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Review Article

Population Dynamics, Yield Loss and Management of Major Insect Pests of Rice (*Oryza sativa* L.) Crop: A Review

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Abstract

Rice insect pests are a major biological constraint in rice production. They affect every part of the rice plant throughout all growth stages, leading to decreased productivity, yield, and grain quality. Over 100 species of insect pests target rice crops at different growth stages. From these insect pests around 15 to 20 cause economic damage to the rice crop. Some of the insect pests that can lead to considerable yield losses are grasshoppers, plant hoppers, leaf hoppers, leaf folder, stem borer, gall midge, rice hispa, whorl maggot, grain-sucking bugs, rice gundhi bugs, and green stink bugs. The yield loss of rice varies from one production season to another and from one area to another due to the fluctuating populations of insect pests. The population dynamics of insect pests fluctuate along with the varying conditions of the environmental (abiotic) factors. The development of sustainable rice crop protection strategies, along with an understanding of insect pest population dynamics and the influence of abiotic and biotic factors on pest incidence, is crucial for the timely adoption of different management practices. Therefore, understanding rice insect pest population dynamics regarding abiotic factors is essential and can be used in cultural, biological, host plant resistance, chemical, and integrated pest management approaches. The dynamic population of rice insect pests is varied, and their damaging stage is also different. It is recommended that appropriate control methods for insect pests during the rice crop growing season should be taken to reduce the yield loss of rice.

Keywords

Rice, Insect Pests, Yield Loss, Population Dynamics, Management Methods

1. Introduction

Rice (*Oryza sativa* L.) belongs to the genus *Oryza* and the grass family [1], and it is one of the most significant cereal crops globally. It serves as a staple food for over half of the global population [2] and is also a major source of employment and income for those who live in rural areas of developing countries. This crop is grown in nearly all tropical, subtropical, and temperate countries of the world [3]. The people living in sub-Saharan Africa are increasingly incorporating rice into their regular diets. This dietary shift directly impacts the region's poorest consumers, many of whom rely on rice as their primary food source and means of income, making them particularly vulnerable to fluctuations in rice availability and price [4]. In Ethiopia, rice is a vital staple food crop cultivated in swampy areas where other crops do not grow. However, its cultivation and use as a food source have only recently emerged as significant practices in the country [5].

The yield of rice is significantly impacted each year by various insect pests, with over 100 insect species and 15 to 20

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of them causing economic damage [6]. The major insect pests that damage the rice crop and cause significant yield losses are stem borer, grain-sucking bugs, leaf hoppers, gall midge, grasshoppers, plant hoppers, rice hispa, whorl maggot, green stink bugs, rice gundhi bugs, and leaf folder [7, 8]. The rice insect pests cause high yield loss every year by attacking almost all parts of the rice crop and if they are not managed in time they cause huge yield losses. However, the yield loss estimates due to this rice insect pest vary greatly from one production season to another [9].

Weather and climate conditions have a major impact on the dynamics and status of insect pest populations [10]. Insect pests of crop and their population dynamic are affected by biotic as well as abiotic factors [11]. Climate change significantly impacts insect pest populations. Factors such as temperature, relative humidity, and rainfall play a crucial role in determining the status and outbreaks of insect pests [12, 13]. Awareness of abiotic factors such as temperature, day length, precipitation, and relative humidity can be vital for forecasting and predicting the severity of insect pest populations, which is essential for developing effective control strategies. Understanding the dynamics of insect pest populations is crucial for creating long-term crop protection plans as well as for analyzing and predicting insect pest population outbreaks [14].

Populations of insect pests fluctuate based on the dynamic condition of their environment [15]. Thus, the relation of important factors both biotic and abiotic on insect pest population dynamics could be used to forecast the insect populations and it is vital to warrant timely vigilance to deal with future pest problems and prevent crop losses [16]. Studying the population dynamics of rice insect pests is a crucial aspect of pest management. It provides valuable information that can enhance cultural practices, host plant resistance, chemical, and integrated pest management methods. Therefore, this paper aims to review the population dynamics of major insect pests of rice for the timely implementation of different management practices to minimize the yield loss of rice crops.

2. Population Dynamics of Major Insect Pests of Rice

Population dynamics refers to the study of changes in species composition and numbers over time [17]. The population dynamics, distribution, abundance, intensity, and feeding behavior of insect pests are all impacted by climatic and weather changes [18]. According to Singh et al. [11] revealed that the insect pest population dynamics are influenced by both biotic and abiotic factors such as temperature, relative humidity, and rainfall. The population dynamics of rice insect pests fluctuate according to the varying or dynamic conditions of the environment [16].

The population dynamics of rice insect pests gradually increased from the tillering stage to the late vegetative stage and were found to be highest during the second week of August. Following this, the population gradually decreased to the ripening and early growth stages, rather than the late growth stage of the plant, which was adversely affected by the pests [7]. The maximum population of brown plant hoppers (BPH) occurred from the last week of August up to the third week of September at the minimum and maximum temperatures of 24.8 ℃ to 26.8 ℃ and 31.6 ℃ to 34.2 ℃, respectively [19] and the population was declined as the crop reached the harvesting stage [3]. According to Sulagitti et al. [20], BPH first appeared in rice crops during the first week of August, peaking in the second week of October. Their population declined as the crop reached the harvesting stage around the third week of November. Figure 1 indicates that BPH exhibited a positive, non-significant correlation with rainfall, temperature, and relative humidity.

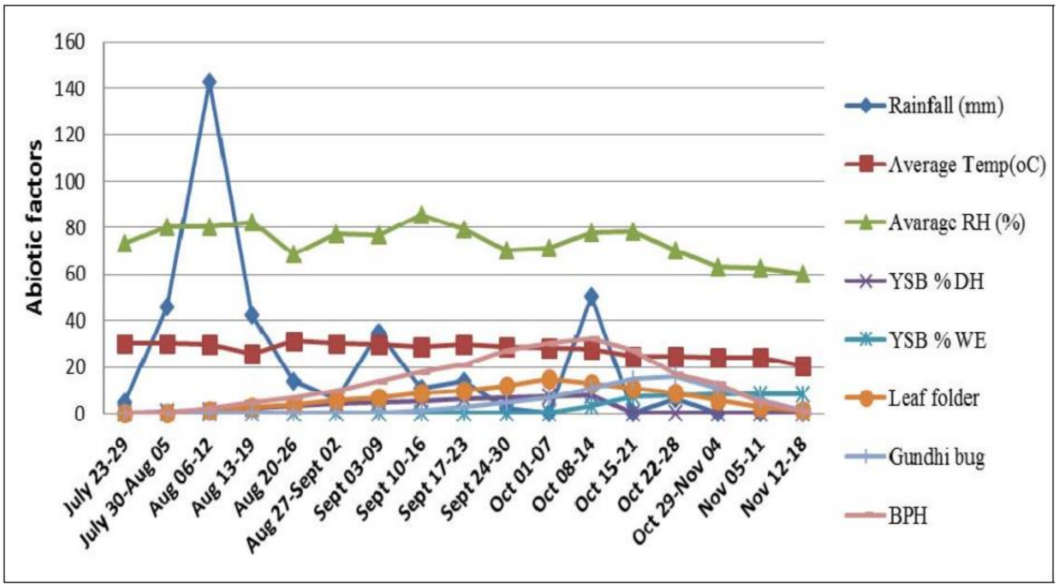

Figure 1. *Influence of abiotic factors on the population of different insect pests in rice crop [20].*

The leaf folder population was at its highest during the latter part of August and the early part of September [21]. A research conducted by Sulagitti et al. [20], the incidence of leaf folder infestation began during the first fortnight of August, and the pest populations reached their highest level during the first week of October (Figure 1). The leaf folder population began to decline once the crop reached the maturity stage. Heavy fertilizer use contributed to an increase in the leaf folder's multiplication rate, while higher humidity and rainfall also boosted its population in rice fields [3]. Correlation studies on the leaf folder population revealed negative correlations with minimum temperature, relative humidity, and rainfall. Conversely, damage caused by the leaf folder showed positive correlations with maximum temperature and morning relative humidity [22].

Yellow stem borer (YSB) occurred in September with the peak incidence in October to November [23]. According to Sulagitti et al. [20], YSB appeared in the rice crop during the last week of July, with its population peaking in the second week of October and then decreasing (Figure 1). However, the most intense activity of the YSB occurred during the first week of September, indicating that the peak pest activity occurred from September to October. Additionally, the incidence of YSB demonstrated a significant positive correlation with evening and average relative humidity, while showing a positive but non-significant correlation with morning relative humidity and rainfall. Compared to the reproductive stage, incidences of the YSB are higher during the vegetative stage. The population gradually increased with the advancement of the crop age and reached the peak in the first week of October when the crop was in the reproductive stage. Outbreaks of YSB were associated with low temperatures, high humidity, and significant rainfall [24].

The population of the gundhi bug peaks when the crop reaches the milky stage during the first fortnight of October [21]. According to Bhattacharjee and Ray [25], the highest population levels and severe infestations of the gundhi bug were observed from September to October. Sulagitti et al. [20] observed that the gundhi bug was first noted during the second week of September, with its population peaking in the fourth week of October (Figure 1). The gundhi bug exhibited a negative correlation with minimum temperature and wind velocity. High humidity, rainfall, and diurnal temperature fluctuations during the milky stage of paddy promote gundhi bug infestations [19]. Additionally, another study showed that the maximum population of the gundhi bug was observed on the seventh of October [26].

The incidence of green leaf hoppers was found in the middle of August and then increased in the last week of August. Green leaf hoppers are most active during the vegetative phase of rice growth, with their incidence gradually declining as the crop approaches the harvesting stage [3]. Infestation by whorl maggots begins in the early stages of the crop, peaking in the second fortnight of July, when damage is most severe [21]. The incidence of rice hispa was recorded from the last week of July to mid-August and absent in September [7]. Rice hispa damage was observed immediately after transplanting and exhibited a positive correlation with rainfall and wind velocity [19]. The population of grasshoppers showed a negative correlation with minimum temperature and rainfall, while positively correlating with maximum temperature [22].

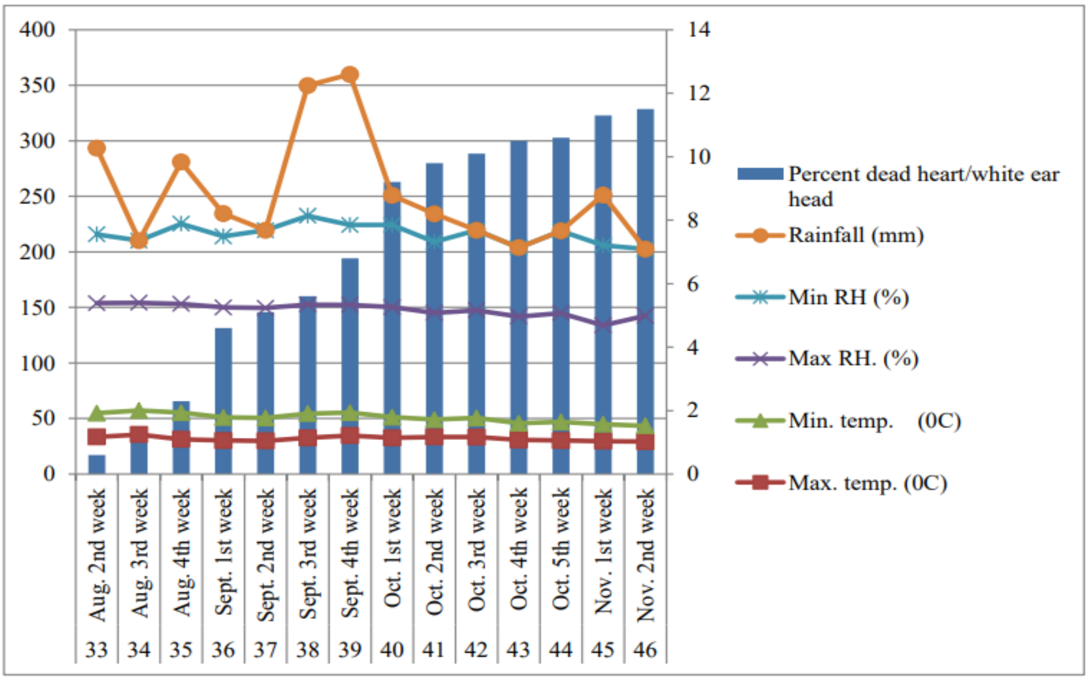

Figure 2. *Population dynamics of rice stem borer in rice crop [27].*

The population dynamics of rice stem borers, like that of other species, fluctuate in response to changing environmental conditions [16]. These notorious pests significantly damage rice crops, making them one of the most important insect pests of rice crops. They also target rice crops during the reproductive stage, causing the formation of white ear heads. The peak occurrence of white ear heads was recorded in the second fortnight of October [21]. Solanki et al. [27] reported an average number of larvae or pupae per dead heart found in the first week of October and the infestation appeared on the crop in the second week of August (Figure 2). Stem borers attack rice nurseries and transplanted crops but their activity is observed at peak in September [28].

3. Yield Loss of Rice Due to Insect Pests

Rice is cultivated in various agro-climatic conditions, and its yield is influenced by numerous factors, with climatic conditions and pest outbreaks being the most significant factors. The crop is damaged by a lot of insect pest species and some of the insect pests cause economic damage. If these insect pests are not controlled in time, they cause huge grain yield losses, which may vary from 20 to 50% (Krishi, 2005 cited in [29]. However, the actual yield lost to insect pests can vary significantly from one production season to another [9]. In certain regions where rice is grown, the insects cause significant damage that lowers the rice yield economically; however, in other regions, these insects are of low significance [30]. Other studies showed that insect pests alone cause approximately 30-40% of annual yield loss in rice, affecting nearly all aerial parts of the plants as well as their root systems in the soil (Henrich et al., 1979; Dhaliwal et al., 1984 cited in [22].

The damaging insect pests affecting rice yield include the yellow stem borer, pink stem borer, leaf hopper, leaf folder, grasshopper, stem borer, and plant hopper. The rice stem borer is found in all rice-growing countries, with invasion symptoms varying according to the crop's age. In young plants, damage often leads to the death of growing points, resulting in a typical "dead heart" formation. Severe infestation can empty panicle formation. Yield losses due to stem borers depend on factors such as pest population density, timing of damage, and growing conditions [30]. In Asia, losses have been reported at 4% to 7%, with individual fields in Japan experiencing up to 100% loss [31]. Stem borers attack rice nurseries and transplanted crops but their activity is observed at its peak in September [28] and causes severe losses to the crop. Striped stem borers and yellow stem borers are considered the most serious pests. The estimated yield loss due to yellow stem borer ranges from 20 to 70% [13]. Cheng et al. [32] found that stem borers consistently cause yield losses of around 20% in rice-producing countries. According to Kega et al. [33], failing to implement control measures during the early stages of rice growth can result in yield losses of 50% to 90% due to the stem borer *M. separatella*.

Sucking insect pests like white-backed plant hopper and brown plant hopper constitute nearly 35% of the insect pests affecting rice. Plant hoppers suck the phloem sap of the rice plants, leading to significant yield losses [34]. The white-backed plant hopper specifically damages phloem tissues, resulting in a condition known as hopper burn, which impairs growth and reduces overall crop production [35]. Rice plant hoppers are among the most destructive agricultural insect pests, capable of damaging approximately 20 million hectares annually [36, 37].

Yield losses attributed to rice insect pests in developing countries, particularly in sub-Saharan Africa, are estimated at around 20%. In Kenya, for example, losses can reach up to 45% [38]. The average area affected by the rice pests also ranges from a low 11% in Guinea to a high 49% in Kenya [39]. Among the key pests, stem borers feed on the leaves and stems of rice plants. Additionally, rice gall midges are also significant pests in sub-Saharan Africa and are a primary focus for control efforts in rice fields [40]. Rice bugs are also another serious threat as grain-sucking pests, particularly during the milky stage of rice, when they damage crops by sucking sap from developing spikelets. In contrast, root-feeding insects are considered less important in terms of overall impact [39].

In Ethiopia especially in South Gondar stem borers, stalk-eyed flies, leaf hoppers, rice bugs, stink bugs, whorl maggots, grasshoppers, rice leaf folders, leaf worms, and termites are some of the insect pests of rice. The majority of these mentioned insect pest infestations were below 10%, there may not have been significant economic losses from the insects. This could be the presence of an effective natural enemy of the insect pests [29]. The rice stem borer and termites are common insect pests of rice. Termites occur at the harvesting stage of lowland rice and at any growth stage of upland rice are common in Ethiopia [4].

4. Management of Rice Insect Pests

4.1. Cultural Practices

Cultural control involves the modification of production practices to create an environment less favorable for insect pest invasion, reproduction, survival, and dispersal. It aims to attain reductions in the insect pest population. Most traditional agronomic practices play a dual importance in enhancing crop production and suppressing pests. These methods are needed to decrease insect pest populations and certain farm activities could be adjusted to create an environment antagonistic to insect pests but favorable for rice crop production. Cultural practices such as modification of sowing date, plant density, crop rotation, trap crop, weeding, straw and stubble destruction, mixed cropping, flooding, tillage, fertilizer, and water management may prevent, or even delay, the buildup of the rice insect pests [30, 4].

An understanding of the life history and habitats of the insect and its plant host is necessary for the development of the cultural management method. Farmers should decide which cultural techniques are best for their location such as direct seeding or transplanting seedlings in a swamp environment, time of planting, and others. A cultural control method is regarded as the first line of defense against insect pests [41]. They are particularly suitable for farmers in developing countries, as they are easy to implement, cost-effective, and compatible with other pest control methods [42].

The right choice of sowing date is essential to get a high rice yield and in the meantime to avoid the periods of destructive attacks of the rice insect pests especially, rice leaf miners [30]. Early planting can reduce the incidence of various insect pests, including stem borers. In Pakistan, the timing of sowing influenced the occurrence of stem borers, with early-planted rice showing the most resistance and the lowest levels of borer infestation compared to other planting times [43]. The elimination of rice stubbles, destruction of alternative pest hosts, and appropriate irrigation and others are vital for the management of stem borers and other rice insect pests. This method is an economical way of stem borer management which seems to be pertinent to most resource-poor farmers. Control of stem borers through cultural methods is closely linked to understanding their biology, ecology, and interactions with their host crops [41].

Other research studies in Tanzania showed that raising nitrogen rates beyond 80 kg/ha has been reported to increase damage caused by rice stem borers, such as *C. partellus*, and *S. calamistis*, while also reducing grain yield. Thus, fertilization with nitrogen directly affects rice yield; however, over-fertilization may promote stem borer damage. For maximum yield, nitrogen fertilization of rice crops is still encouraged, but only at optimal levels [44].

4.2. Host Plant Resistance

Host plant resistance refers to the plant's ability to defend itself by using physical barriers that limit the feeding of insect pests. It is the most effective, economical, practical, and easiest means of managing insect pests. Additionally, it is compatible with other pest control methods. The development of insect pest-resistant varieties should be the highest priority as well as an important component of integrated pest management. The development and use of pest-resistant varieties will not only reduce pesticide usage but also slow the rate at which pests develop resistance to pesticides. Additionally, it will enhance the activity of beneficial microorganisms, reduce pesticide residues in food and food products, and create a safer living environment [45].

Rice varieties showing resistance or moderate resistance to the considered insects were promoted in the improvement program depending on the evaluation of other traits required by the plant breeders. Several promising lines were resistant to rice stem borer, but most of the new plant types like super rice materials were highly susceptible. All hybrid rice entries exhibited moderate susceptibility to insect pests. Farmers in Africa rely on traditional varieties, many of which are low-yielding and less resistant to stem borers [46]. Advancements in biotechnology can support the development of resistant materials and accelerate the transfer of genes to improve new genotypes that are resistant to rice stem borer damage [44].

4.3. Biological Control

Biological control is a method that utilizes living organisms to manage insect pests. It involves employing natural enemies, such as predators, parasitoids, pathogens, antagonists, or competing populations, to suppress pest populations, making them less abundant and less harmful [47]. This approach is environmentally friendly and effectively reduces reliance on pesticides, minimizing their impact on natural organisms [44].

The role of indigenous predators, parasitoids, and insect pathogens is central to modern integrated pest management programs for rice. Although hundreds of insect species feed on rice, only about 8% are classified as major pests. This indicates that, over thousands of years of rice cultivation, a relatively stable relationship has formed between rice insects and their natural enemies. When this balance is disrupted, such as by the use of insecticides that harm predators, insect outbreaks can occur [4].

In the rice ecosystem, natural enemies are crucial for maintaining pest populations below the economic threshold level. Numerous species of predators and parasitoids have been identified as attackers of rice insect pests. Many predatory species specifically attack the eggs and small larvae of stem borers before they penetrate the rice plant's stem. Coccinellid beetles, carabid beetles, and ants are some of the important predators that feed on stem borer larvae, along with other predators like spiders, dragonflies, and earwigs that target both larval and adult stem borers [48]. Additionally, *Trichogramma australicum* and *Trichogramma japonicum* are significant egg parasitoids of rice stem borer insect pests. The importance of egg parasitoids is greater than that of larval or pupal parasitoids, and at harvest, egg parasitism can reach up to 90%. It is advisable to refrain from early insecticide applications to enable egg parasitoid populations to be established early in the season [4].

4.4. Chemical Control

Chemical control is one of the most effective and rapid methods for reducing insect pest populations. It is often the only viable solution for addressing the sudden emergence of insect pests during the early or later stages of crop growth. Chemicals should be used only when all other control methods prove ineffective. The application of insecticides to manage rice pests has become common, particularly in regions lacking suitable resistant varieties [44].

Insecticides are crucial for controlling rice insect pests, as evidenced in the late sixties and early seventies [49]. Currently, a variety of pesticides are available to farmers, beginning with chlorinated hydrocarbons, followed by phosphates, and more recently, carbamates and pyrethroids. These have been assessed for their effectiveness in managing various rice pests, particularly in cases of heavy infestation [47]. Important insecticides for the control of insect pests include Virtako 0.6 GR at 10 kg/ha, Pymetrozine 50 WG at 175-300 g/ha, Virtako 40 WG at 100 g/ha, and Lambda-cyhalothrin 2.5 EC at 500 ml/ha. Additionally, Fipronil, Carbofuran, Carbosulfan, Diazinon, Chlorpyrifos, Phenthoate, and Quinalphos are some of the insecticides employed to manage rice stem borers [50].

Chemical control can also be used as part of an integrated pest management approach with cultural practices or resistant plant varieties [42]. In addition to being expensive and harmful to the environment, chemical insecticides can lead to pest resistance when they are used frequently to control a single species of insect pest [51]. The use of insecticides in stem borers remains within the stem, leaf folders inside leaf folds, and brown plant hoppers are found at the base of the plant. This situation complicates rice pest management significantly, and also the development of resistance to insecticides in leaf hoppers is making their control more challenging [52]. To reduce these problems and others, it is essential to choose selective systemic insecticides that minimize adverse effects on non-target organisms and biodiversity [44].

An effective chemical control strategy requires careful selection of the active ingredient, appropriate formulation, and application techniques based on pest biology and crop phenology. Knowledge of the most susceptible stages of pests, quantitative data on pest incidence, and the impact of specific pest populations on yield loss is vital for economically successful pest control. Additionally, it is essential to understand the potential hazards of pesticides to users, consumers, and the environment. When damage exceeds 10% for dead hearts and 5% for whiteheads, the application of chemical insecticides is recommended [53]. While using chemical insecticides can pose environmental risks, they remain the only viable option when pest populations are already established. The insecticides used must have low toxicity to humans and other non-target species [54].

4.5. Integrated Pest Management

Integrated pest management (IPM) employs environmentally sound strategies to prevent pests from invading and damaging crops. Successful IPM combines multiple methods to address pest issues while minimizing harm to humans, wildlife, and the environment. It is an ecosystem-based approach that combines various management techniques to grow healthy crops and reduce pesticide use. In practice, IPM is a site-specific approach aimed at managing pests in a cost-effective, environmentally sound, and socially acceptable manner. The implementation primarily relies on farmers, who choose practices they find practical and beneficial for their activities. Integrated rice insect pest management combines various methods to control rice insect pests cost-effectively while adhering to sound environmental practices. No single method can guarantee efficient and sustainable protection; instead, the approach often integrates resistant varieties, crop management techniques, and limited use of chemicals [4].

To reduce yield losses caused by moderate to severe incidences of stem borers, gall midges, plant hoppers, and other rice insect pests in rice-growing areas, the development of effective integrated pest management strategies is crucial. These strategies are essential for overcoming biotic constraints and maximizing the yield potential of rice. Successful management of rice insect pests relies on integrating various control tactics, including host plant resistance, cultural practices, biological control, and chemical control [30].

5. Conclusion

Rice is a vital staple food for over half of the global population and serves as a crucial source of employment and income for many people. However, during its growth, rice is susceptible to a variety of insect pests that can lead to significant yield losses. The main insect pests of rice are stem borers, grain-sucking bugs, leaf hoppers, gall midges, grasshoppers, plant hoppers, rice hispa, whorl maggots, green stink bugs, rice gundhi bugs, and leaf folders. Yield loss estimates due to these insect pests can vary widely from season to season. To develop effective insect pest management strategies, understanding the population dynamics of these pests is essential. This knowledge is critical for devising sustainable rice crop protection methods, including cultural practices, host plant resistance, biological controls, chemicals, and integrated pest management methods. The population dynamics of rice insect pests fluctuate according to the varying conditions of the environment. Therefore, studies should be done in various rice-producing areas to identify the critical periods of damage to rice crops that could aid in the effective and timely management of rice insect pests, to reduce yield loss.

Abbreviations

BPH	Brown Plant Hoppers
IPM	Integrated Pest Management
YSB	Yellow Stem Borer

Author Contributions

Esuyawkal Demis is the sole author. The author read and approved the final manuscript.

Conflicts of Interest

The author declares no conflicts of interest.

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