani rice has been cultivated in 3,304 hectares of agricultural land and exported worldwide. Rice is also increased by 0.6% of Pakistan's Gross Domestic Product (GDP) (Arsani *et al.,*2020). It contributes 1.9 percent of value added in agriculture and 0.4 percent in GDP. During 2022-23, the crop was cultivated on 2,976 thousand hectares, recorded decline of 15.9 percent over 3,537 thousand hectares last year. Its production declined from 9.323 million tonnes in 2021-22 to 7.322 million tonnes in 2022-23, registering a negative growth of 21.5 percent (Maitah *et al.,*2020). The old and manual process of rice classification is more expensive and time-consuming. Rice is the second largest crop among these in Pakistan. Sindh and Punjab are the two-leading rice-growing provinces that produce 92% of rice around the total area. Punjab covers nearly one million (Hectares) per year (Afzal *et al.,*2021). The soil condition was perfected for rice production in the Punjab districts: Sialkot, Bahawalpur, Jhaang, Gujranwala, Okaraa, Sheikhupuraa, and Multan (*Shah et al.,*2020). These districts produced more than 70% of rice in Pakistan. Pakistan's agriculture sector still stands at 2nd important position in contribution to economy. In the year 2019-2024, this sector contributed 19.3% to gross domestic production (GDP) which has increased in comparison to previous year (18.5%) in year 2018- 2024 (Rizwan *et al.,*2019). Conferring to Food and Agriculture Organization (FAO) report nearly, 2.57 billion people rely on agriculture, hunting fishing forestry for their livelihood. On the other side rice yield per hectare was highest in Australia followed by Egypt, USA, and Uruguay with the yield 10386, 8826.5, 8621.1, 8500 kg/hectare respectively (Dey *et al.,*2020). In this ranking, Pakistan falls at 57th position yielding 3844.4 kg/ hectare whereas in the production it was ranked as 10th in the major rice producer countries (Javed *et al.,*2020). Asian farmers produce about 90% of the total, with China and India accounting for 50% of the global rice supply. Asian farmers accounted for 92% of world rice production. Agriculture has historically been a dominant sector in South Asian economy, employing about 60% of the labor force and contributing 22% of the regional GDP (Laiprakobsup *et al.,*2019). The agricultural GDP share of the total GDP of Bangladesh at the current price was 30% and rice alone occupied 75% of the cultivable land which became 79.4% (Khushi *et al.,*2020). In Nepal, agriculture remains the principal economic activity, employing 66% of the population and providing 39% of GDP (Gadal *et al.,*2019). Rice alone accounted for 87.5% of the agriculture share of its total GDP. Sri Lanka's rice sector contributes 30% to the agricultural GDP. Rice is the single most important crop occupying 34% (0.77 /million hectares) of the total cultivated area in Sri Lanka. India and Bangladesh together contributed 28% (22 and 6 respectively) of global rice production and 33.57% in 2009 (26 and 7.5 respectively) (Manik, M. H. 2023). However, the share of rice in total agricultural output (Figure 4) and total GDP has been declining. Rice accounted for 8.4% of GDP in South Asia, declined to 2.7% (Aslam *et al.,*2021). According to the Food Balance Sheet, feed use of rice is less than 1.8% of total production. In recent years, a rice production deficit due to high population growth has threatened the historic trend of sustainable global rice production. Rice (Oryza sativa) stands first among the cereal crops in Nepal, which accounts for 50% of total edible cereal production and about 20% to Agricultural Gross Domestic Product (AGDP) on the country and provides more than 50% of the total calories required to the Nepalese people (Gairhe *et al.,*2021). Also, in terms of area under cultivation rice comes first among the cereals which account about 50% of the total area under food crops of 3.2 million hectare (Hoang *et al.,*2021).



1.2-Rice bran components

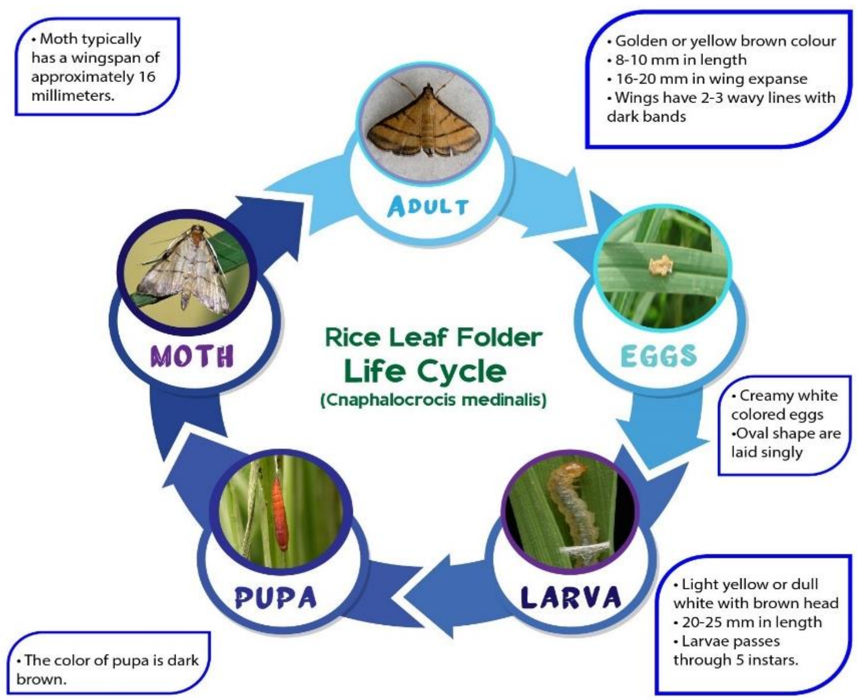
It has been reported to show anticancerous activity via various mechanisms involving antiapoptosis activity, anti-inflammatory activity, chemo-protective action, and so forth (Sapwarobol *et al.,*2021). Other phytoactive compounds of rice bran have also been documented to show other pharmaceutical activities like antidiabetic activity, anti-inflammation, antihypertensive activity, cholesterol-lowering activity, antioxidant activity, antimicrobial activity, and others, which elucidates the medicinal significance of rice bran in present time reported that in high-fat diet-fed mice, red rice bran extract mitigates the different pathological complications of dyslipidemia and hepatosteatosis by regulating the expression of various major genes involved in apoptosis, oxidative stress, inflammation, and lipid metabolism (Spaggiari *et al.,*2021). The role of rice bran oil in health-related and disease-preventive benefits has been also documented in various literature. Rice is the most important dietary staple for about 3.5 billion people, accounting for at least 35-75% of total calories (Yu *et al.,*2019). The rice-wheat (RW) system is critical to food security in Pakistan. One strategy to satisfy the expected increase in future food demand is to produce more food from existing agricultural land. In addition, the studies showed that the seeding methods influence the rice yield and milled rice quality (Behl *et al.,*2021). However, researchers are divided on the best method for planting rice. Some believe that the transplanting method is a new approach to increasing grain yield, for improving water and fertilizer use efficiency, for improving significantly the milling characters and the 1,000-grain weight (Sahini *etal.,*2023). Others argue that the direct seeding and broadcasting methods get many advantages like less labor, low production cost, less water use, less methane emission, high economic profit, low crop maturity duration. Facing this scientific divergence, determining the difference in yield and milled rice quality and farmers' profitability under various (Ilias *et al.,*2020).

2-Sowing methods

Sowing methods is the way to sustainable rice growing. The objective is to assess the effects of rice sowing methods on yield and milled rice quality for improving the small farmers' income and consequently enhancing the rate of transplanting method uptake (Kumar *et al.,*2019). Timely screening rice of different growth stages to do field operation, such as fertilizer, irrigation, cultivation and disease control, is of great significance of crop management (Ali, *et al.,*2019). During the whole growth cycle, rice panicles change significantly in their external morphological structures, such as shape, color, size, texture, and posture, which enables us to explore new technologies to automatically observe, detect and distinguish rice panicles of different critical growth stages (Kashid *et al.,*2022). Computer vision and machine learning has been widely reported in the application of phenotypic traits detection of crops (Roseli et al.,2021). Lepidopteron insect-pests are the main class of pests causing significant damage to crop plant yields. The rice leaf folder (RLF), Cnaphalocrocis medinalis (Guenee) (Lepidoptera: Pyralidae), is a predominant foliage feeder and one of the most destructive pests, affecting in all the rice ecosystems in Asia (Rautaray *et al.,*2019). An increase in C. medinalis population could be attributed to the large-scale cultivation of high yielding varieties, application of fertilizers, and continuous use of insecticides leading to outbreak of this pest in several countries, including India) (Liu *et al.,*2021). The larvae fold the leaves longitudinally by stitching the leaf margins and feed by scraping the green mesophyll tissue from within the folded leaves (Singh & R. K. 2021). This feeding causes linear, pale white stripes that result in membranous patches. Out of the eight species of leaf folder, the most widespread and important one is Cnaphalocrocis medinalis cause significant losses to rice ecosystem (Kamakshi *et al.,*2020). In their studies, 17.5% damaged leaves resulted in 16.5% yield loss, and 21.3% yield loss corresponded to 26.6% damaged leaves. Second instars leaf folder larvae glue the growing paddy leaves longitudinally for accommodation and feeds on green foliage voraciously which results in papery dry leaves (DALVI & N. S. 2020). A single larva can damage a number of rice leaves, disturbing photosynthesis and reducing the rice yield. Loss incurred to the growing paddy crop is insurmountable (Marina *et al.,*2019). Feeding often results in stunting, curling or yellowing of plant green foliage. The extent of loss may extend up to 63 to 80 percent depending on agro-ecological situations (Bilal *et al.,*2019). The heavy use of insecticides and high fertilizer rates seem to favors leaf-folder population outbreaks. Rice leaf folder, Cnaphalocrocis medinalis is an important rice pest and become a major threat to rice production in many Asian countries including China, Sri Lanka, Vietnam Pakistan, Japan, Korea, Malaysia and India (Hajjar *et al.,*2023).

3-Life History:

In broad daylight, moths hide under leaves and on stems as they are nocturnal. During the early hours of the morning, moth activity is at its peak, but as the day continues, the moth activity lessens (Manikandan *et al.,*2023). Moths are attracted to light. As adults, the moths are very small, and they have a yellowish-brown appearance. They are 10–12 mm in length with wingspans of around 13–15 mm (Marina *et al.,*2019). When the wings are not moving, they form an equal-sided triangle. Three oblique lines of different lengths run across the forewings. The area of the hind wings is large (Zhang *et al.,*2019). The male moth's tibiae are tufted with black hairs, whereas the females are not. Males have a broad abdomen tip, while females have a pointy tip (Hajjar *et al.,*2023). The female uses a pheromone to attract its mate, and they usually mate between the hours of dusk and midnight. Adults have a life expectancy of one week. After one or two days of mating, the eggs begin to be laid (Ardestani, M. 2023). On both surfaces of young leaves, females lay flat, oval, creamy golden eggs, either singly or in rows parallel to the midrib of the leaf, and either in one or two layers (Jian *et al.,*2019). Eggs are laid in batches of ten to twelve. Female moths have the ability to deposit up to 300 eggs during the course of their lives. The duration of incubation can range anywhere between 3 and 6 days (Mahesh *et al.,*2019). Upon hatching, the newly hatched larva has a light brown head and a white, transparent body. Nevertheless, the larva's body turns green once it starts feeding (Arya *et al.,*2023). It starts feeding on the youngest leaf that is yet to open immediately after hatching by climbing to the bottom of the leaf that has just emerged. The second instar moves to a more mature leaf and wraps it together (Lella, N., & Jagadeesh, K. 2023). Some of the freshly born larvae hang from the leaf tip on silken threads and are dispersed by the wind to adjacent plants. A total of five larval instars are present. Upon reaching full size, the larva measures roughly 16 mm in length and 1.7 mm across the thorax (Amer *et al.,*2019). In appearance, it has a yellowish-green head and a dark brown prothoracic shield. When touched, larvae quickly jump or squirm. The larval stage takes 15 to 25 days to complete. Pupation occurs in looser woven silk strands inside the leaf roll. The pupa is slender and greenish-brown when it is first created, but it eventually turns b rown. After 6–8 days, the molt develops (Rajadurai *et al.,*2023).



4-Mode of Damage of Rice Leaf Folder:

They scorch the leaves by folding them inward and scraping away at their green tissues from within, causing them to dry and scorch. To survive, each larva must consume several leaves. Each attacked rice crop may have several rolling leaves during a serious infestation that reduces its capability to manufacture food. Filling grain may be partly completed when flag leaf stage plants are attacked (Adhikari *et al.,*2022).

4.1-Bio- ecology of Rice leaf folder

The heavy use of (nitrogen) fertilizer persuades rapid multiplication of the leaf folder population in rice field. High humidity, high temperature and shady areas of the field favor their growth and developments (Dutta *et al.,*2024). The presence of alternate host in rice fields and around the field provided shelter for insect and create favorable environment for complete several generations in one growing season (Nagdev *et al.,*2022). Expanded rice areas with irrigation systems, multiple rice cropping and insecticide induced resurgences are important factors in the leaf folder's abundance. The adults of leaf folder are nocturnal they hide in rice leaf during the day time to escape predation. They are active year-round and moths fly short distances when disturbed (Panse *et al.,*2022).

4.2-Nature of Damage:

The leaf folder damages the crop in its larval stage. Mostly Damage is caused by the Second instars larvae due to the folding of leaves and feeding on the green mesophyll tissue which caused the loss of output by 20% to 30% generally (Senthil-Nathan, S. 2019). From within the folds which results in papery dry leave. However, the young larvae feed on open leaves but later feed inside the rolled leaf formed by folding the leaf longitudinally with a sticky substance (Morshed *et al.,*2020). *The* larvae chew inside the fold by scraping the green matter. The scraped leaves become membranous, turn whitish and finally wither. This results in longitudinal white streaks causing reduced photosynthesis and plant vigor, ultimately affecting the plant growth and yield (Jasrotia *et al.,*2019). At vegetative stage, crop generally recovers from the leaf folder damage but at reproductive stage, feeding damage on the flag leaf significantly reduces the grain filling resulting in yield loss. Generally, one larva was found in each leaf fold and after feeding on that leaf it moves to another leaf (Moses *et al.,2019).* Thus, single larvae feeds on a number of leaves can damage during its growth period. Heavily infested fields show many folded leaves and a scorched appearance of leaf blades. The damaged plants also pre-dispose the plants to fungal and bacterial infection. Severe infestations may annihilate the plant totally (Huan *et al.,*2019).

4.3-Seasonal occurrence and abundance:

Although moths are recorded in the warm tropic's region around the years but during the rainy season, they usually are most abundant. In cool regions, the insect is active from May to October, during these periods they completes four to five generations; the later generations usually overlap (Morshed *et al.,*2020). High humidity and optimum temperature are the important factors for the insect's abundance. Every year the initial population migrates to these temperate countries from tropical regions. Leaf folders have importance both in upland as well as lowland rice growing fields in the last few to the growing paddy crop are insurmountable (Samrit *et al.,*2019).

5-Control of Rice leaf folder:

Rice belongs to the grass family, along with wheat and maize, is one of the three crops on which the human species largely depend. Around the global level rice now become one of the most important crops, as in most countries of the world it is used as a staple food and will continue to be for the foreseeable feature (Soomro *et al.,*2020). According to the FAO, the crop is grown in at least 114 mostly developing countries and in Asia and Africa is the main source of income and providing jobs for more than 100 million households. Countries like China and India contribute together for more than half of world's rice area, while, along with Indonesia consume more than three fourth of the worldwide rice production (Javvaji *et al.,*2021). Brown planthopper (Nilaparvata lugens) is the potentially very damaging secondary pest for rice crop. In the past, disastrous losses have occurred by largescale sudden occurrence of this small but mighty insect although these sudden occurrences were mainly pesticide induced – triggered by pesticide subsidies and policy mismanagement (Quan *et al.,*2020). However, the brown planthopper still remain a restricted problem, especially in those areas where pesticide overuse and mistreatment are common, and can therefore be well thought-out as an ecological hub around which both ecological understanding and management are vital to get gainful and constant rice cultivation (Karthikeyan, K. 2019). For all Integrated pest management educational programs, brown planthopper has also become the major entrant because it is always needed to take protective actions against an outbreak during crop management (Bhardwaj *et al.,*2019).

5.1-Biological Conservation Control of Rice leaf folder

Conservation Biological Control

There is an ecological complexity associated with the rice crop, which is characterized by a high diversity of cultivated plants and a redundant food web among them (Zhu *et al.,*2020). Predators and parasitoids from a variety of classes and orders prey on and parasitize herbivorous insects in rice ecosystems, including Araneae, orthopterans, coleopterans, aquatic and terrestrial heteropteran, hymenopterans, strepsipterous, and dipterans (Sharma *et al.,*2020).

At a very early stage of the crop season, showed that generalist predators (e.g., spiders and mirid bugs) were abundant through the irrigated rice production sites in Java at an early stage of the crop season (Iamba, K. 2021). An increase in the organic matter prior to the season led to an increased abundance of decomposers and a further increase in populations of predators. These correlations show that rice predators use decomposer communities as alternative prey before phytophagic insects arrive (Shyamrao *et al.,*2019). Widespread staggered planting in the intensive cultivation areas of rice could further ensure continued availability and abundance of prey and hosts in rice fields.

In rice environments, biological conservation management capitalizes on and increases the natural pest controls provided by these prevalent natural enemy populations (Bodlah *et al.,*2019). Annual monoculture cropping practices are frequently linked to high disturbance regimes in natural enemies' habitats. Pesticide use is high, and there may be a dearth of adult food and shelter in certain agricultural systems. Conservation biological control tries to address this problem by reducing insecticide use, promoting selective insecticides, and changing crop habitats to improve natural enemy populations' support (Jaglan *et al* 2024).

5.2-Augmentative Biological Control

Whilst the irrigated rice ecosystem is a redundant food network, it is plausible that the populations of insect pests sometimes have economic damage. Cure measures are necessary, and the first curative option, wherever available, should be increased biological control (Guo *et al.,*2024). While conservation biological controls aim to improve the effects of indigenous enemy communities, increased biological control usually aims to increase the number of specific natural enemies for a short period of time, to temporarily suppress pesticide populations and activities, and to prevent economic damage to the yield, as opposed to conservation biological controls, which aim to improve the effects of indigenous enemy communities (Pathak *et al.,*2020). A good way to achieve enhanced controls is usually by releasing predators, parasitoids, or pathogens into the field that are predicted to produce the desired effects for a long or short period of time. Inoculate biological control, with the expectation of rapid increase of the small number of natural enemies released during that short period of time (inundate biological control [mass releases], where a natural enemy is unlikely to reproduce quickly enough), is one way to achieve this (Bonaventure, J. 2020).

As a biological control agent, provided a bibliography of all major fungal groups, bacteria, viruses, and nematodes that have been identified as rice insect pests between 1960 and 1985. Since then, there have been a number of studies that have demonstrated the effectiveness of rice pests of two entomopathogens, *Metarhizium* and *Beauveria*. Furthermore, toxins from *Bacillus thuringiensis* (Bt) were found to inhibit feeding larvae from rice-stray borer (*Chilo Suppressalis* (Walker)) during a laboratory experiment using an artificial diet (Ahmed *et al.,*2021).

As an alternative to using invertebrate pathogens in rice production as a biocontrol agent, a common argument is that invertebrate pathogens take a long time to control and have only limited effect at the field level (Mitku *et al.,*2021).

5.3-Bacteria

Microbial pesticides, also known as biopesticides, have gained popularity as an alternative to chemical pesticides in the pesticide market. In the years 1988–1995 in the United States, 90% of the bio pesticide market was dominated by *Bacillus thuringiensis* (80). Even though BT insecticides still make up only around 1% of the global market for insecticides, they have been used for decades as a means of controlling larvae of lepidopterous insects, and they have recently been combined with strains capable of controlling other insects (Karenina *et al.,*2019). It produces crystalline insecticide protein (1CP) or 6-endotoxins in protein crystalline parasphorus inclusions that are released into the soil by Gram-positive, aerobic soil bacteria (Reuolin *et al.,*2021). It is known that Bt 6-endotoxins are oral toxins that do not demonstrate any contact activity. The processes that explained the modes of operation of endotoxins are ingestions, Solu ionization, proteolytic activation, transit via peritrophic, binding of the receptor, insertion of the membrane, creation of the ion channel, and lysis of a cell (Baruah *et al.,*2023). The downside of Bt as a bio pesticide is that UV sunlight can make the toxin ineffective against insect pests quickly. Because of high transgenic crop selection pressure, Bt endotoxin resistance is of great concern to the population of pests, and this may also apply to other insecticide proteins (Zang *et al.,*2021). It is recommended that the use of Bt endotoxins (natural or biotechnology-based) and synthetic chemical pesticides should be combined with a pest complex with little selection of resistance to ensure efficient control of the pests. The other potentially useful toxic proteins made in crop plants (protease inhibitors, lectins, etc.) are of less field use (Chakravorty *et al.,*2023).

Biological Control	**Family**	**Life Stage**	**Reference**
Acinetobacter	**Moraxellaceae**	**Capsid**	(Karenina *et al.,*2019).
Lactococcus garvieae	**Streptococcaceae**	**Capsid**	(Reuolin *et al.,*2021).
Aeromonas media	**Aeromonadaceae**	**Capsid**	(Baruah *et al.,*2023)
Chryseobacterium cucumeris	**Weeksellaceae**	**Capsid**	(Zang *et al.,*2021)
Brucella pseudogrignonensis	**Brucellaceae**	**Capsid**	(Chakravorty *et al.,*2023)
Klebsiella pneumoniae	**Enterobacteriaceae**	**Capsid**	(Mitku *et al.,*2021)
Enterobacter asburiae	**Enterobacteriaceae**	**Capsid**	(Bonaventure, J. 2020)

5.4-Fungi

Metarhizium, *Beauveria*, *Hirsutella*, *Nomuraea*, and *Paecilomyces* are among the most regularly collected entomopathogenic fungi in agricultural crops. As biological pesticides, they offer a great deal of promise (Das *et al.,*2023). Because of the harmful consequences of chemical pesticides, there has been a renewed interest in exploring their possibilities in recent years. Entomophagy fungi probably do not acquire a large portion of the pesticide sector but have a specialist place in the field of insect pest control systems and integral applications (Abdullah *et al.,*2021). The rice ecosystem in Pakistan should be the focus of future growth rather than a single pest or pathogen. Unless genetic alterations increase the number of fast-damaging pathogens, in the future, the number of successful inundative augmentations will probably be restricted. Natural L, a recognized product based on Beauveria species, is the only one available in Pakistan (Nilamudeen *et al.,*2020).

Biological Control	**Family**	**Life Stage**	**Reference**
Metarhizium	Clavicipitaceae	**Spores**	(Das *et al.,*2023)
Beauveria	Cordycipitaceae	**Spore**	(Nilamudeen *et al.,*2020)
Hirsutella	Ophiocordycipitaceae	**Spore**	(Abdullah *et al.,*2021)
Nomuraea	Clavicipitaceae	**Spore**	(Sharma *et al.,*2020)
Paecilomyces	Thermoascaceae	**Spore**	(Jaglan *et al* 2024)
Metarhizium anisopliae	Clavicipitaceae	**Spore**	(Bonaventure, J. 2020)
Nomuraea rileyi	Clavicipitaceae	**Spore**	(Shyamrao *et al.,*2019)
Verticillium lecanii	Cordycipitaceae	**Spore**	(Bodlah *et al.,*2019).
Fusarium spp	Nectriaceae	**Spore**	(Zhu *et al.,*2020)

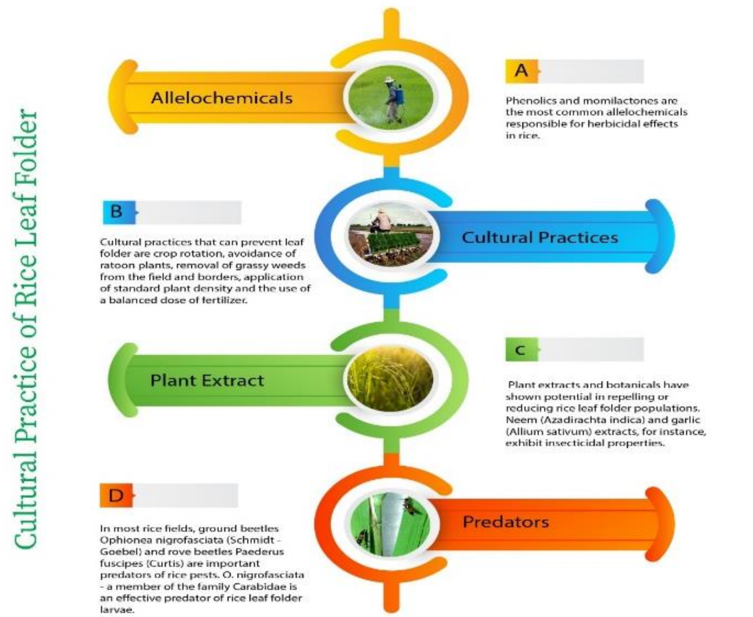
5.5-Viruses

Insects can be infected by viruses in many different ways. Among all lepidopterous pests, only a small number of them have baculoviruses, which have not been shown to have negative health effects or be harmful to the environment (Basit *et al.,*2021). As control agents, they have been used in a variety of ways; however, issues such as sluggish action and photosensitivity restrict their usefulness and economic value (Satheesha *et al.,*2020). Several attempts have been made to improve the potency and speed with which baculoviruses kill by incorporating other genes to express them, such as chitinase, poisons, insect hormones, and juvenile hormone esterase; however, none have been successful. So far, there has not been a single report of baculoviruses being used to control insects in Pakistan (Iqbal, S. 2020).

6-IPM Strategies

6.1-Cultural Practices

A key component of IPM is cultural practices. The following practices are used for pest management in rice paddies: removing weeds from fields, raising healthy nurseries, planting at the right time, selection of healthy seeds, summer plowing, and applying fertilizers as recommended (Morya *et al.,*2019).



6.2-Mechanical Practices

Biocontrol agents are conserved in bamboo cages by removing and destroying pest-infested plant parts, clipping the tips of rice seedlings, and collecting egg masses and larvae of pests (Chatterjee *et al.,*2021).

6.3-Biological Control Practices

It is important to conserve biocontrol agents such as coccinellids, spiders, damsel flies, and dragonflies. Rice seedlings are treated with chlorpyriphos as part of a root dip treatment. The eggs and masses of borers are collected and placed in bamboo cages until they flower. By allowing the parasites to escape, it also traps and kills the hatching larvae (Nayak *et al.,*2024).

7-Conclusion:

It is clear from this study that indiscriminate use of pesticides harms human health and the environment. Insects that are beneficial to the environment are destroyed by excessive pesticide use, resulting in pest outbreaks. Hence, to manage rice insect pests in fields, integrated pest management is the best alternative to pesticides. Therefore, it is necessary to understand the problems of farmers better so that the key constraints can be reduced and control strategies developed more adequately. Considering the fact that foreign exchange is spent on importing chemical pesticides, it is evident that Pakistan has a good potential for developing organic pest control technology and incentive programs. Work is available, and incentives to internalize pest control economies are strong, considering that foreign exchange is spent on importing chemical pesticides. As far as differences between IPM's different approaches are concerned, the participatory approach often proves to be more effective in solving the complex problems that small-scale, risk-prone rice farmers face on a local level. Integrated biological control approaches and the useful development of the IPM for farmers' resistance to host plants should be made use of. To discover the various eco-friendly integrated pest control methods, different studies must be conducted in different parts of the world. Farmers should be involved in pest control activities through the implementation of integrated pest control methods.

Reference:

[1]. Abbas, S., Kousar, S., Shirazi, S. A., Yaseen, M., & Latif, Y. (2022). Illuminating empirical evidence of climate change: impacts on rice production in the Punjab regions, Pakistan. *Agricultural Research*, 1-16.

[2]. Adhikari, B., Mohapatra, L. N., Mohapatra, S. D., Senapati, R., Singh, R., & Satapathy, S. N. (2022). The Effect of Differential Pest Load of Leaf Folder, Cnaphalocrocis medinalis (Guenee) on Extent of Leaf Damage and Alteration in Leaf Biochemical Composition in

Rice. *International Journal of Plant & Soil Science*, *34*(22), 1360-1368.

[3]. Afzal, H., Hassan, S., Bashir, M. K., & Ali, A. (2021). Estimation of Total factor productivity growth of agriculture sector in Pakistan. Growth, yield and economic analysis of dry-seeded basmati rice. *Sarhad Journal of Agriculture*, *37*(4), 1298-1305.

[4]. Ali, M. P., Kabir, M. M. M., Afrin, S., Nowrin, F., Haque, S. S., Haque, M. M., ... & Pittendrigh, B. R. (2019). Increased temperature induces leaffolder outbreak in rice field. *Journal of applied entomology*, *143*(8), 867-874.

[5]. Amer Rasul, M. Y., Mansoor-ul-Hasan, S. Z., Muhammad Sagheer, H. U., Ali, R. A., Ayub, M. B., Amjad, F., ... & Siddique, M. A. (2019). Population fluctuations of rice leaf folder, Cnaphalocrocis medinalis Guenée (Lepidoptera: Pyralidae) in relation to the meteorological factors. *Pak Entomol*, *41*(2), 141-145.

[6]. Ardestani, M. (2023). The Most Important Natural Enemies of Oryza Sativa L. Pests in Asian Rice Fields: A Survey. *Pests in Asian Rice Fields: A Survey (February 6, 2023)*.

[7]. Arsani, A. M. (2020). The future of Indonesia and global agriculture: Rice consumption and agricultural modernization. *Jurnal Litbang Sukowati: Media Penelitian dan Pengembangan*, *4*(1), 57-64.

[8]. Arun, A., Ambethgar, V., Kalyanasundaram, A., Loganathan, M., Senthil, K., & Mohanasundaram, A. (2023). Unleashing the potential of endophytic Beauveria bassiana as a biocontrol agent against rice leaf folder (Cnaphalocrocis medinalis). *Pharma Innov. J*, *12*(8), 2136-2141.

[9]. ARYA, P., Chander, S., Rajna, S., Tenguri, P., & Yele, Y. (2023). Unveiling the Population Dynamics of the Rice Leaf Folder (Cnaphalocrocis medinalis): A Life Table Study. *Indian Journal of Entomology*.

[10]. Aslam, M. S., Xue, P. H., Bashir, S., Alfakhri, Y., Nurunnabi, M., & Nguyen, V. C. (2021). Assessment of rice and wheat production efficiency based on data envelopment analysis. *Environmental Science and Pollution Research*, *28*, 38522-38534.

[11]. Ahmed, M., Shahbaz, M., Ahmed, F., ur Rehman, H., & Yasir, M. (2021). Comparative toxicity of some insecticides against rice leaf folder (Cnaphalorosis medinalis) under field situations. *Journal of Global Innovations in Agricultural Sciences*, *9*, 71-75.

[12]. Abdullah, T., Kuswinanti, T., Aminah, S. N., & Asman, A. (2021, March). The potential of Beauveria bassiana vuill to control rice leaf roller Cnaphalocrocis medinalis guenee. In *IOP Conference Series: Earth and Environmental Science* (Vol. 681, No. 1, p. 012037). IOP Publishing.

[13]. Babendreier, D., Tang, R., & Horgan, F. G. (2022). Prospects for Integrating augmentative and conservation biological control of leaffolders and stemborers in rice. *Agronomy*, *12*(12), 2958.

[14]. Behl, T., Kumar, S., Sehgal, A., Singh, S., Kumari, S., Brisc, M. C., ... & Bungau, S. (2021). Rice bran, an off-shoot to newer therapeutics in neurological disorders. *Biomedicine & Pharmacotherapy*, *140*, 111796.

[15]. Bilal, M., Hussain, M., Umer, M., Ejaz, N., Noushahi, H. A., Atta, B., & Rizwan, M. (2019). Population incidence and efficacy of chemical control against rice leaffolder (Cnaphnalocrocis medinalis Guenée) (Pyralidae: Lepidoptera). *Asian Pl. Res. J*, *2*, 1-7.

[16]. Bhardwaj, U., Kumar, R., Sarao, P. S., Mandal, K., & Singh, B. (2019). Bioefficacy of chlorantraniliprole against yellow stem borer and leaf folder and persistence in basmati rice. *Pesticide Research Journal*, *31*(2), 233-241.

[17]. Bodlah, M. A., Gu, L. L., Wang, G. R., & Liu, X. D. (2019). Rice leaf folder larvae alter their shelter-building behavior and shelter structure in response to heat stress. *Journal of economic entomology*, *112*(1), 149-155.

[18]. Bonaventure, J. (2020). *Management options for Rice Stem borers in irrigated low land rice ecosystems in Tanzania* (Doctoral dissertation, Sokoine University of Agriculture Morogoro, Tanzania).

[19]. Baruah, M., Dutta, B. C., Borah, S. R., & Bharali, A. (2023). Organic management approaches of stem borer in rice ecosystem of Assam.

[20]. Basit, A., Farhan, M., Essa, M., Abbas, M., Wang, Y., Zhao, D. G., ... & Hargis, B. M. (2021). Effect of two protein elicitors extracted from Alternaria tenuissima and Beauveria bassiana against rice leaf folder (Marasmia exigua). *Journal of King Saud University-Science*, *33*(8), 101652.

[21]. Chatterjee, S., Gangopadhyay, C., Bandyopadhyay, P., Bhowmick, M. K., Roy, S. K., Majumder, A., ... & Chattopadhyay, C. (2021). Input-based assessment on integrated

pest management for transplanted rice (Oryza sativa) in India. *Crop Protection*, *141*, 105444.

[22]. Chandio, A. A., Magsi, H., & Ozturk, I. (2020). Examining the effects of climate change on rice production: case study of Pakistan. *Environmental Science and Pollution Research*, *27*, 7812-7822.

[23]. Chintalapati, P., Balakrishnan, D., Venu Gopal Nammi, T. V., Javvaji, S., Muthusamy, S. K., Lella Venkata, S. R., ... & Katti, G. (2019). Phenotyping and genotype× environment interaction of resistance to leaffolder, Cnaphalocrocis medinalis Guenee (Lepidoptera: Pyralidae) in rice. *Frontiers in Plant Science*, *10*, 49.

[24]. Chakravorty, S., Muralikrishnan, L., & Rana, R. (2023). Pest management modules for basmati rice and farmer's perception. *Indian Journal of Entomology*, 303-307.

[25]. DALVI, N. S. (2020). *EFFECT OF SOWING TIME AND ESTABLISHMENT METHODS ON PEST COMPLEX OF RICE VARIETIES (Accession No. T06879)* (Doctoral dissertation, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli Dist-Ratnagiri).

[26]. Dey, S. (2020). Relationship between Rice Production, Fisheries Production and Gross Domestic PRODUCT (GDP) IN Bangladesh: Co Integrating Regression Analysis (1971-2017). *International Journal of Economics and Financial Issues*, *1*(4), 201-216.

[27]. Dutta, S., A. Hossain, and N. Roy. "Bioecology and management of major insect pests of rice in West Bengal." (2024): 300-318.

[28]. Dwivedi, S. A., & Tomer, A. (2021). Mass production and quality of biological control agents for pest management. *Recent Developments in Microbial Technologies*, 243-266.

[29]. Das, J., Sahoo, B., Panigrahy, M., & Dangar, T. K. (2023). Genetic polymorphism and plant growth promotion traits of potent fungal entomopathogens of rice leaf folder. *Archives of Microbiology*, *205*(5), 216.

[30]. Fahad, S., Adnan, M., Noor, M., Arif, M., Alam, M., Khan, I. A., ... & Wang, D. (2019). Major constraints for global rice production. In *Advances in rice research for abiotic stress tolerance* (pp. 1-22). Woodhead Publishing.

[31]. Gadal, N., Shrestha, J., Poudel, M. N., & Pokharel, B. (2019). A review on production status and growing environments of rice in Nepal and in the world. *Archives of Agriculture and Environmental Science*, *4*(1), 83-87.

[32]. Gairhe, S., Gauchan, D., & Timsina, K. P. (2021). Temporal dynamics of rice production and import in Nepal. *Journal of Nepal Agricultural Research Council*.

[33]. Guo, X., Zhou, Q. Y., Ru, M. M., Cao, B., Huang, X., Zheng, X. S., & Zhu, P. Y. (2024). Effects of a Bank Plant on the Control of Rice Planthoppers: A Field Study.

[34]. Hajjar, M. J., Ahmed, N., Alhudaib, K. A., & Ullah, H. (2023). Integrated insect pest management techniques for rice. *Sustainability*, *15*(5), 4499.

[35]. Hajjar, M. J., Ahmed, N., Alhudaib, K. A., & Ullah, H. (2023). Integrated insect pest management techniques for rice. *Sustainability*, *15*(5), 4499.

[36]. Hoang, V. N., Nguyen, T. T., Wilson, C., Ho, T. Q., & Khanal, U. (2021). Scale and scope economies in small household rice farming in Vietnam. *Journal of Integrative Agriculture*, *20*(12), 3339-3351.

[37]. Huan, L. I. U., & Mao-Lin, H. O. U. (2019). Progress in research on the relationship between host plants and the occurrence of the rice leaf folder and the degree of crop damage caused by this pest. *Chinese Journal of Applied Entomology*, *56*(6).

[38]. Ilias, N. N., Rozalli, N. H. M., Vy, N. H. T., & Eng, H. Y. (2020). Rice bran of different rice varieties in Malaysia: Analysis of proximate compositions, antioxidative properties and fatty acid profile for data compilation. *Advances in Agricultural and Food Research Journal*, *1*(2).

[39]. Iqbal, S. (2020). Insect, pest and disease management in rice. *Austin Publication, Irving, TX*, *85*.

[40]. Javed, I., Rehman, A., Nabi, I., Razzaq, A., Saqib, R., Bakhsh, A., ... & Luqman, M. (2020). Performance and macroeconomic determinants of basmati rice exports from Pakistan. *Sarhad Journal of Agriculture*, *36*(2), 617-624.

[41]. Jian, X. U., Qin, L. I. U., LI, C. M., & HAN, G. J. (2019). Field effect of Cnaphalocrocis medinalis granulovirus (CnmeGV) on the pest of rice leaffolder. *Journal of integrative agriculture*, *18*(9), 2115-2122.

[42]. Jasrotia, P., Khippal, A., Yadav, J., Kashyap, P. L., Kumar, S., & Singh, G. P. (2019). Effect of weather variables on the incidence of yellow stem borer (Scirpophaga incertulas W.) and leaf folder (Cnaphalocrocis medinalis G.) in rice. *Journal of Cereal Research*, *11*(3), 247-251.

[43]. Javvaji, S., Maheswari Telugu, U., Damarla Bala Venkata, R., Sheshu Madhav, M., Rathod, S., & Chintalapati, P. (2021). Characterization of resistance to rice leaf folder, Cnaphalocrocis

medinalis, in mutant Samba Mahsuri rice lines. *Entomologia Experimentalis et Applicata*, *169*(9), 859-875.

[44]. Jaglan, M. S., Chaudhary, O. P., Singh, S., Ahlawat, S., & Yadav, J. (2024). Comparative bio-efficacy of flubendiamide 20 WG against yellow stem borer, Scirpophaga incertulas Walker and leaf folder, Cnaphalocrocis medinalis Guenee, safety to natural enemies and residues in basmati rice under field conditions of semi-arid region of India. *International Journal of Tropical Insect Science*, 1-16.

[45]. Kamakshi, N., Rajasekhar, P., Rao, G. R., Kumar, P. A., & Harathi, P. N. (2020). Diversity of rice leaffolder species and its natural enemies in SPSR Nellore district of Andhra Pradesh. *Indian Journal of Plant Protection*, *43*(2).

[46]. Kashid, N. V., Kokare, A. A., Sthool, V. A., Deshmukh, A. P., & Jadhav, J. D. (2022). Pest Incidence as Influenced by Different Sowing Methods and Varieties of Rice. *Journal of Agriculture Research and Technology*, *47*, 66-71.

[47]. Khushi, H., Moniruzzaman, M., & Tabassum, N. (2020). Growth scenarios oF area, production and yield of rice in Bangladesh. *Bangladesh Journal of Agricultural Economics*, *41*(2), 81-97.

[48]. Kumar, A., Ram, L., Singh, R., & Singh, B. (2019). Impact of crop establishment methods on rice insect pest's incidence in Indo Gangetic Plain (IGP). *The Indian Journal of Agricultural Sciences*, *89*(3), 475-481.

[49]. Karthikeyan, K. (2019). Efficacy of new insecticide molecules against yellow stem borer and leaf folder in rice. *Journal of Rice Research*, *12*(1), 52.

[50]. Karenina, T., Herlinda, S., Irsan, C., & Pujiastuti, Y. (2019). Abundance and species diversity of predatory arthropods inhabiting rice of refuge habitats and synthetic insecticide application in freshwater swamps in South Sumatra, Indonesia. *Biodiversitas Journal of Biological Diversity*, *20*(8).

[51]. Laiprakobsup, T. (2019). The policy effect of government assistance on the rice production in Southeast Asia: Comparative case studies of Thailand, Vietnam, and the Philippines. *Development Studies Research*, *6*(1), 1-12.

[52]. Lella, N., & Jagadeesh, K. (2023). Ecological IPM strategies for management of pests of rice. *The Pharma Innovation*, 3814-3818.

[53]. Liu, H., Han, Y., Zhong, Y., Ali, A., & Hou, M. (2021). Preference and performance of the rice leaf folder, Cnaphalocrocis medinalis, in relation to rice developmental stage. *Entomologia Experimentalis et Applicata*, *169*(8), 701-710.

[54]. Iamba, K. (2021). Biological role of marigold (Tagetes erecta L.) in habitat manipulation and sustenance of natural enemy populations in upland rice. *Arthropods*, *10*(3), 66.

[55]. Mahesh, P., Srikanth, J., Chandran, K., Singaravelu, B., Salin, K. P., Jayabose, C., & Balan, S. (2019). Occurrence, damage pattern and status of the rice leaf folder Cnaphalocrocis ruralis Walker (Lepidoptera: Crambidae) in Erianthus spp. in India. *Experimental agriculture*, *55*(3), 471-483.

[56]. Maitah, K., Smutka, L., Sahatqija, J., Maitah, M., & Phuong Anh, N. (2020). Rice as a determinant of Vietnamese economic sustainability. *Sustainability*, *12*(12), 5123.

[57]. Manik, M. H. (2023). Movement of the economy of Bangladesh with its sector-wise contribution and growth rate. *Journal of Production, Operations Management and Economics*, *3*(02), 1-8.

[58]. Manikandan, N., Kennedy, J. S., & Geethalakshmi, V. (2023). Stage Specific Life Table of Rice Leaffolder, Cnaphalocrocis medinalis (Guen.) at Different Temperature Regimes. *International Journal of Environment and Climate Change*, *13*(3), 200-205.

[59]. Marina, R., Nur Azura, A., Lau, W. H., & Yaakop, S. (2019). Life table and demographic parameters of rice leaffolder, Cnaphalocrocis medinalis Guenee (Lepidoptera: Pyralidae). *Serangga*, *24*(2), 49-60.

[60]. Marina, R., Nur Azura, A., Lau, W. H., & Yaakop, S. (2019). Life table and demographic parameters of rice leaffolder, Cnaphalocrocis medinalis Guenee (Lepidoptera: Pyralidae). *Serangga*, *24*(2), 49-60.

[61]. McClung, A. M., Edwards, J. D., Jia, M. H., Huggins, T. D., Bockelman, H. E., Ali, M. L., & Eizenga, G. C. (2020). Enhancing the searchability, breeding utility, and efficient management of germplasm accessions in the USDA− ARS rice collection. *Crop Science*, *60*(6), 3191-3211.

[62]. Morshed, M. N., Howlader, M. T. H., Rafiqul, M., Islam, N. S., & Hera, M. H. R. (2020). Effect of abiotic factors on the seasonal incidence of Rice yellow stem borer, Scirpophaga incertulas (Walker) and rice leaf folder, Cnaphalocrocis medinalis (Guenee) population at the south-east coastal region of. *J. Entomol. Zool. Stud*, *8*(3), 1321-1326.

[63]. Moses, S., Kishor, D. R., Misra, A. K., & Ahmad, M. A. (2019). Identification and quantification of major insect pests of rice and their natural enemies. *Current Journal of Applied Science and Technology*, *32*(2), 1-10.

[64]. Morshed, M. N., Howlader, M. T. H., Rafiqul, M., Islam, N. S., & Hera, M. H. R. (2020). Effect of abiotic factors on the seasonal incidence of Rice yellow stem borer, Scirpophaga incertulas (Walker) and rice leaf folder, Cnaphalocrocis medinalis (Guenee) population at the south-east coastal region of. *J. Entomol. Zool. Stud*, *8*(3), 1321-1326.

[65]. Mitku, G., Birhan, M., & Yalew, D. (2021). Incidence and Distribution of Rice Insect Pests and their Natural Enemies in Rice Growing Area of South Gondar, Ethiopia. *International Journal of Research in Agricultural Sciences*, *8*(3), 132-139.

[66]. Morya, G. P., & Kumar, R. (2019). Screening of rice germplasm resistance against major insect pests under eastern Uttar Pradesh conditions. *Journal of Entomology and Zoology Studies*, *7*(6), 706-712.

[67]. Naseer, M. A. U. R., Ashfaq, M., Razzaq, A., & Ali, Q. (2020). Comparison of water use efficiency, profitability and consumer preferences of different rice varieties in Punjab, Pakistan. *Paddy and Water Environment*, *18*(1), 273-282.

[68]. Nagdev, P., Chandrakar, H. K., & Ganguli, J. (2022). Seasonal incidence and management of rice leaf folder, Cnaphalocasis medinalis (Guenee) through bio-intensive pest management at Raipur, Chhattisgarh. *Journal of Experimental Zoology India*, *25*(1).

[69]. Nilamudeen, M., & Sudharma, K. (2020). Entomopathogenic fungi for managing the Rice leaf roller, Cnaphalocrocis medinalis Guen.

[70]. Nayak, A. K., Sasmal, A., Golive, P., Dash, S. S., Rao, K. R., & Das Mohapatra, S. (2024). Unraveling stability in rice genotypes for resistance against leaffolder (Cnaphalocrocis medinalis) under varied environmental conditions. *Cereal Research Communications*, 1-9.

[71]. Rajadurai, G., Sudhakar, D., Varanavasiappan, S., Balakrishnan, N., Udayasuriyan, V., & Natarajan, N. (2023). Adult oviposition preference and larval performance of Cnaphalocrocis medinalis Guenee (Pyralidae: Lepidoptera) on transgenic Bt rice. *International Journal of Tropical Insect Science*, *43*(3), 1037-1048.

[72]. Rautaray, B. K., Bhattacharya, S., Panigrahi, D., Panda, T., & Dash, S. R. (2019). Effect of planting dates on incidence of rice leaf folder and its impact on grain yield in north eastern coastal plains of Odisha. *Journal of Entomology and Zoology Studies*, *7*(5), 1287-1290.

[73]. Reddy, B. S., Chaudhari, B. N., & Sanap, P. V. (2023). Evaluation of Insecticides for the management of leaf folder in rice crop. In *Biological Forum-An International Journal* (Vol. 15, No. 1, pp. 182-188).

[74]. Rizwan, M., Qing, P., Iram, S., Nazir, A., & Wang, Q. (2019). *Why and for what? An evidence of agriculture credit demand among rice farmers in Pakistan* (No. 995). ADBI Working Paper Series.

[75]. Roseli, M., Adam, N. A., Hong, L. W., & Yaakop, S. (2021). Population Fluctuation of Rice Leaffolder,(Cnaphalocrocis medinalis) in Two Consecutive Rice Seasons. *Journal Of Agrobiotechnology*, *12*(1), 10-22.

[76]. Reuolin, S. J., Muthukrishnan, N., Paramasivam, M., Subramanian, K. S., & Maragatham, N. (2021). Influence of rice crop stage on the distribution of hymenopteran parasitoids of insect pests. *Entomon*, *46*(2), 113-120.

[77]. Sahini, M. G., & Mutegoa, E. (2023). Extraction, phytochemistry, nutritional, and therapeutical potentials of rice bran oil: A review. *Phytomedicine Plus*, 100453.

[78]. Sapwarobol, S., Saphyakhajorn, W., & Astina, J. (2021). Biological functions and activities of rice bran as a functional ingredient: A review. *Nutrition and metabolic insights*, *14*, 11786388211058559.

[79]. Sarwar, N., Ahmad, S., Khan, M. A., & Hasanuzzaman, M. (2022). World rice production: an overview. *Modern Techniques of Rice Crop Production*, 3-12.

[80]. Shah, M. A. A., Özel, G., Chesneau, C., Mohsin, M., Jamal, F., & Bhatti, M. F. (2020). A statistical study of the determinants of rice crop production in Pakistan. *Pakistan Journal of Agricultural Research*, *33*(1), 97-105.

[81]. Singh, R. K. (2021). Comparative Study of Direct Seeded Rice and Transplanted Rice Against Incidence and Intensity of Stem Borer and Leaf Folder.

[82]. Spaggiari, M., Dall'Asta, C., Galaverna, G., & del Castillo Bilbao, M. D. (2021). Rice bran by-product: From valorization strategies to nutritional perspectives. *Foods*, *10*(1), 85.

[83]. Surendran, U., Raja, P., Jayakumar, M., & Subramoniam, S. R. (2021). Use of efficient

water saving techniques for production of rice in India under climate change scenario: A critical review. *Journal of Cleaner Production*, *309*, 127272.

[84]. Senthil-Nathan, S. (2019). Effect of methyl jasmonate (MeJA)-induced defenses in rice against the rice leaffolder Cnaphalocrocis medinalis (Guenèe)(Lepidoptera: Pyralidae). *Pest management science*, *75*(2), 460-465.

[85]. Samrit, R. M., Chaudhari, B. N., & Khedikar, A. S. (2019). Seasonal incidence of leaf folder Cnaphalocrocis medinalis (Guence) and its correlation with weather parameters and natural enemies. *Journal of Pharmacognosy and Phytochemistry*, *8*(5), 737-739.

[86]. Soomro, A. S., Mazari, S. N., Hulio, M. H., Soomro, J. A., & Junejo, G. Q. (2020). Efficacy of different insecticides against rice leaf folder (Cnaphalorosis medinalis) under field conditions. *International Journal of Applied Sciences and Biotechnology*, *8*(2), 211-215.

[87]. Satheesha, H. Y., Kumar, L. V., Navi, S., Raveendra, H. R., & Somu, G. (2020). Incidence of leafhoppers in rice in relation to meteorological parameters. *IJCS*, *8*(6), 1089-1092.

[88]. Sharma, S., Shera, P. S., & Sangha, K. S. (2020). Species composition of parasitoids and predators in two rice agro-farming systems—effect of ecological intensification. *International journal of tropical insect science*, *40*(2), 233-238.

[89]. Shyamrao, I. D., & Raghuraman, M. (2019). Management of leaf folders, Cnaphalocrocis medinalis (Linnaeus) through conventional and newer insecticides in rice ecosystem of Varanasi region. *Journal of Entomology and Zoology Studies*, *7*(2), 206-209.

[90]. Yu, Y., Zhang, J., Wang, J., & Sun, B. (2019). The anti-cancer activity and potential clinical application of rice bran extracts and fermentation products. *RSC advances*, *9*(31), 18060-18069.

[91]. Zang, L. S., Wang, S., Zhang, F., & Desneux, N. (2021). Biological control with Trichogramma in China: History, present status, and perspectives. *Annual review of entomology*, *66*, 463-484.

[92]. Zhang, F. X., Zhang, Z. F., Zhang, Y., & Wu, W. J. (2019). Adult oviposition preferences and larval performance of rice leaf folder, Cnaphalocrocis medinalis on rice and non-rice graminaceous plants. *Arthropod-plant interactions*, *13*, 31-40.

[93]. Zhou, H., Xia, D., & He, Y. (2020). Rice grain quality—traditional traits for high quality rice and health-plus substances. *Molecular Breeding*, *40*, 1-17.

[94]. Panse, R. K., & Rajak, S. K. (2022). 3.17 Bioecology of Lepidopteran Pests and Natural Enemies in Rice Ecosystem of Balaghat District. *Sustainable Agricultural Innovations for Resilient Agri-Food Systems*, 182.

[95]. Quan, P. Q., Li, M. Z., Wang, G. R., Gu, L. L., & Liu, X. D. (2020). Comparative transcriptome analysis of the rice leaf folder (Cnaphalocrocis medinalis) to heat acclimation. *BMC genomics*, *21*, 1-12.

[96]. Pathak, M., Patidar, R. K., Shakywar, R. C., Riba, T., Sehgal, M., & Singh, J. P. (2020). Biodiversity of natural enemies in rice under Siang belt of Arunachal Pradesh. *ANNALS OF PLANT PROTECTION SCIENCES*, *28*(3), 261-262.

[97]. Zhu, P., Lu, Z., Chen, G., & Heong, K. L. (2020). Enhancement of Natural Control Ecosystem Services for Insect Pest Management by Manipulating Biodiversity in Rice-Based Ecosystems. *Integrative Biological Control: Ecostacking for Enhanced Ecosystem Services*, 73-84.

6/22/2024