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Research Article

Eco-friendly management of rice stem borer in spring rice (chaite-5)

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Abstract

Since chemical pesticides have a variety of short- and long-term social, economic, and environmental repercussions, research was conducted in Baniyani, Jhapa, Nepal from January to July 2021 to manage the Yellow Stem Borer (YSB) of rice in an environmentally responsible manner. The research followed the Randomized Complete Block Design (RCBD) with three replications and seven treatments using the spring rice variety Chaite-2. The seven treatments used were spinosad 45% SC, *Bacillus Thuringensis* var krustaki + *saccharopolyspora spinosad* 15% SC, Azadiractin 0.3%, Chinaberry (Bakaino) leaf extract, Mugwort (Titepati) leaf extract, *Metarhizium anisopliae* and untreated plot. In order to evaluate the efficacy of the treatments, the number of dead heart and white head symptoms were counted at various time intervals, namely 7, 15, and 21 days after spraying (DAS). At the vegetative and reproductive stages of rice, the rice stem borer causes the symptoms known as "dead heart" and "white head," respectively. The eco-friendly insecticides significantly altered how the rice stem borer was affected. Among the insecticides, Spinosad 45%SC caused the highest reduction in dead hearts and whiteheads. Spinosad 45% SC treated plot showed highest yield (7.5tha^{-1}). Given its effectiveness and eco-friendliness, spinosad could be regarded as the most successful eco-friendly insecticide for controlling the rice pest known as the Rice Stem Borer.

Introduction

Rice (*Oryza sativa L.*), belonging to the *Poaceae* family, Sub-family *Oryzoideae*, tribe *Oryzae* with chromosome number 24 i.e. 2n= 24, is the staple food crop for more than 60% of the world population and is particularly important in Southeast Asian countries. The global land area for rice cultivation is about 158 million hectares (Roychoudhury et al., 2020). Rice is the only cereal crop that can be grown submerged in water and requires more water than any other crop (Food and Agriculture Organization, 2004). Grown for more than 6000 years, rice is economically, socially and culturally important to a large number of people across the globe (Pathak et al., 2018). The rice yield in Nepal is the lowest in South Asia (Tripathi et al., 2019). Although Nepal

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contributes very little in global rice production and trade, it plays a significant role in the national economies. In Nepal, the total area covered by rice production is 1,491,744 hectares with an annual production of 5,610,011 metric tons and a yield of 3.76 mt ha^{-1} (Ministry of Agriculture and Livestock Departmen, 2020).

About 26.98% of the GDP is still generated by the agricultural sector, while 60.4% of the people in Nepal is still dependent on agriculture (Acharya et al., 2020). In Nepal, a total of 33 hybrid rice varieties and 78 inbred rice genotypes have been registered for commercial cultivation (Acharya et al., 2019). Rice is the most preferred staple food crop of Nepal and fulfills about 50% of the total calorie requirement of people (Gadal et al., 2019). In Nepal, rice is produced in three main production environments: irrigated, rain-fed lowland and upland (Terai and inner terai- 67 to 900 masl, Mid hills- 1000 to 1500 masl, and High hills- 1500 to 3050 masl) (Bhandari et al., 2020). About 70% of the nation's rice production is produced in the Terai region, which is referred to as the "granary of the country" (Bhandari et al., 2020). According to reports, the Jhapa district's rice has an area of 85,879 ha, a production volume of 365,845 mt, and an annual yield of 4.26 mt ha-1 (Subedi et al., 2020).

In Nepal, rice is the main crop. In general, two seasons are used to grow rice on irrigated land: the main crop is grown during the monsoon season (June to October), and boro rice is grown from January to June (Asian Development Bank, 2019). In some places, spring rice (Chaite Dhan) in March-July is also in the practice of cultivation. Spring rice is cultivated in different parts of the country where irrigation is available round the year by using shallow, canal and deep tube wells. Spring rice is grown in 7.4% of the total rice areas in the country (Crop Development Directorate & Agronomy Society of Nepal, 2017). Spring rice is a short durational, resistant to many diseases and pests, photoperiod insensitive rice with high yield potential (Subedi et al., 2018). Being spring season rice, commonly grown in those places having abundant irrigation facility helps to minimize the weed infestation. Higher intensity of light during spring resulting in a higher yield (Subedi, Sharma, Poudel, & Adhikari, 2018). The extent of areas under spring (chaite) rice is in increasing trend. So far, 11 spring rice varieties have been released in Nepal (Crop Development Directorate & Agronomy Society of Nepal, 2017). Some spring rice varieties are Hardinath-1, Chaite-2, and Chaite-5 and so on.

Rice crop is attacked by more than 100 species of insects, but 20 of them are of economic importance (Kumari et al., 2019). Among the major pest, yellow stem borer *Scirpophaga incertulus* is the dominant and the most destructive pest in rice causing the yield loss of 10-60% (Chatterjee & Mondal, 2014). It results in yield losses of 1% to 19% in early-planted rice crops and 38% to 80% in late-planted rice crops (Singh & Tiwari, 2019). The yellow stem borer *Scirpophaga incertulas* (Walker) has assumed the number one pest status and attacks the rice crop at all stages of its growth. This insect causes "dead hearts" in tillering stage and "white ear heads" at the reproductive stage. The farmers highly rely on synthetic insecticides against destructive insect due to their broad-spectrum activity, relatively low cost and rapid killing attributes. However, the excessive use of synthetic chemicals in the field results in severe adverse effects on the agro ecosystem, human health and wildlife. So, an attempt is to be made for the eco-friendly management of the rice stem borer to overcome the crisis resulted from the overuse of synthetic insecticides.

A warm, humid atmosphere is necessary for rice crop growth and for the survival and spread of pests like yellow stem borer. Insecticides play a significant part in the management of this insect pest, although repeated doses of the same class of insecticides or a single pesticide become less efficient in managing insect pests when used continuously (Sharma et al., 2018). Additionally, pesticides that are applied to a target harm non-target arthropods, usually pollinating insects and predators like spiders and ground beetles. Particularly in rice farming, insecticide residues find their way into water sources, affecting both the water we drink and the food we eat (Cork et al., 2003). In addition to creating risks for the environment and food safety, the indiscriminate and uncontrolled use of pesticides has resulted in several difficulties, including the development of insect resistance and the reappearance of previously minor pests. A vicious cycle will result from these significant negative effects, which will harm the ecology, cause repeated pest outbreaks, and necessitate using more pesticides (Conway & Pretty, 2013). In this context, biopesticides are said to be less hazardous to the environment. Plant extracts are becoming increasingly important as a result of the dangers posed by chemical pesticides. The use of indigenous botanicals has been appreciated (Gurung & Azad 2013). Numerous plants, spices, and their extracts are known to have insecticidal properties. The traditional application of plant matter is based on firsthand knowledge. The vast majority of plant materials are used as basic materials (powder or liquid). Application rates can vary depending on the circumstance. Contrary to conventional pesticides based on a single active ingredient, plant bioactive components are a complex array of novel compounds with a variety of behavioral and physiological impacts on insects. Products that have been treated with plant extracts repel and discourage insects from feasting. However, the bulk of these chemicals cannot be produced on a large scale because of their complex molecular architectures. Therefore, it is important to encourage the use of fundamental plant derivative formulations, such as oils and extracts. These pesticides are excellent for usage since they are harmless to non-target species such as predators and parasites (Gurung & Azad 2013). Thus, Baniyani, Jhapa, Nepal conducted an experimental study to determine the most environmentally friendly method of controlling rice stem borer in spring rice (Chaite-5).

Materials and methods

The experiment was carried out from third week of January to last week of June 2021 in the farmer's field. The different materials and methods were used and the techniques were adopted during the course of experiment performance. Those are described briefly under following headings.

Experimental site

The experimental research was conducted in Kachankawal-6, Baniyani, Jhapa in the farmer's field. We selected this place as there was proper facility of solar irrigation which could fulfill the requirement of water needed for the rice cultivation in spring season.

Selection of cultivar

The experiment was carried out in Chaite-5, a common spring rice variety grown by farmers in this region. The rice stem borer is a significant insect pest that causes the greatest production loss in this region.

Sample and sampling technique

The samples were collected from the replications made on the plots of rice fields. Ten samples were taken from each of the plots. The samples from each plot were taken randomly.

Experimental details and procedures:

To determine the eco-friendly management of rice stem borer in spring rice, the field experiment was conducted under Completely Randomized Block Design (RCBD) with three replications and seven treatments including control (untreated) plot. Pretreatment observation was recorded before the application, while post treatment observations were under taken after 7 days of each spray. The variety Chaite-5 was transplanted in plot size of (4*2.5) m2 with a spacing of (20*20) cm2 as per normal recommended agronomical practices. The knapsack sprayer was used to impose the uniform spray of the eco-friendly insecticides in each treatment application.

Treatments

Table1. List of botanicals with doses

Trade Name	Generic Name	Concentration	Notations
ONEUP	Spinosad 45% SC	0.3 ml/l	T1

Table1. List of botanicals with doses
(continued)

Trade Name	Generic Name	Concentration	Notations
Minchu+	Bacillus Thuringensis var krustaki + saccharopolyspora spinosad 15% SC	2 ml/l	T2
Multineem	Azadirachtin 0.3%	2 ml/l	T3
-	Chinaberry (Bakaino) leaf Extract	15 ml/l	T4
-	Mugwort (Titepati) leaf extract	15 ml/l	T5
Multiplex	Metarhizium	2 g/l	T6

Method of plant extracts preparation

Fresh leaves of *Melia azedarach* (Chinaberry - Bakaino) and Mugwort (Titepaati) was identified and collected separately from the nearby locality. Those leaves were washed efficiently with clean water and then dried in shade to evaporate the water. Those leaves were then cut into small pieces and soaked individually for 6 hours then boiled those chopped leaves in water at the rate of 1:3 ratios at 100°C for two hours and the mixtures were stirred gently twice during boiling. At the end, material was sieved through muslin cloth. Moreover, the extractions were preserved in separate bottle for further use.

Meteorological data

There was fluctuation in the various environmental factors. However, the maximum precipitation recorded was 83.33mm and lowest precipitation recorded was 0mm. During the period of experiment the maximum and minimum temperature recorded was 40.29°C and 14.55°C respectively. The maximum and minimum relative humidity recorded was 90% and 14.55% respectively.

Observation, pest identification and calculation

The identification of the symptoms and the pest was done under the guidance of entomologist. The parameters taken during the experiment were:

1. Insect Damage
   - Dead hearts
   - White heads
2. Yield attributing parameters
   - Plant height
   - Filled grain
   - Unfilled grain
   - Test weight
   - Yield

Observations on stem borer incidence were recorded after ensuring the incidence of dead heart on ten randomly chosen hills from each plot one day prior to the application of insecticides as a pre-treatment. The dead heart and white head percent were calculated by using the following formula:

Dead heart (%) =
$$\frac{\text{Total number of dead hearts}}{\text{Total number of tillers}} \times 100$$

White head (%) =
$$\frac{\text{Total number of white heads}}{\text{Total number of panicles}} \times 100$$

The calculated dead hearts and white heads percentage was computed and mean was calculated. The mean dead heart and mean white head of each treatment were compared with that of untreated plot and Percentage Reduction Over Control (PROC) was calculated. The percent dead heart and white head reduction over control was calculated by using the following formula:

Percent population reduction over control
$$=\frac{X2-X1}{X2}*100$$ (Khosla, 1997)

Where, X_1 = the mean value of treated plots
X_2 = the mean value of untreated plot

Crop cutting was completed after about 90% of the crops had achieved an 85 percent maturity stage. After measuring moisture content using a moisture meter, the yield was calculated from the 1m2 sections of each plot. The yield weight was then measured and recorded.

The test weight was determined when the harvested rice reached its dry moisture content (13°C). 1000 seeds were counted and weighed using a weighing machine for the test weight. Test weight= weight of 1000 seeds.

Data analysis

Data collected from the research field were firstly recorded in the data sheet. The recorded data were entered in MS-Excel. The entered data were subjected to ANOVA with the help of Gen stat (15th version). Then the mean dead heart and mean white head were statistically analyzed after converting into square root transformation and percentage of filled and unfilled grain were converted into arc sign transformation suggested by Gomez and Gomez (1984). Mean comparison was carried out among significant variable by Fisher-LSD 5% Level of Significance.

Results and discussion

The field experiment was conducted in Complete Randomized Block Design against rice stem borer in the spring rice under field condition in farmer's field of Kachankawal-6, Baniyani, Jhapa, Nepal. Eco-friendly management using different eco-friendly insecticides against rice stem borer in spring rice were used and evaluated. The following subheadings are used to present and discuss the experiment's findings regarding yield attributing factors and insect damage. The pre-treatment data were recorded before the application of different insecticides and the post-treatment data were recorded after seven days of each spraying. The effectiveness of treatments against rice stem borer was evaluated by counting the pre-treatment dead hearts and post-treatment dead hearts and white heads which were compared with the result of untreated plot.

Effect of different insecticides on Rice Stem Borer

Effect on dead heart symptom and percentage reduction over control (PROC).

A day prior to applying insecticides following a 5% stem borer infection level, the dead hearts of 10 randomly chosen plants from each plot were counted. No significant difference was observed in the mean dead heart symptoms before the application of different eco-friendly treatments. Even after the 7 days of application of the different eco-friendly insecticides, there was no significant difference seen in the mean dead heart among the treatments. However, the mean dead heart among the treatments ranges from 8.10 to 10.10. The maximum dead heart symptom was seen in untreated plot (10.10) which was followed by Mugwort extract (9.32), Neemicide (9.21), and minimum dead heart symptom was observed in Spinosad (8.10) which was followed by Metarhizium (8.26), Chinaberry extract (9.04), and Minchupls (9.16) (Table 2).

The maximum Percentage Reduction over Control (PROC) was observed in Spinosad (19.80%) which was followed by Metarhizium (18.22%) and Chinaberry extract (10.49). And the minimum Percentage Reduction over Control was observed in Mugwort extract (7.72%) which was followed by Neemicide (8.81%) and Minchuplus (9.31%) (Table 2).

Effect on white head symptom and percentage reduction over control (PROC)

There was high significant difference (at 0.1% LSD) in the mean white head symptom among the treatments after 7 and 14 days of application of different eco-friendly insecticides. The control group had the highest mean dead heart percentage (2.431), followed by mugwort extract (1.987), metarhizium (1.937), and chinaberry (bakaino) extract (1.769). A significantly similar result was found in Spinosad (1.275) and Minchuplus (1.194) which was the minimum mean dead heart percentage which was followed by Neemicide (1.736) (Table 2).

The maximum Percentage Reduction over Control (PROC) was observed in Minchuplus (82.62%) which was followed by Spinosad (79.11%), and Neemicide (53.23%). Similarly, the minimum percentage reduction over control was observed in Mugwort extract (36.23%) and this was followed by Metarhizium (39.37%) and Chinaberry extracts (51.38%) (Table 2).

Table 2. Effect of treatments on mean dead heart and white head of spring rice at Baniyani, Jhapa during 2021

Treatments	Mean dead heart (%)	PROC of mean dead heat	Mean white head (%)	PROC of mean white head
Minchu+	9.16 (3.092)	9.31	0.94[a] (1.194)	82.62
Spinosad	8.10 (2.928)	19.80	1.13[a] (1.275)	79.11
Neemicide	9.21 (3.095)	8.81	2.53[b] (1.736)	53.23
China berry extract	9.04 (3.082)	10.49	2.63[bc] (1.769)	51.38
Metarhizium	8.26 (2.96)	18.22	3.28[bc] (1.937)	39.37
Mugwort extract	9.32 (3.127)	7.72	3.45[c] (1.987)	36.23
Control	10.10 (3.255)	-	5.41[d] (2.431)	-
Mean	9.02		2.77	
LSD(0.05)	-		0.22	
CV %	7.4		7.0	
F-test	Ns		***	

Values are mean of three replications at different day of observation; PROC: Percentage over control CV: Coefficient of variation; ns: non-significant; ***: Significant at 0.1% level of significance; LSD: Least Significant Difference; Values with the same letters in a column are not significantly different at 5% level significance by Fisher-LSD test and figures in the parenthesis indicate square root transformation values.

Effect of treatments on yield and yield attributing characters in spring rice at Baniyani, Jhapa.

The effects of six different eco-friendly insecticides were observed and evaluated in yield and other yield attributing parameters of spring rice of each plot of the experiment. Firstly, the plant height of ten randomly selected plants from each plot was measured just a day before application of treatment and 14 days after first spraying of insecticides. There was no significant difference in mean plant height among the treatments. However, the mean plant height ranges from 74.17cm to 79.75 cm (Table 3).

The filled grains from each treated and untreated plots were counted of randomly selected 10 panicles of each plot after 85% maturity of the about 90% plants of the field. The maximum filled grain percentage was found in Spinosad (70.85%) which was followed by untreated plot (69.24 %), Metarhizium (65.71 %), Mugwort extract (64.99 %), and the minimum filled grain percentage was observed in Chinaberry extract (59.61%) which was followed by Neemicide (64.16 %), an Minchuplus (64.16%) (Table 3).

The test weight (weight of 1000 seeds) of each plot was measured after the moisture content of seeds reached 13%. There was high significant difference at 0.5 % LSD in the test weight among the treatments. Here, the maximum test weight was observed in the case of Spinosad (24.14gm) which was followed by Minchuplus (23.71gm), Neemicide (23.48gm), and Metarhizium (23.16gm). Similarly, the minimum test weight was observed in Chinaberry extract (22.74gm) which was continuously followed by untreated plot (22.92gm) and Mugwort extract (23.06gm) (Table 3).

No significant difference was observed in the case of mean yield of the spring rice among the treatments of the esperiment. However, the highest mean yield was observed in Spinosad (7.50 t ha^{-1}.) which was followed by Mugwort extract (6.83t ha^{-1}.), Minchuplus (5.97t ha^{-1}.) and Chinaberry extract (5.93 t ha-1.). And the lowest mean yield was observed in Neemicide (4.98 mt ha^{-1}.) which was followed by Metarhizium (5.65 t ha^{-1}.) and the untreated plot (5.93mt ha^{-1}.) (Table 3).

Table 3. Effect of treatments on yield and yield attributing characters of spring rice at Baniyani, Jhapa during 2021

Treatment	Mean plant height (cm)	Filled grain (%)	Test weight (g)	Yield (t ha^{-1})
Spinosad	76.18	70.85 (57.44)	24.14^{a}	7.50
Michu+	75.48	64.97 (53.71)	23.71^{ab}	5.97
Neemicide	74.17	64.16 (53.23)	23.48^{bc}	4.98
Metarhizium	79.75	65.71 (54.16)	23.16^{cd}	5.65
Mugwort extract	77.43	64.99 (53.79)	23.06^{cd}	6.83
Chinaberry extract	79.75	59.61 (50.57)	22.74^{d}	5.93
Control	78.77	69.24 (56.34)	22.92^{d}	5.67
Mean	77.36	65.65	23.316	6.08
LSD(0.05)	-	-	0.4327	-
CV %	3.2	4.7	1.0	15.8
F-test	Ns	Ns	***	Ns

Values are mean of three replications; CV: Coefficient of variation; ns: non-significant; ***: Significant at 0.1% level of significance; LSD: Least Significant Difference; Values with the same letters in a column are not significantly different at 5% level significance by Fisher-LSD test and figures in the parenthesis indicate arcsine transformation values.

In the recent experiment, the pest incidence was found to be changed at different time intervals in the research field. The efficacy of insecticides is influenced by a variety of additional parameters, including ambient conditions, pesticide concentrations, spray interval days, and total number of sprays. The occurrence of the rice stem borer is influenced by the concentration of pesticides used to treat it, as well as other environmental factors such as minimum and maximum temperatures, relative humidity, and rainfall. Low temperature, higher rainfall, and higher RH favors the rice stem borer (Hugar et al., 2009; Nag et al., 2018; Zainab et al., 2017). During the week of May 28 to June 3, there was low control of the pesticides despite the spray of different insecticides. There was fluctuation in the efficacy of insecticides during the week. In this week, there was a lot of humidity, a lot of rain and a little drop in the temperature. This might explain the high infestation of rice stem borer since the environmental condition was favorable for the rice stem borer infestation. The research done by R.K. Murali Baskaran also showed the influence of environmental factors on the pest infestation (Baskaran et al., 2019). Along with the environmental factors, the concentration used of pesticides also might be one of the reasons for the pest incidence.

On the basis of present results of the recent experiment, the maximum yield (7.5t ha^{-1}) and best results in terms of dead heart and white head reduction were both achieved. Spinosad and Minchuplus outperformed the other eco-friendly pesticides in terms of dead heart and white head reduction, as well as improved filled grains and yield. Their overall performance was superior to others'. Karthikeyan et al. (2008) stated that Spinosad was superior to all other insecticides in reducing the damage caused by rice stem borer with lowest incidence of dead heart and white head in his research paper which supports my experiment. In their trial, Chatterjee et al. (2014) also determined that Spinosad was the most effective pesticide. Spinosad's effectiveness was demonstrated by a decrease in dead hearts and white heads as well as a rise in yield.

The neemicide also have the insecticidal properties due to which it can control the rice stem borer. In our experiment, the neemicide was found not to be much effective. Though it reduced the dead heart and white head symptoms in the rice more than metarhizium, chinaberry extract and mugwort extract did, it couldn't give good yield which was 5.97 t ha^{-1}. Md. Madafujur also reported neem insecticide as non-effective insecticide in his result which supports our result (Rahman et al., 2020). But in the research done by Choudhary in 2017, neemicide was reported to be one of the most effective insecticides against rice stem borer (Choudhary et al., 2017). Julien mentioned neem pesticide as effective insecticide as it affects the metabolism of insects, leading female infertility and disruption of the molting process. It possesses antifeedant properties (Dougoud et al., 2019).

The Chinaberry extract and Mugwort extract had less effect on the pests in the recent experiment. They also gave less yield than spinosad and minchuplus i.e. 5.93t ha^{-1}. and 6.83 t ha^{-1}. respectively. Chinaberry contains limonoids, whose antifeedant and insecticidal properties have been demonstrated in laboratory trials on lepidoteran, dipteran, and coleopteran (Dougoud et al., 2019). According to Zibaee, muggwort extract has insecticidal properties for management of insect due to which it can control the rice stem borer (Zibaee et al., 2008). Mugwort has low toxicity towards natural enemies (Zibaee et al., 2008). The use of such products can favorably shift the pest/natural enemy balance and result in prolonged efficacy of the control intervention. Although the efficacy of chinaberry and mugwort extract was inferior to other pesticides, they have lower toxicity to non-targeted pests. The application of these insecticides should thus be done with care and use them in combination with crop diversification, habit management. These insecticides can fit in the IPM system.

Metarhizium had lower efficacy than the other pesticides used in terms of dead heart and white head reduction and yield (5.65 t ha^{-1}) in the field experiment. Sitesh Chatterjee got the similar results in his research in 2014 which supports our result. He also included in his paper that though *M. anisopliae* not suitable for sole control measure, it can be incorporated in IPM programme (Chatterjee & Mondal, 2014).

Conclusion

The six eco-friendly insecticides; spinosad, minchuplus, neemicide, chinaberry extract, mugwort extract and metarhizium were used against rice stem borer in Baniyani, Jhapa in spring rice. All those insecticides somehow controlled the pest but spinosad gave the best result. Spinosad 45% SC was found to be most effective eco-friendly insecticide against rice stem borer which was followed by minchuplus. They reduced the incidence of insect and reduce the dead heart and white head in the field and also have better yield result in comparison to other insecticides.

In the present condition of experiment, the efficacy of the insecticides was affected by the various factors of environment i.e. relative humidity, temperature and rainfall. Hence, considering the present situation of the experiment, this experiment should be carried out at least 3 years for the confirmation of the results.

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References

Acharya, B., Shrestha, S. M., Manandhar, H. K., & Chaudhary, B. (2019). Screening of local, improved and hybrid rice genotypes against leaf blast disease (*Pyricularia oryzae*) at Banke district, Nepal. *Journal of Agriculture and Natural Resources*, *2*(1), 36–52. CrossRef

Acharya, P., Regmi, P. P., Gauchan, D., KC, D. B., & KC, G. B. (2020). Comparative study on technical efficiency of mechanized and traditional rice farm in Nepal. *Journal of Agriculture and Natural Resources*, *3*(2), 82–91. CrossRef

Asian Development Bank (2019). Climate-smart practices for intensive rice-based systems in Bangladesh, Cambodia, and Nepal (Issue October). CrossRef

Baskaran, R. K. M., Sridhar, J., Sharma, K. C., & Senthil-Nathan, S. (2019). Influence of summer weather on prevalence of rice yellow stem-borer in central India: Monitoring and biocontrol strategy. *Biocatalysis and Agricultural Biotechnology*, *21*(September), 101340. CrossRef

Bhandari, S., Sapkota, S., & Gyawali, C. (2020). Effect of different methods of crop establishment on growth and yield of a spring rice at Janakpurdham-17, Dhanusha. *Malaysian Journal of Sustainable Agriculture*, *4*(1), 10–15. CrossRef

Chatterjee, S., & Mondal, P. (2014). Management of rice yellow stem borer, *Scirpophaga incertulas Walker* using some biorational insecticides. *Journal of Biopesticides*, *7*(January), 143–147.

Choudhary, R., Chandrakar, G., Bhardwaj, J. R., Khan, H., & Sahu, R. (2017). Assessment of the efficacy of neem based insecticides for the management of yellow stem borer , *Scirpophaga incertulas Walk* in paddy field. *Journal of Pharmacognosy and Phytochemistry*, *6*(5), 1446–1449.

Conway, G. R., & Pretty, J. N. (2013). Unwelcome harvest: agriculture and pollution. Routledge.

Cork, A., Alam, S. N., Rouf, F. M. A., & Talekar, N. S. (2003). Female sex pheromone of brinjal fruit and shoot borer, *Leucinodes orbonalis (*Lepidoptera: Pyralidae): trap optimization and application in IPM trials. *Bulletin of Entomological Research*, 93(2), 107–113. CrossRef

Crop Development Directorate, & Agronomy Society of Nepal. (2017). *Rice Science and Technology in Nepal (A historical, socio-cultural and technical compendium)*. *2017*, 976.

Dougoud, J., Toepfer, S., Bateman, M., & Jenner, W. H. (2019). Efficacy of homemade botanical insecticides based on traditional knowledge. A review. *Agronomy for Sustainable Development*, *39*(4). CrossRef

Food and Agriculture Organization. (2004). International Year of Rice 2004: Rice and water: A long and diversified story. *FAO Factsheet, 2004*, 1–2. Direct Link.

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. CrossRef

Gomez, K. A., & Gomez, A. A. (1984). *Statistical procedures for agricultural research*. John wiley & sons.

Gurung, T. R., & Azad, A. K. (2013). Extent and potential use of bio-pesticides for crop protection in SAARC Countries. *SAARC Agriculture Centre*.

Hugar, S. V., Venkatesh, H., Hanumanthaswamy, B. C., & Pradeep, S. (2009). Influence of weather factors on the infestation of yellow stem borer, *Scirpophaga incertulas* (Walker) in aerobic rice. *Asian Journal of Environmental Science*, *4*(2), 151-154.

Karthikeyan, K., Purushothman, S. M., & Revi, S. (2008). Effect of spinosad against major insect pests and natural enemies in rice ecosystem. *Journal of Biological Control,* 22(2), 315–320. Direct Link.

Khosla, R. K. (1977). Techniques for assessment of losses due to pests and diseases of rice. *Indian Journal of Agricultural Sciences*, *47*(4), 171-174.

Kumari, P., Prasad, R., Jha, S. K., Yadav, M., & Prasad, D. (2019). Bioefficacy of some botanical and chemical insecticides against yellow stem borer *Scirpophaga incertulas* (Walker.) In rice field at Jharkhand. *Journal of Pharmacognosy and Phytochemistry*, *2*, 200-203.

Ministry of Agriculture and Livestock Development. (2017). Statistical Information in Nepalese Agriculture. *Ministry of Agriculture and Livestock*, 290. Direct Link.

Ministry of Agriculture and Livestock Development. (2020). Statistical Information in Nepalese Agriculture. *Ministry of Agriculture and Livestock* Direct Link.

Nag, S., Chaudhary, J. L., Shori, S. R., & Netam, J. (2018). Influence of weather parameters on population dynamics of yellow stem borer (YSB) in rice crop at Raipur. *Journal of Pharmacognosy and Phytochemistry*, *7*(4), 37-44.

Pathak, H., Nayak, A. K., Jena, M., Singh, O. N., Samal, P., & Sharma, S. G. (2018). Rice research for enhancing productivity, profitability and climate resilience. *ICAR-National Rice Research for Institute*, 1–527.

Rahman, M. M., Jahan, M., Islam, K. S., Adnan, S. M., Salahuddin, M., Hoque, A., & Islam, M. (2020). Eco-Friendly management of rice yellow stem borer, *Scirpophaga Incertulus* (Pyralidae: Lepidoptera) through reducing risk of insecticides. *Malaysian Journal of Sustainable Agriculture*, *4*(2), 59–65. CrossRef

Roychoudhury, A. (2020). *Rice Research for Quality Improvement: Genomics and Genetic Engineering*. Springer. CrossRef

Sharma, K. R., Raju, S. V. S., Jaiswal, D. K., & Singh, P. (2018). Efficacy of certain newer insecticide formulations against yellow stem borer, *Scirpophaga* *incertulas (Walker)* infesting on rice crop. *Journal of Experimental Zoology India*, *21*(2), 771-775.

Singh, D. P., & Tiwari, T. (2019). Assessment of extent of damage and yield loss caused by stem borer in rice. *Journal of Pharmacognosy and Phytochemistry*, *8*(2), 2112–2115.

Subedi, S., Ghimire, Y. N., Kharel, M., & Sharma, B. (2020). Profitability and resource use efficiency of rice production in Jhapa District of Nepal. *International Journal of Social Sciences and Management*, *7*(4), 242–247. CrossRef

Subedi, S., Sharma, S., Poudel, A., & Adhikari, S. (2018). Varietal evaluation and preference analysis of promising spring rice genotypes in Dhamilikuwa, Lamjung, Nepal. *Open Journal of Plant Science*, *3*(1), 015-017. CrossRef

Tripathi, B. P., Bhandari, H. N., & Ladha, J. K. (2019). Rice Strategy for Nepal. *Acta Scientific Agriculture*, *3*(2), 171–180.

Zainab, S., Ram, B., & Singh, R. N. (2017). Environmental effect on yellow stem borer, *Scirpophaga incertulas (Walker)* and rice leaf folder, *Cnaphalocrocis medinalis (Guenee)* on rice crop. *Journal of Environmental Biology*, *38*(2), 291–295. CrossRef

Zibaee, A., Bandani, A. R., & Ramzi, S. (2008). Lipase and invertase activities in midgut and salivary glands of *Chilo suppressalis (Walker)* (Lepidoptera, Pyralidae), rice striped stem borer. *Invertebrate Survival Journal*, *5*(2), 180-189.