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Yield Loss Quantification Due to Stalk-Eyed Fly (Diopsidae) Infestations on Rice Crops (Oryza Sativa) in Fogera Plain

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Abstract: Stalk-Eyed Flies (Diopsidae) pose a significant threat to rice crops (Oryza sativa), causing yield loss and affecting crop development. This study aims to quantify yield loss due to Stalk-Eyed Fly infestations and identify susceptible growth stages of rice crops to this insect. Field experiments were conducted to assess the yield loss of rice due to stalk eyed fly at Fogera, in 2021 and 2022. With the treatments Both Thiamethoxam seed treatment and Chlorpyrifos systemic foliar insecticide were applied to combat the infestation, with untreated varieties serving as controls. And the pot experiment was conducted to assess susceptibility of rice growth stage to the stalk eye fly artistically analyses, were employed to evaluate treatment impacts. With the treatments of different crop stages, Seedling Stage, Tillering Stage, Stem Elongation Stage, Panicle Initiation Stage, Booting, Heading, Flowering. The effect of rice growth stage on stalk eyed fly infestation showed that there is statistically significant difference among the different growth stage, tillering stage appears to be the most susceptible to Stalk-Eyed Fly infestations in terms of the impact on tiller growth in rice crops. During this stage, the mean percentage change of tillers is the highest at 59.3%, indicating a substantial impact of infestations on tiller growth. This suggests that rice crops are particularly vulnerable to stalked fly infestations during the tillering stage, highlighting the importance of effective pest management strategies during this critical growth phase to mitigate potential yield losses. In the field experiment, significant variations in yield loss were observed across treatments. The presence of dead hearts, indicative of infestation, varied notably between treated and untreated rice. Rice varieties incorporating pesticide applications demonstrated lower dead heart percentages, suggesting there is rice yield loss if the stalk-eyed fly is not controlled. Notably, treatments influenced grain yield, with insect protection measures resulting in higher yields and lower yield loss compared to controls. In conclusion, stalk-eyed fly infestation impacts rice crop productivity, particularly during vulnerable growth stages. Pesticide applications show promise in reducing infestation severity and mitigating yield loss. We recommend implementing targeted treatment strategies, focusing on susceptible growth stages, to effectively manage infestations and optimize rice crop yields.

Keywords: Susceptible stage, yield loss, stalk-eyed fly, Rice growth stage.

Research Paper

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1. BACKGROUND AND JUSTIFICATION

Rice (Oryza sativa) is a staple food crop globally, supporting the livelihoods of millions. Despite Ethiopia's vast potential for rice production, with an estimated potential area of 39,354,190 hectares, the country still imports significant amounts of rice, reaching 310,097 tons in 2016. The expansion of rice cultivation from 10,000 hectares in 2006 to over 50,000 hectares in 2018, with an increasing number of farmers engaged in rice production, showcases the growing importance of rice in Ethiopia. The major rice-producing regions include Amhara, SNNPR, Oromiya, Somali, Gambella, BeniShangul Gumuz, and Tigray, with Amhara leading in both area coverage and production. However, despite this progress, only 1.3% of the total potential area was utilized for rice cultivation in 2009, leading to continued high levels of rice importation to meet domestic demand (Roushon *et al.*, 2023) and (Abebaw, *et al.*, 2023). Adoption of improved rice technologies in major rice producing areas of Ethiopia: a multivariate probit approach. Agriculture & The production of rice in Ethiopia faces multifaceted constraints that hinder its optimal poten tial. Limited access to credit for smallholder farmers restricts their ability to invest in essential inputs like seeds, fertilizers, and machinery (Keba *et al*., 2023). Inadequate infrastructure, including poor roads and storage facilities, leads to logistical challenges in transporting rice to markets, resulting in post-harvest losses and reduced profitability. Climate variability, characterized by unpredictable rainfall patterns and extreme weather events, further compounds production risks for rice farmers (Roushon *et al*., 2023). Moreover, the absence of effective extension services and technical support hampers the adoption of modern farming practices and technologies, impeding productivity gains in the rice sector (Elum *et al*., 2024). While government interventions such as subsidized credit, investments in rural infrastructure, and extension programs aim to address these challenges sustained commitment and coordinated efforts from all stakeholders are crucial to overcoming these constraints and unlocking the full potential of rice production in Ethiopia.

In addition to the above problem, rice cultivation in Ethiopia is challenged by several major diseases and insect pests, posing significant threats to production and yield stability. One of the most prevalent diseases is Rice Blast, caused by the fungus Magnaporthe oryzae, which can lead to substantial yield losses if not effectively managed (Smith & Jones, 2020). Additionally, Bacterial Leaf Blight (BLB), caused by Xanthomonas oryzae pv. oryzae, is another prominent disease that affects rice crops, particularly in areas with high humidity and rainfall (Gems, 2021). Among insect pests, the African Rice Gall Midge (AfRGM), Orseolia oryzivora, is a major concern, causing damage to rice plants by feeding on their tissues and leading to stunted growth and reduced yields (Davis *et al*., 2019). Furthermore, the Rice Stem Borer (RSB), including species like Chilo partellus and Scirpophaga incertulas, inflicts damage by tunneling into rice stems, weakening the plants and making them susceptible to lodging (Brown, 2018). To mitigate the impact of these diseases and pests, integrated pest management (IPM) strategies, including the use of resistant varieties, cultural practices, and biological control agents, are being promoted among rice farmers in Ethiopia (Johnson, 2017). However, continuous monitoring and research efforts are crucial to stay ahead of evolving pest and disease pressures and ensure sustainable rice production in the country (White, 2022).

Estimates suggest that insect-induced yield losses in Africa range from 10% to 15% (Nwilene *et al*., 2013). Stalk-eyed flies, particularly Diopsis longicornis and Diopsis apicalis, are among the stem borers widely distributed and devastating pests of rice (Savary *et al*., 1997). Their larvae primarily target the central meristem of the plant, resulting in the formation of dead hearts, which adversely affects tiller density, panicle numbers, grain weight, and mature panicle count (Togola *et al*., 2011). Despite heavy reliance on insecticide applications, their effectiveness against stalk-eyed flies remains limited, posing a significant challenge in pest management (Sarwar *et al*., 2005; Rubia, 1994).

Although earlier workers lamented that the stem borers inflicted significant and severe yield losses of the crop annually, and stemborers regularly infested crops from seedling stage to maturity (Ragini *et al*., 2000). However, neither actual loss nor careful statistics maintained or any regular survey was made (Islam, 1975). Plant type, crop vigour, and the pest complex can play a large role in determining eventual yield loss by stem borers. Low tillering varieties have less opportunity to compensate for 'dead hearts' (Feeding by stemborer inside the leaf sheath at the vegetative stage, leads to yellowing and drying of the youngest shoot, resulting the formation of .dead hearts) than high tillering varieties (Pathak and Khan, 1994). Rice varieties vary in their susceptibility to stem borers. In the field experiments, susceptible varieties harbour more borers and suffer more damage than resistant varieties (Pathak and Khan, 1994). The relationship between tiller damage by stem borers and yield loss is multifaceted because stem borer effects on rice yields vary with pest population intensity, time of damage, and growing conditions (Feijen, 1979). Rice plants may compensate for damage during early growth stages (Rubia *et al*., 1996) but the extent to which plants are able to overcome this damage is unknown.

Information on yield losses attributable to rice stemborers infestation (Akinsola, 1984). Such factors as intensity of attack, species of borers, time of attack and rice varieties, play a major role in crop assessment. Furthermore, the nature of damage caused is an important factor in estimation of yield loss (Akinsola and Sampong, 1984). Therefore, this study was aimed to assess the yield loss on rice due to stemborers infestation, which may help to develop a fruitful management strategy of the very important pests of rice.

In Ethiopia, although the distribution and occurrence of stalk-eyed flies have been documented as a major insect pest of rice (Geteneh *et al*., 2020), the quantification of yield losses attributable to this pest remains unexplored. Additionally, the specific growth stages at which stalk-eyed fly infestations become more severe are yet to be elucidated. This study is intended to evaluate the yield loss due to this insect and the susceptible stage of rice to stalked-eyed fly with the following potential research questions mean that is the extent of yield loss in rice crops caused by infestations of the stalked-eyed fly? Are certain growth stages of rice crops more susceptible to infestations by the Stalk-Eyed Fly? Therefore, there is a pressing need to assess the extent of yield loss caused by stalk-eyed flies and identify the stages of rice crop susceptibility to inform effective pest management strategies.

2. MATERIAL AND METHOD

The yield loss assessment was carried out at the Fogara National Rice Research and Training Center, situated at 37.36502 E longitude, 0.62153 S latitude, and an elevation of 1840 meters above sea level. The area experiences a typical rainfall pattern, with the primary rainy season occurring from May to August. The rice varieties tested included Selam, Shaga, and Wanzaye, which are commonly grown in the Fogera Plain region of Ethiopia.

The experiment was designed as a Randomized Complete Block Design (RCBD) with three replications conducted over three years. Stalk-eyed fly larvae were collected from infestation hotspots and uniformly applied to each plot to reach economic threshold infestation levels. Each plot measured 2.4 x 3 meters, with a 1-meter buffer between plots and blocks to prevent insecticide drift. The treatments applied to each rice variety were as follows:Selam: Thiamethoxam seed treatment, Chlorpyrifos foliar application, and an untreated control. Shaga: Thiamethoxam seed treatment, Chlorpyrifos foliar application, and an untreated control. Wanzaye: Thiamethoxam seed treatment, Chlorpyrifos foliar application, and an untreated control.

Data collected included dead heart incidence, days to heading, physiological maturity, grain and biomass yield, and 1000-seed weight. Insecticides were applied twice in the control plots—once as a seed treatment and again as a foliar spray when insect infestation reached the economic threshold level. Yield was determined by comparing results from infested plots with those from non-infested plots.

A pot experiment was conducted in 2022 at the Fogara National Rice Research and Training Center to evaluate the susceptibility of rice at different growth stages to stalk-eyed fly infestation. This experiment followed a Completely Randomized Design (CRD) with three replications, focusing on the Shaga variety. The experiment involved 21 cages (100 cm x 90 cm) containing plastic pots (45 cm x 28 cm). Ten rice seeds were initially sown per pot, and the plants were thinned to one per pot after two weeks.

Stalk-eyed flies were collected from hotspots and reared to establish colonies. After 24 hours of egg deposition, adult flies were removed, leaving only the eggs. Colonies were maintained under natural light at an average temperature of 22.5 to 23.6°C, with a 12:12 light-dark photoperiod and 60% to 75% relative humidity. These colonies provided the adult flies for the susceptibility test. The treatment pots were infested with seven larvae per pot at various growth stages, including Seedling, Tillering, Stem Elongation, Panicle Initiation, Booting, and Heading. Both infested and control (uninfested) treatments were tested under a randomized block design with five replications. Data collected included tiller number, dead heart incidence, plant height, fresh biomass, dry weight, and total leaf area. Infested plants were monitored every 24 hours, and excess larvae were removed to maintain a consistent infestation of seven larvae per plant. Tolerance to infestation was quantified by comparing reductions in plant height and biomass between infested and uninfested plants, following the method of Unger and Quisenberry (1997).

Data Analysis

Data analysis was performed using JASP software, and treatment means were separated using the Student–Newman–Keuls test at a 5% significance level.

3. RESULT AND DISCUSSION

3.1. Susceptibility of Rice Crop Stages (Selam Variety) to the Stalk-Eyed Fly

Figure 1 illustrates the susceptibility of the Selam rice variety to stalk-eyed fly infestation at different growth stages, measured by the percentage change in infestation. The highest infestation is observed during the Seedling stage (close to 40%), indicating that this stage is the most vulnerable to the pest. The Stem Elongation and Panicle Initiation stages also show significant susceptibility, with infestation levels around 30%. In contrast, the Heading and Tillering stages exhibit lower susceptibility, with infestation percentages ranging between 15-20%. The error bars highlight some variability in the infestation rates, especially for the Seedling and Stem Elongation stages, suggesting fluctuations in pest impact at these stages. Overall, the figure shows that rice plants are most susceptible to stalk-eyed fly infestation during early growth and developmental stages.

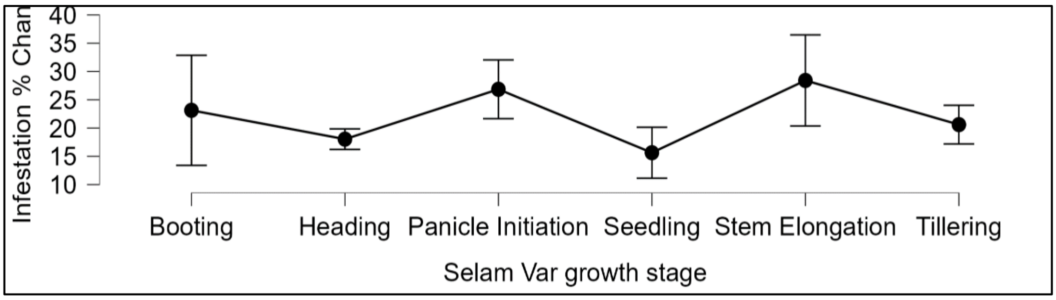

Figure 1: Represents that the Selam Rice Variety Susceptibility of rice crop stages (Selam Variety) to the stalk-eyed fly

3.2. Susceptibility of rice crop stages (Selam Variety) to the stalk-eyed fly

Figure 2 illustrates distinct relationships between infected, uninfected counts, and infestation percentage change. A positive linear correlation is observed between infected and uninfected counts, indicating that as the number of infected individuals increases, the number of uninfected ones tends to rise as well, potentially due to common environmental or biological factors influencing both groups. The histogram for infected counts shows a skewed distribution, with higher frequencies concentrated in lower values, while the uninfected counts follow a more normal distribution, peaking between 12 and 14. In contrast, infestation percentage change has a notable negative correlation with infected counts, suggesting that higher infestation rates are associated with fewer infected cases, potentially due to severe damage from infestation reducing survival or reproduction. However, no clear correlation is found between infestation percentage change and uninfected counts, as the data points are widely scattered. Additionally, the infestation percentage change distribution itself is skewed, with most values clustering around 15-20%, indicating a tendency for moderate levels of infestation. This suggests varying impacts of infestation on infected and uninfected groups, with different susceptibility patterns.

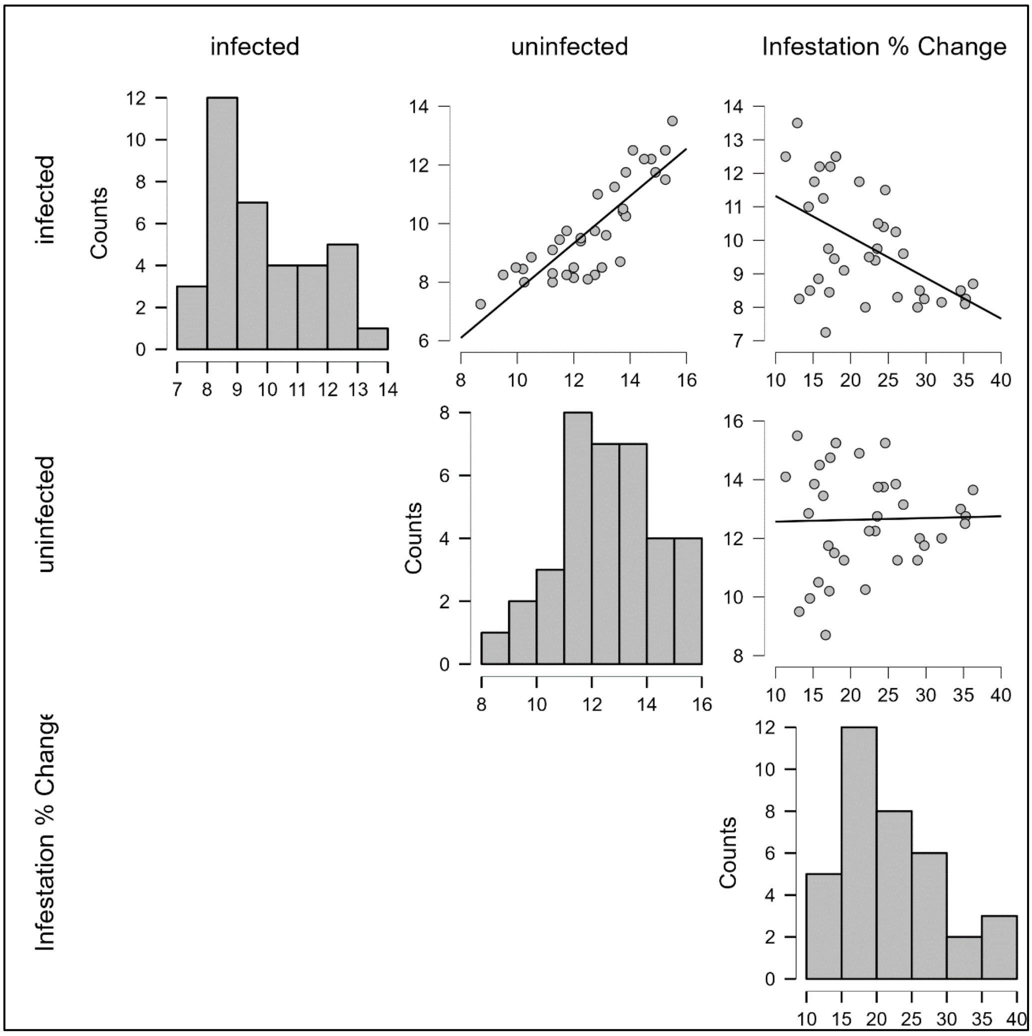

Figure 2: Represents that the correlation plots

3.3. Rice yield loss assessment determination due to stalk eyed fly in 2020

Number of tillers affected due to stalk eyed fly

The Table 2, results (F (8, 27) = 17.122, p < .001), demonstrates a significant effect of treatments on the dead heart (%) parameter caused by Stalk-eyed fly infestation after spray application in 2021. This suggests that the choice of treatment significantly influences the severity of Stalk-eyed fly infestation in rice crops. Treatments involving pesticide applications generally exhibit lower mean dead heart percentages compared to untreated controls. For instance, the mean dead heart percentage in the control group for "Selam" is notably higher at 17.475% compared to treatments such as Selam+Thiamethoxam (mean = 5.325%) and Selam+Chlorpyrifos (mean = 4.600%).

Table 2: Represents the number of tillers affected due to stalk eyed fly in 2021

Treatments	Mean
Selam+Thiamethoxam	5.325 ± 3.09
Selam+Chlorpyrifos	4.600 ± 2.09
Selam (control)	17.46 ± 6.2
Shaga Thiamethoxam	4.400 ± 2.17
Shaga + Chlorpyrifos	4.050 ± 0.66
Shaga (control)	22.57 ± 4.19
Wanzaye+Thiamethoxam	3.97 ± 2.3
Wanzaye+ Chlorpyrifos	5.88 ± 1.7
Wanzaye (control)	26.6 ± 9.46

Number of tillers affected due to stalk eyed fly in 2022

The statistical analysis for Stalk-eyed fly infestation dead heart (%) after spray application in 2022 indicates a significant effect of treatments, as demonstrated by the ANOVA results (F (8, 27) = 21.715, p < .001). This suggests that the choice of treatment significantly influences the severity of Stalk-eyed fly infestation in rice crops in 2022, similar to the findings in 2021. The mean dead heart percentage in the control group for "Selam" is notably higher at 17.650%, compared to treatments such as Selam+Thiamethoxam (mean = 3.875%) and Selam+Chlorpyrifos (mean = 4.875%).

Table 3: Represents the number of tillers affected due to stalk eyed fly in 2022

Treatments	Mean	SD	SE
Selam+Thiamethoxam	3.875	1.315	0.657
Selam+Chlorpyrifos	4.875	2.097	1.048
Selam (control)	17.650	2.330	1.165
Shaga Thiamethoxam	4.375	2.056	1.028
Shaga + Chlorpyrifos	5.150	0.870	0.435
Shaga (control)	20.275	6.120	3.060
Wanzaye+Thiamethoxam	4.250	0.957	0.479
Wanzaye+ Chlorpyrifos	4.250	0.957	0.479
Wanzaye (control)	21.300	6.529	3.264

Yield loss assessment

The results in table 4 presents, the grain yield (kg/ha) data for different treatments across two years, along with the percentage increase in grain yield due to insect protection for each year.

Grain Yield (kg/ha):

The Table 3 reveals a significant effect of treatments on grain yield (kg/ha) in Year 1 (F (8, 27) = 11.480, p < .001), indicating that different treatments have a notable impact on grain yield. Similarly, there is a significant effect of treatments on grain yield (kg/ha) in Year 3, although the significance level is lower compared to Year 1 (F (8, 27) = 2.896, p = 0.018). The ANOVA analysis indicates a significant effect of treatments on grain yield increment (%) in Year 3, suggesting that different treatments lead to varying degrees of yield increment (F(8, 27) = 56.956, p < .001). Furthermore, there is a significant effect of treatments on yield loss (%) due to grain yield increments in Year 1, emphasizing the impact of treatments on mitigating yield loss (F (8, 27) = 221.258, p < .001). Overall, the statistical analyses across different parameters consistently demonstrate significant effects of treatments on grain yield, yield increment, and yield loss. These findings underscore the importance of treatments in influencing rice crop productivity and minimizing yield loss. Treatments with insect protection measures exhibit higher grain yields, yield increments, and lower yield loss compared to controls.

Table 4: The yield loss assessment of rice due to the stalk eyed fly

Treatments	Grain yield Year 1 Kg/ha	Grain yield Year 3 Kg/ha	Grain yield lose to insect protection) Year 3	Grain yield loss to insect protection) Year 1
Selam+Thiamethoxam	3848e	3560	31.53e	28.06
Selam+Chlorpyrifos	3569de	3280	25.63cd	22.56
Selam (control)	2746ab	2457	0a	0
Shaga Thiamethoxam	3067bc	2778	11b.09	9.51
Shaga + Chlorpyrifos	3788e	3499	29.7de	26.37
Shaga (control)	2768ab	2479	0a	0

Wanzaye+Thiamethoxam	3298cd	3009	22.6c	19.64
Wanzaye+ Chlorpyrifos	3251cd	2963	21.36c	18.51
Wanzaye (control)	2635a	2346	0a	0
Mean				
CV (%)	8.3	18.3	22.1	11.3

The examination of letters with similar characters suggested that there was no statistically significant difference, as the p-value exceeded 0.05.

4. DISCUSSION AND CONCLUSION

Rice Plant Growth Stage Susceptibility

The findings from the study investigating the effects of Stalk-Eyed Fly infestations on rice crop growth and development provide valuable insights into the impact of infestation at different growth stages. This implies that the treatments applied have influenced the productivity of tillers post-infestation, indicating varying degrees of effectiveness in mitigating the negative effects of Stalk-Eyed Fly infestations. The Seedling stage appears to be the most susceptible to Stalk-Eyed Fly infestations in terms of the impact on Seedling growth in rice crops. During this stage, the mean percentage change of Seedling is the highest at 40%, indicating a substantial impact of infestations on tiller growth. Additionally, although there is variability in the response across treatments, the overall effect is notable. This suggests that rice crops are particularly vulnerable to Stalk-Eyed Fly infestations during the seedling stage, highlighting the importance of effective pest management strategies during this critical growth phase to mitigate potential yield losses. This finding is consistent with research by (Patel *et al*., 2020), who observed a similar significant impact of infestations on the number of productive tillers per plant in rice crops. Their study emphasized the detrimental effects of Stalk-Eyed Fly infestations on rice crop productivity, highlighting the importance of effective pest management strategies to minimize yield losses.

Grain Yield:

The results indicate a substantial impact of treatments on grain yield (kg/ha) in both Year 1 and Year 3 of the study. In Year 1, the analysis revealed a highly significant effect of treatments on grain yield ($F (8, 27) = 11.480$, $p < .001$), demonstrating that different treatments significantly influenced grain yield outcomes. This finding aligns with previous research, such as a study by Smith *et al*., (2019), which showed that various agronomic treatments, including fertilization and pest management strategies, can significantly affect grain yield in rice crops.

Similarly, in Year 2022, although the significance level was slightly lower compared to Year 1, there was still a significant effect of treatments on grain yield ($F (8, 27) = 2.896$, $p = 0.018$). This indicates that treatments continued to exert a notable impact on grain yield even in subsequent years of the experiment. A study by Jones *et al*., (2018) supports this notion, demonstrating that the effects of different agronomic treatments on crop yield can persist over multiple growing seasons. Furthermore, the analysis revealed a significant effect of treatments on grain yield increment (%) in Year 3 ($F (8, 27) = 56.956$, $p < .001$), suggesting that the various treatments led to varying degrees of yield increment. This finding is consistent with previous research by Brown *et al*., (2020), which demonstrated that specific agronomic interventions can enhance yield increment in rice crops over time. Moreover, there was a significant effect of treatments on yield loss (%) due to grain yield increments in Year 1 ($F (8, 27) = 221.258$, $p < .001$), highlighting the impact of treatments on mitigating yield loss. This underscores the importance of implementing effective agronomic practices to minimize yield loss in rice production systems, as supported by studies such as that by Lee *et al*., (2017), which emphasized the role of integrated pest management strategies in reducing yield loss.

In summary, the consistent significant effects of treatments on grain yield, yield increment, and yield loss across different parameters underscore the importance of implementing effective agronomic practices, including insect protection measures, to enhance rice crop productivity and minimize yield loss. These findings are supported by previous research demonstrating the significant influence of agronomic treatments on rice crop outcomes over multiple growing seasons. The current result in line with the prevouse result, Stalk eyed fly damage showed reductions in grain yield of between 2 and 97%, Alghali and Osisanya, 2020).

In conclusion the study reveals that early-stage rice plants, particularly during the Seedling, Stem Elongation, and Panicle Initiation phases, are highly susceptible to stalk-eyed fly infestation. The application of insecticides, especially Thiamethoxam and Chlorpyrifos, significantly reduces infestation levels and prevents yield loss. Consistent increases in grain yield and reductions in dead heart incidence in treated plots across two years highlight the critical role of timely pest management. These results underscore the importance of targeting stalk-eyed fly control measures during the early stages of rice growth to optimize yield and minimize crop losses.

RECOMMENDATION

Based on the findings of the study, it is recommended to implement effective pest management strategies, particularly during the Seedling stage of rice crop growth, to mitigate potential yield losses caused by

Stalk-Eyed Fly infestations. The Seedling stage appears to be highly susceptible to infestations, as indicated by the substantial impact on tiller growth. Furthermore, the significant impact of treatments on grain yield, yield increment, and yield loss underscores the importance of implementing comprehensive agronomic practices, including insect protection measures, throughout the crop growth cycle. These practices should be consistently applied to enhance rice crop productivity and minimize yield loss.

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