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Infestation of Yellow Stemborer (*Scirpophaga incertulas* Walker) on Different Rice Cultivars Under Irrigated Lowland Ecosystem in Western Visayas

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ABSTRACT

The yellow stemborer (YSB) is an invasive and destructive pest in rice production in Western Visayas. The search for resistant rice varieties is the primary concern to minimize losses due to infestation. Considering these, this study aimed to screen different rice cultivars for resistance against YSB. The study found that the number of tillers and culm girth did not significantly affect the infestation of YSB in the vegetative phase. However, the rice cultivar white dinorado obtained the highest number of tillers while the red dinorado significantly recorded the thickest culm girth. A significantly low percent incidence of deadhearts was observed in Black basmati, White dinorado cultivars, and resistant check TKM6 on the reproductive phase. Moreover, a significantly high tiller count was observed in the rice cultivars white dinorado, red wagwag, and TKM6 during the reproductive phase at 90 DAS, but only the white dinorado exhibited the thickest culm girth among other cultivars. The number of tillers significantly negatively correlated with the percent incidence of whiteheads. Among the different rice cultivars screened, the white dinorado showed potential resistance during the vegetative and reproductive phases against yellow stemborer infestation under irrigated lowland rice ecosystem.

Keywords: deadhearts, whiteheads, insect resistance, varietal improvement

INTRODUCTION

The Philippines ranked eighth in world rice production in 2018 (FAOSTAT 2020). About 60% of the total production came from Luzon mostly from irrigated rice ecosystems and the rest are in the Visayas and part of Mindanao under rainfed lowland (Roberts et al 2009).

The Rice Tariffication Law (RTL)'s implementation has made resources available for use in initiatives and services that will assist the nation's rice producers. However, the recently approved Executive Order No. 135 slashed the tariffs on imported rice, endangering the supply of domestic rice and increasing the nation's reliance on Vietnam and Thailand (Rappler 2021; Dela Cruz 2022). These are the primary causes of losses in the rice sector that have a direct impact

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on the revenue of rice farmers, along with pest infestation, which results in an estimated 37% yield loss per year (Cabasan et al 2018). The Department of Agriculture Regional Crop Protection Center 7 warned that the visayas area is currently at high risk of the five most crucial pests in rice which include leaf blight, tungro virus, rice black bug, rodents, and rice stemborer during prolonged heavy rains (Nazario et al 2019)

There are six species of rice stemborers known to exist in the country. These comprise the following: (a) yellow stemborer (YSB) (Scirpophaga incertulas) (Renuka et al 2017); (b) white stemborer (WSB) (Schirpophaga innotata) (Litsinger et al 2006); (c) striped stemborer (SSB) (Chilo suppressalis) (Jiang et al 2011); (d) gold-fringed stemborer (GFSB) (Chilo auricilius) (Catindig et al 2012); (e) dark-headed stripe stemborer (DHSB) (Chilo polychrysus) (Mashhoor et al 2018); and (f) pink stemborer (PSB) (Sesamia inferens) (Baladhiya et al 2018).

Out of all the species, the yellow stem borer was thought to be the most damaging and invasive to rice cultivation. About 60% of the total production came from Luzon mostly from irrigated rice ecosystems and the rest are in the Visayas and part of Mindanao under rainfed lowland (Roberts et al 2009). It possesses complicated metabolic processes, and genes linked to such specialized behavior, and is monophagous on rice, making it challenging to govern (Kattupalli et al 2021). Due to its persistence in the double and triple rice cropping system, it is one of the most essential pests targeted during the application of chemical pesticides. But through time, this species developed adaptive mechanisms to chemical and even biological control. Upon infestation, the stemborer larvae damage the rice crop's growth points and cause "whiteheads," which are empty or partially full heads of discolored grains, as well as "dead hearts," or the youngest, still-unfolded leaves, to wilt and die. Dead hearts are commonly observable when borers attack at the vegetative stage while whiteheads occur when the stemborers attack at the time of ear development or booting to panicle initiation in rice (Deka & Barthakur 2009).

In order to minimize the impact of rice stemborers, rice lines are constantly tested for resistance. Breeders have attempted to utilize natural and induced resistance of existing rice varieties to develop new resistant genotypes. However, the development of these resistant lines is unsuccessful due to the limited source of resistant rice germplasms (Kattupalli et al 2021).

The utilization of traditional native rice lines (TRLs) and other imported rice across countries that possess high resistance are considered for further development. TRLs not only possess high nutritive value but are also highly adapted to a wide range of environmental conditions and have a high level of resistance to pests and diseases (Rabara et al 2014).

The actual field evaluation and assessment of TRLs have been limited and additional studies on the mechanisms and factors of resistance are needed. Considering its potential as a source of germplasm in developing new resistant rice varieties against stemborers especially in Western Visayas, this study was conducted. This aimed to (a) identify promising common rice cultivars currently utilized in Western Visayas possessing resistance against YSB and (b) evaluate the morphology of each cultivar and its effect on the severity of infestation under field condition.

MATERIALS AND METHODS

The study was conducted at Sitio Cayap, Brgy. Rizal, Oton, Iloilo, with a latitude of 10.76 and a longitude of 122.44. The elevation was 39.0 meters above sea level and the total area allocated for the study covered 2,000 sq meters. It was classified under an irrigated lowland rice ecosystem with sufficient irrigation sources throughout the study.

Experimental Set-up

The research was laid in a Randomized Complete Block Design (RCBD) with three replications and six treatments in an open-field condition. The six treatments included were V1 – Black basmati, V2 – White dinorado, V3 - Red wagwag, V4 – Red dinorado, V5 – TN1 (check variety, S), and V6 – TKM6 (check variety, R). The farmers' fertilizer recommended rate of 90-60-60 was used as the basis of fertilization. There were 18 plots established with a dimension of 2.5 x 2.5 meters per plot. One meter distance between the main plot was established to provide space during field monitoring and data collection. During the direct wet seeding, two vertical nylon ropes were placed at both ends of the plot that served as guides on the plating distance between rows, and a horizontal line was used as a guide to having proper spacing between hills in the column. The planting distance was 20 x 20 cm and each plot had a total of 144 hills.

Site preparation. The bunds around the field were checked and repaired if cracks or holes were present. It was followed by irrigation maintaining the water depth of 3-5 cm for three days to soften the soil that will favor the rice crop establishment, growth, and development. Primary tillage followed four days after irrigation. The field was plowed using a hand tractor, the first pass started along the edges of the field in a clockwise pattern, and the second pass was countered-clockwise, and finished at the center. The field was submerged for 7 days after the primary tillage to soften clods and decompose plant debris and organic materials. After submergence, secondary tillage was performed using a power tiller (drum wheel tractor) with an attached comb-tooth harrow. It passed crosswise to break soil clods and the second pass was done lengthwise. The water depth was reduced to locate uneven and high surfaces of the field before the harrowing. A wooden plank attached to the tractor was used during the final leveling. A level, smooth field surface was assured to provide uniform germination, nutrient gradient, and water distribution.

Seed preparation. The different rice cultivars were placed in a perforated plastic bag and soaked in clean tap water for 12 hours to ensure proper germination. After soaking, the seeds were incubated overnight using a clean sack and cloth until it sprouted in preparation for direct wet seeding.

Irrigation, Fertilization, and Weeding. Irrigation started on the tenth day after sowing. Water depth was maintained to control weeds and to provide sufficient moisture for crop growth. The first application of fertilizer was performed at 40 % N, 100% P, and 100% K. The second application of N was in the tillering stage at 30% of the recommended rate and another 30% during the early panicle initiation. The post-emergence herbicide was used seven days after the emergence of the rice crop and manual weeding or the use of a mechanical weeder was performed by the researcher and hired labor in the later stages of the crop. No other chemical inputs were used until the termination of the study.

DATA COLLECTION

Deadhearts and Whiteheads. At 35 DAS (tillering stage), data collection on the deadheart tillers started, and at 90 DAS (heading to maturity), the data collection on whiteheads was conducted. During the vegetative stage, 10 hills were randomly selected per treatment/replicate and the total number of deadhearts over the total number of tillers on the hill was counted. The same method was used during the reproductive stage for the number of whiteheads but the 10 selected samples during the vegetative stage were excluded during sampling (Ganesh et al 2020; Horgan et al 2020). Systematic random sampling was used in selecting samples from each plot using the formula:

where:

k = systematic sampling interval
N = population size
n = sample size

$$k = \frac{N}{n}$$

Deadhearts and Whiteheads Severity Rating and Incidence. From the observed deadhearts and whiteheads on the selected hills, the incidence was calculated using the formula suggested by Ganesh et al (2020).

$$\text{Stemborer infestation incidence} = \frac{\text{Number of damaged tillers}}{\text{Total number of tillers}} \times 100$$

The severity rating was based on the Standard Evaluation System for Rice (SES), International Rice Research Institute, 5th edition 2014 (Table 1). Where R: resistant=1, MR: moderately resistant=3, I: intermediate=5, MS: moderately susceptible=7, and S: Susceptible = 9.

Table 1. Severity scale and category of deadhearts and whiteheads damage percentage

SCALE	CATEGORY	DAMAGE PERCENTAGE (DEADHEARTS)	DAMAGE PERCENTAGE (WHITEHEADS)
1	R	1-10	1-5
3	MR	11-20	6-10
5	I	21-30	11-15
7	MS	31-60	16-25
9	S	61 and above	26 and above

Morphological Data

Tiller Density. The selected 10 random sample hills on the vegetative and reproductive stages also served as samples in determining tiller density. All of the productive tillers including the damaged and undamaged were counted and recorded. Its mean was obtained and represented each rice entry across replications.

Culm Girth. The stem diameter was measured at the fifth phytomere position of selected sample tillers using a digital caliper. The data was used to compare if there is a relationship between the diameter of the culm to nitrogen and the incidence of stemborer infestation.

Statistical Analysis

The data were analyzed using Two-Way Analysis of Variance (ANOVA). Significance among means was further subjected to *post-hoc* analysis using the Least Significant Difference (LSD) Test run in Statistical Tool for Agricultural Research (STAR) vr. 2.0.1. Pearson correlation test with Linear regression was used to identify the significant relationship between the number of tillers vs incidence and culm girth vs incidence. The interpretation was based on the suggested scale by Turney (2022).**Results and Discussion**

Morphology of Different Rice Cultivars at 35 DAS

The analysis revealed no significant differences in terms of the tiller count of the different rice cultivars [F(2,5)=1.21, p = 0.3699] (Fig. 1A). Numerically, white dinorado and red dinorado obtained the highest average of 19.44 and 19.11 tillers per hill, respectively. While the resistant check TKM6 exhibited a low tiller count of 17.02 tillers per hill. However, the culm on each cultivar significantly differs (Fig 1B). The analysis showed that red dinorado and black basmati comparably obtained the highest culm girth with an average of 5.03 and 4.58 millimeters, respectively [F(2,5)=44.86, *p* = 0.0000]. On the other hand, the susceptible check TN1 was observed to have the smallest girth at 3.13 mm, but, is still comparable to other entry cultivars (*p* = 0.0000, 95% C.I.= 2.87, 5.26).

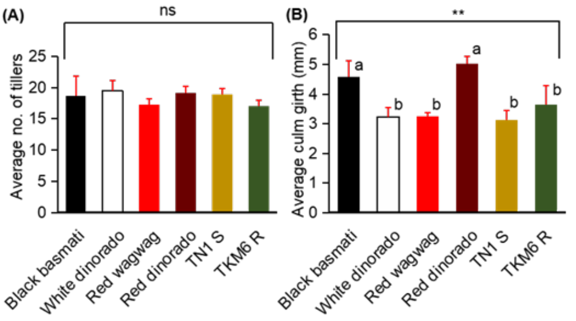


Figure 1. Morphology of different rice cultivars at 35 DAS. Panel (A) shows the average number of tillers of each cultivar. Panel (B) shows the average culm girth of different rice cultivars. The data were analyzed using Two-way ANOVA with Least Significant Difference (LSD) *post-hoc* test. The double asterisks (**) indicate a statistically significant difference ($p < 0.01$). Vertical bars in the graphs represent standard deviations of mean from the three determinations

Incidence and Severity Scale of Deadhearts at 35 DAS

The infestation of yellow stemborer on the different rice cultivars at 35 DAS is shown in Figure 2A. The analysis observed a significant difference among the means in terms of the percent incidence of deadhearts on the entry cultivars [$F(2,5)=30.86$, $p = 0.0000$](Fig. 2B). Out of the six test cultivars, the red wagwag and red dinorado together with the susceptible check obtained the highest percent incidence of whiteheads. Having an average incidence of 27.29, 27.96, and 30.50 percent, respectively. The damage percentage of these two rice cultivars is equivalent to a rating scale of 5, which corresponds to an intermediately resistant (I) category (Table 1). On the contrary, the black basmati and white dinorado recorded the lowest percent incidence of 12.40 and 7.26, which was comparable to the resistant check TKM6 ($p = 0.0000$, 95% C.I.= 5.21, 31.41). In terms of scale, the black basmati obtained a rate of 3, while the white dinorado rated a scale of 1 which corresponds to a moderately resistant (MR) and resistant category, respectively.

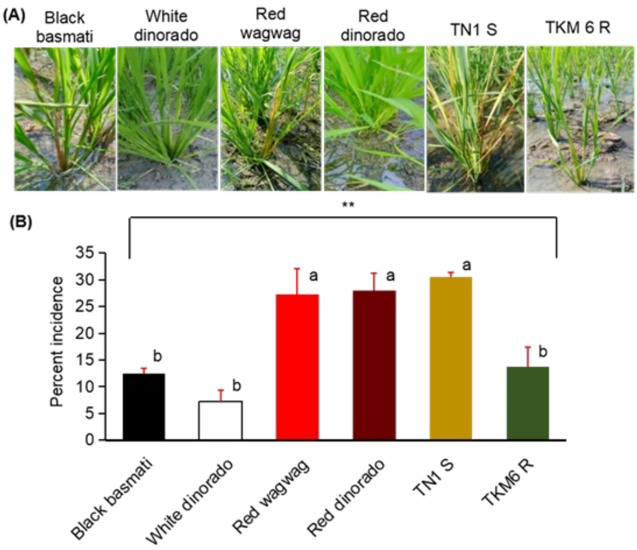


Figure 2. Percent incidence of deadhearts on different rice cultivars at 35 DAS. Panel (A) shows the deadhearts on the different test cultivars. Panel (B) shows the average percent incidence of deadhearts on different rice cultivars. The data were analyzed using Two-way ANOVA with Least Significant Difference (LSD) *post-hoc* test. The double asterisks (**) indicate a statistically significant difference ($p < 0.01$). Vertical bars in the graphs represent standard deviations of the mean from the three determinations

Table 1. Severity rating scale and category of resistance based on the damage percentage of deadhearts

RICE CULTIVAR	DAMAGE PERCENTAGE OF DEADHEARTS	SCALE	CATEGORY
Black basmati	12.40	3	MR
White dinorado	7.26	1	R
Red wagwag	27.29	5	I
Red dinorado	27.96	5	I
TN1 S	30.50	7	MS
TKM6 R	13.76	3	MR

The severity scale and rating category were based on the Standard Evaluation System for Rice (SES), International Rice Research Institute, 5th edition (2014). R: resistant=1, MR: moderately resistant=3, I: intermediate=5, MS: moderately susceptible=7, and S: Susceptible = 9

Percent Incidence of Deadhearts vs Number of Tillers and Culm Girth

Pearson's product-moment correlation analysis revealed a negative but not significant relationship between the number of tillers and the percent incidence of deadhearts on the different rice cultivars at 35 DAS (r = -0.06, p > 0.05) (Fig 3A). This implies that the number of tillers on each cultivar could be one of the factors in reducing the incidence of deadhearts in the vegetative phase of the rice. Furthermore, a positive but not significant correlation was noted in terms of culm girth and percent incidence of deadhearts (r = -0.03, p > 0.05) (Fig 3B). This signifies that an increase in the culm girth during the vegetative phase of the rice might potentially increase the incidence of deadhearts.

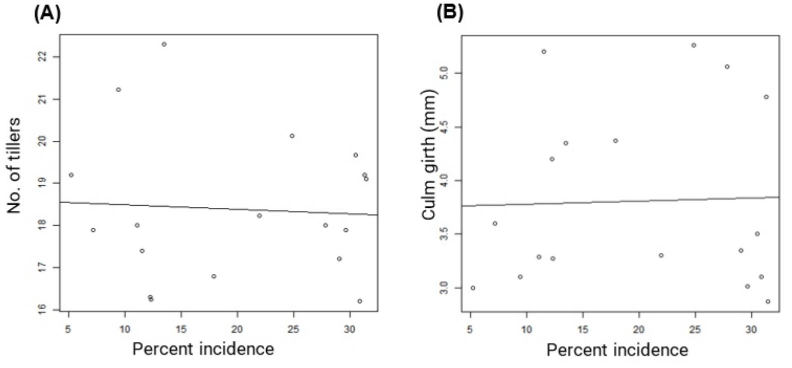


Figure 3. Linear regression of the relationship of the number of tillers and culm girth on the percent incidence of deadhearts at 35 DAS of different rice cultivars

Morphology of Different Rice Cultivars at 90 DAS

The analysis of the number of tillers 90 days after sowing revealed highly significant differences among rice cultivars [F(2,5)= 12.38, p = 0.0005] (Fig. 4A). Among the cultivars, the resistant check TKM6 obtained the highest number of tillers with an average of 13 tillers per hill. Statistically, the white dinorado and red wagwag are comparable to the resistant check having an average tiller count of 11 and 11.33 tillers per hill, respectively (*p* = 0.0005, 95% C.I.= 8, 15). On the other hand, the test cultivar red dinorado recorded the least number of tillers having only an average of 8.67 tillers per hill. Moreover, the culm girth was observed to differ in each test cultivar (Fig. 4B). The analysis of variance revealed that the white dinorado significantly possesses the thickest culm girth among other entry cultivars [F(2,5)= 10.35, *p* = 0.0011], having an average culm girth of 8.35 millimeters. The rest of the test cultivars are comparable possessing an average culm girth ranging from 5 to 5.55 millimeters (*p* = 0.0011, 95% C.I.= 4.02, 8.89).

Incidence and Severity Scale of Whiteheads at 90 DAS

The infestation of the reproductive phase of the test cultivars was observed on the 90th day after sowing (Fig. 5A). The analysis significantly revealed differences among the means in terms of the percent incidence of whitehead on the different rice cultivars [F(2,5)= 125.08, *p* = 0.0000]. The susceptible check TN1 recorded the highest percent incidence having an average incidence of 42.96 percent. The test cultivars black basmati, red wagwag, and red dinorado are statistically comparable with an average incidence of 24.83, 27.33, and 29.15 percent, respectively (*p* = 0.0000, 95% C.I.= 6.67, 44.44). The black basmati rated a scale of 7 equivalent to a moderately susceptible (MS) category, while the red wagwag, red dinorado, and TN1 rated a scale of 9, equivalent to a susceptible (S) category. On the other hand, white dinorado cultivars obtained a low whitehead infestation at 9.81 percent incidence, which is comparable to the resistant check TKM6 which possesses the lowest infestation of 7.82 percent incidence. The white dinorado was the only test cultivar that parallels the resistant check TKM6 that rated the scale of 3, which corresponds to a moderately resistant (MR) category.

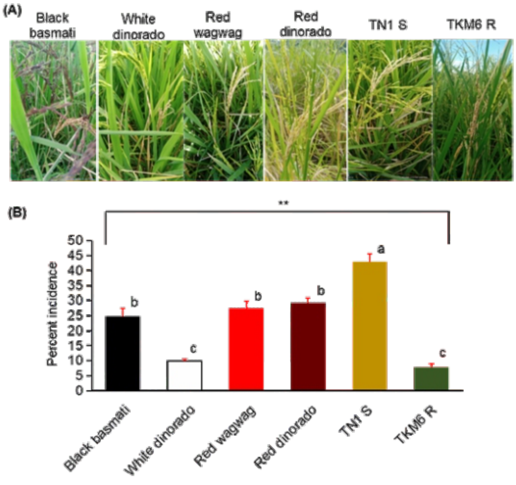


Figure 5. Percent incidence of whiteheads on different rice cultivars at 90 DAS. Panel (A) shows the whiteheads on the different test cultivars. Panel (B) shows the average percent incidence of whiteheads on different rice cultivars. The data were analyzed using Two-way ANOVA with Least Significant Difference (LSD) *post-hoc* test. The double asterisks (**) indicate a statistically significant difference ($p < 0.01$). Vertical bars in the graphs represent standard deviations of the mean from the three determinations

Table 2. Severity rating scale and category of resistance based on the damage percentage of whiteheads

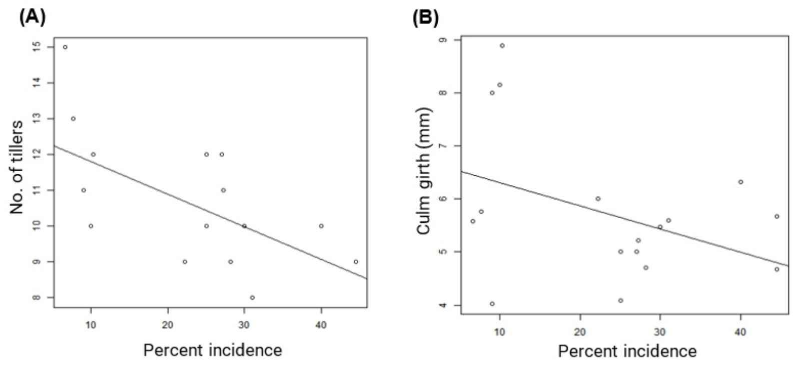
RICE CULTIVAR	DAMAGE PERCENTAGE OF WHITEHEADS	SCALE	CATEGORY
Black basmati	24.83	7	MS
White dinorado	9.81	3	MR
Red wagwag	27.33	9	S
Red dinorado	29.15	9	S
TN1 S	42.96	9	S
TKM6 R	7.82	3	MR

The severity scale and rating category were based on the Standard Evaluation System for Rice (SES), International Rice Research Institute, 5th edition (2014). R:

resistant=1, MR: moderately resistant=3, I: intermediate=5, MS: moderately susceptible=7, and S: Susceptible = 9

Percent Incidence of Deadhearts vs Number of Tillers and Culm Girth

Pearson's product-moment correlation analysis revealed a significant negative correlation between the number of tillers and the percent incidence of whiteheads on the different rice cultivars at 90 DAS ($r = -0.6450, p < 0.01$) (Fig 6A). This indicates that as the number of tillers per hill increases, a significant decrease in the incidence of whiteheads will be assured. Moreover, the analysis also revealed a non-significant but negative correlation between the culm girth and the percent incidence of whiteheads ($r = -0.3982, p > 0.05$) (Fig 6B). This implies that the culm girth of the rice could play a potential role in the reduction of whitehead incidence in which an increase in culm girth might lessen the infestation of YSB on the reproductive phase.



and culm girth on the percent incidence of whiteheads at 90 DAS of different rice cultivars

DISCUSSION

The YSB is a pest of deep-water rice commonly found in areas where continuous flooding occurs. The second larval instars enclose themselves in a leaf tube that will be detached and fall into the water that will serve as their mode of transport to the target tillers (Catindig & Heong n.d; Islam & Catling 1995; Rapusas et al 1999). In Asia, the rice stem borer was highlighted as the major production constraint in the Philippines, Indonesia, and China, considering the yellow and striped stemborer as the most invasive species that causes a tremendous reduction in yield of up to 70% (Babendreier et al 2020).

The incidence of stemborer infestation can be observed in the mid-tillering up to the late tillering stage. During this period, rapid production of tillers and the development of other morphological components occurred. Upon the initial stage of infestation, the larva will attack the basal region of the tillers, leading to dead hearts. The injury caused by the larva enables the plant to compensate for the damage by producing new tillers. Two weeks after infestation, the stemborerinjured plant can significantly produce many tillers per hill (Rubia et al 1996). It is notably observable in the study that during the vegetative phase of the planted rice cultivars, the percent incidence of deadheart is not directly correlated with the number of tillers and girth of the cultivars because of damage compensation. But Alghali (1983) and Bianchi et al (1993) elaborated that even if the damage of stemborers can be compensated by the rice crop, the life cycle will be prolonged. This will ensure the effect on the stages of the rice crop towards the reproductive phase because the compensation is greater when damages take place at the early stage than at the late stages of the rice. This compensatory behavior will directly cause yield loss due to the production of secondary smaller panicles (Nwilene et al 2013).

Furthermore, the infestation of the stemborer during the reproductive stage will damage the central culm holding the panicle, leading to what they called "whiteheads" (Deka & Barthakur 2009). In this study, whiteheads were observed on the 90th DAS and severely noted on the red wagwag and red dinorado. The infestation primarily targets the rice tiller, affecting the panicle initiation and thus the yield (Bolarinwa et al 2021). However, the tillering capacity possessed by rice cultivars may affect the degree of the infestation (Litsinger et al 2012; Horgan et al 2021). It was observed in this study that the number of tillers negatively reduces the incidence of whiteheads in the reproductive phase. This parallels the findings of Shahjahan and Hossain (2003) which concluded that the number of tillers is negatively correlated with stemborer infestation rate. This indicates that if the tillers of the rice become dense per hill, the occurrence of infestation is minimized. According to Jackson (2019), the high tillering capacity of rice contributes to its ability to withstand 20% infestation of stemborer in the field and one must consider upon concluding that the certain cultivar is resistant. During the maximum tillering, the leaf sheath that covers the culm which gives additional time for the larvae to bore and penetrate inside (Lin 1980; Litsinger 2011)

Traditional native rice varieties or heirloom rice found in the Philippine province specifically the Dinorado cultivars can withstand extreme climatic and these varieties can thrive despite torrential rain and insect infestation (Zapico et al 2015). These rice cultivars are known to produce a maximum of 25-30 tillers per hill (Thwe & Zamora 200). Two of the Dinorado cultivars were used in this study which include White dinorado and Red dinorado. However, the White dinorado was the only cultivar that possessed an ideal resistance between the two and even to other cultivars except for the resistant check TKM6. The severity of the infestation could differ in terms of the cultivars planted and the ecosystem where the rice crop was established (Patel & Singh 2017; January et al 2020). The study of Litsinger et al (2012) observed that the established traditional varieties in Oton, Western Visayas (Panay) obtained a maximum crop loss of 13.4 due to stemborer infestation significantly lower compared to modern varieties. Their sampling further concluded that 91% of the rainfed wetlands and 99% of irrigated wetlands are infested by stemborers, which is the location where this study was conducted.

CONCLUSION

During the vegetative phase on the 35th day after sowing both of the dinorado cultivars produced the highest number of tillers, while the red dinorado measured the thickest culm girth. The incidence of deadhearts in this phase is low in black basmati, white dinorado, and the resistant check TKM6, but only the white dinorado was classified as resistant in terms of severity scale. To sum it up, the culm girth of the different rice cultivars did not significantly affect the incidence of deadhearts in the vegetative and reproductive phases of the different rice cultivars. Moreover, the resistant check TKM6 has the highest number of tillers during the reproductive phase on the 90^{th} day after sowing. In terms of culm girth, the white dinorado has the thickest girth among the test cultivars, and together with the resistant check TKM6, they obtained the lowest incidence of whiteheads. Out of the tested rice cultivars, only the white dinorado was categorized as moderately resistant to the infestation of the YSB in the reproductive phase.

RECOMMENDATION

Based on our findings, the white dinorado can be classified as a possible source of resistant traits for breeding resistant inbred varieties against yellow stemborers. It is also necessary to consider other morphological parts and the biochemical component of this cultivar which could be its mechanism of resistance.

Since the study was conducted in a one-season set-up only, it is best to adopt the same set-up and establish a long-season experiment across a multi-location setting in Region 6. Insect pests are widespread and adapted to the locality they colonized, as are the different varieties. Even though these cultivars are highly adapted to multiple environmental conditions, it is still vulnerable to changes such as weather patterns, soil fertility, irrigation systems, population, and species of pests present.

The severity of the infestation cannot only be concluded based on rating and the percent incidence. It is ideal to establish further research relevant to the studies extending the parameter to harvest. Since harvest is one of the best indicators of an ideal resistant variety for production or as a source of germplasm for breeding.

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