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Research Article

ASSESSMENT OF YIELD RELATED TRAITS OF RICE CULTIVARS AND EFFICACY OF DIFFERENT PESTICIDES AGAINST SCIRPOPHAGA INCERTULAS WALKER (LEPIDOPTERA: PYRALIDAE)

Fazeela Zarin[1], Muhammad Asif[1], Ahmad Nawaz[1], Muhammad Amjad Bashir[2*], Sagheer Atta[2], Sanober Gul Khan[3], Munaza Batool[4], Nasir Mahmood[5]

[1]*Entomology Department of the University of Agriculture Faisalabad, Pakistan*
[2]*Department of Plant Protection, Faculty of Agricultural Sciences Ghazi University DG Khan*
[3]*Department of Plant Breeding and Genetics, Faculty of Agricultural Sciences Ghazi University DG Khan*
[4]*Department of Soil and Environmental Sciences, Faculty of Agricultural Sciences Ghazi University DG Khan*
[5]*Govt. College for Women University Faisalabad, Punjab, Pakistan*
**Corresponding Authors: abashir@gudgk.edu.pk*

Abstract

Rice (*Oryza sativa* L.) is a staple food crop worldwide. Yellow stem borer (*Scirpophaga incertulas* Walker) is considered a major pest of rice. The present study aimed to evaluate the yield-contributing traits of different rice cultivars and to assess the efficacy of various control strategies against yellow stem borer under field conditions. Seven rice cultivars—C1 (Chenab Basmati), C2 (PK-386), C3 (KSK-133), C4 (KSK-434), C5 (Super Basmati), C6 (KSK-282), and C7 (Kissan Basmati)—were collected from the Rice Research Institute, Kala Shah Kaku, and evaluated for their yield performance. Additionally, PK 1121 Aromatic was transplanted at Madina Colony, Meclod Gunj, Bahawalnagar during the 2020 season to study YSB infestation and its management. Key yield parameters included the number of tillers per plant, grains per panicle, 100-grain weight (g), and spike length (cm). Among the cultivars, the yield potential ranked as C7 > C3 > C6 > C4 > C1 > C5 > C2. The efficacy of neem extract (30ml/L), chlorpyrifos (1ml/L), and *Metarhizium anisopliae* (2ml/L) was tested against YSB, along with a control treatment. Chlorpyrifos (T2) showed the highest effectiveness, with dead hearts recorded as 20.00%, 13.33%, and 13.30% and white heads as 23.66%, 20.33%, and 19.00% after 1st, 2nd, and 3rd applications respectively. Neem extract (T1) showed moderate effectiveness with dead hearts at 33.33%, 22.11%, and 20.99% and white heads at 28.99%, 24.99%, and 22.85%. *M. anisopliae* (T3) resulted in dead hearts of 28.66%, 20.67%, and 19.75% and white heads of 26.21%, 23.23%, and 22.57%. The control showed the highest infestation with dead hearts of 40.33%, 39.54%, and 42.11%, and white heads of 37.12%, 38.23%, and 40.14%. In conclusion, the number of tillers per plant, grains per panicle, 100-grain weight, and spike length are critical yield-determining traits. Neem extract and *M. anisopliae* were effective alternatives to chemical pesticides in reducing yellow stem borer infestation.

Keywords: *Metarhizium anisopliae, neem extract, chlorpyrifos, Scirpophaga incertula, Deadhearts, Whiteheads.*

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1. INTRODUCTION

Rice is a staple food for over 3.5 billion people worldwide, providing 20% of the global dietary needs, while maize and wheat contribute 5% and 19% respectively (Gadal *et al*., 2019). Major rice-producing countries include China, India, Myanmar, Thailand, the Philippines, Japan, Pakistan, Bangladesh, the United States, Indonesia, Korea, and Vietnam. Nearly half of the total global rice is grown in China and India. Rice cultivation spans approximately 158 million hectares, with developing countries accounting for 90% of global production (Ane and Hussain, 2016). It is the primary staple food in seventeen Asian and Pacific countries, nine in the Americas, and eight in Africa, with Asia contributing the most to global production. In 2015-16, China led rice production with an output of 145.5 million tonnes, while Japan achieved the highest yield at 4.91 t/ha, followed closely by China with 4.79 t/ha. Globally, rice stands as the most crucial crop, covering over 42.5% (168,047 ha) of the total food grain area and accounting for 51.6% of food grain production (Gadal *et al*., 2019).

In Pakistan, rice is the second most vital food crop after wheat and serves as the most profitable agricultural export. It contributes 3% to the value-added in agriculture and 0.6% to the national GDP (Economic Survey of Pakistan, 2016–17). Pakistan is ranked fifth among global rice exporters in 2016–17 and exports approximately 4.2 million metric tonnes out of a total production of 6.85 million metric tonnes and therefore generates US$1.86 billion in foreign exchange (Akhter *et al*., 2019). Grown on 2.8 million hectares, the average rice yield in Pakistan stands at 2387 kg/ha, which remains significantly lower than that of other rice-producing nations. Yield is a complex trait which has been modulated by multiple genes and further influenced by environmental factors. Therefore, selecting parental lines solely based on yield is unreliable. For effective selection, it is essential to understand the relationship between yield and its contributing traits. Correlation studies help evaluate these interactions and guide breeders in identifying key yield-related characteristics (Rashid *et al*., 2014).

Evaluating the variability in grain yield and its components is crucial for breeding efforts aimed at improving productivity. Grain yield is determined by various traits, and understanding both the correlations and the direct and indirect effects of these traits enhances the efficiency of selection strategies (Sudeepthi *et al*., 2020). Yield is the result of several interacting features, and its improvement depends on analyzing these relationships thoroughly. Studies have shown that traits such as pollen fertility, grains per panicle, spikelet fertility, and panicle fertility significantly correlate with yield (Ramakrishnan *et al*., 2006). As grain yield is a multigenic and environmentally influenced characteristic, breeders must base their selections on yield components rather than yield alone. Knowing the association between morphological and physiological characteristics and yield is vital for developing selection criteria (Rajeswari and Nadarajan, 2004; Moosavi *et al*., 2015).

Despite improvements from the introduction of high-yielding IRRI cultivars, the average rice yield in Pakistan remains below the global average. Traits contributing to yield are interconnected, and understanding their phenotypic and genotypic correlations helps plant breeders develop superior rice lines with greater yield potential. The main objective of research in this area is to evaluate the genetic variability and character associations of yield-contributing traits to determine which are most effective for breeding (Zia-Ul-Qamar *et al*., 2005). Traits like test weight, grains per panicle, panicle length, and the number of effective tillers play an important role in determining rice yield (Sreedhar *et al*., 2019).

Insect pests attacking different stages of rice crops reduce the rice productivity. Over 100 insect species attack rice, with 20 capable of causing economic losses. Major pests include the rice brown plant hopper, leaf folder, green leafhopper, grasshopper, ear head worm, white backed plant hopper, yellow stem borer, and white leafhopper. It has been reported that the brown plant hoppers cause 20% yield loss, leaf folders 10%, gall midge 15%, and other insect pests cause a yield loss of 25% (Lisha *et al*., 2020). Among these, the rice stem borer and leaf folder are particularly destructive. At various growth stages, stem borers damage leaves and growing points, causing symptoms like "dead heart" and "white head," which significantly reduce yield (Neelakanth *et al*., 2017). In Iran, yellow stem borer is the most dangerous pest, responsible for significant yield losses and heavy insecticide use. Managing these pests requires extensive chemical inputs, including Diazinon (active ingredient: diazinon) and Padan (active ingredient: cartap hydrochloride), though the prolonged emergence of pest and its multiple generations make the management difficult.

Due to the drawbacks of chemical insecticides—such as resistance development, environmental pollution, and health risks—alternative pest management methods are being explored. Botanical pesticides like neem are promising eco-friendly alternatives, offering insect-repelling and anti-feeding properties against a wide range of pests (Choudhary *et al*., 2017). Biological control using entomopathogenic fungi such as *Metarhizium anisopliae* and *Beauveria bassiana* is an effective and sustainable strategy (Majidi-Shilsar, 2017). These fungi are natural enemies of various insect pests and are essential for integrated pest management (IPM) systems. Globally, more than 1400 insect species affect rice, and non-chemical pest management is vital for maintaining ecological balance and reducing reliance on synthetic chemicals. Plants like neem offer safe alternatives that help protect pollinators and preserve natural predators (Bhojane *et al*., 2020).

Scirpophaga incertulas Walker (Lepidoptera: Pyralidae), commonly known as the yellow stem borer, is one of the most destructive pests affecting rice cultivation across Asia. Its larval feeding inside the stem causes significant damage in the form of dead hearts and white heads, ultimately leading to considerable yield losses. Recent reports have shown that infestations by lepidopteran pests like *S. incertulas* can lead to measurable reductions in crop productivity, emphasizing the urgent need for sustainable and integrated pest management strategies. Among these, biocontrol agents such as neem oil and entomopathogenic fungi like *Metarhizium anisopliae* have demonstrated promising insecticidal properties against lepidopteran pests (Varshney *et al*., 2021). The integration of botanical and synthetic insecticides offers a potentially effective and eco-friendly approach for managing *S. incertulas* infestations in rice fields.

Objectives of the Study:

1. To evaluate the efficacy of selected botanical and synthetic insecticides against *Scirpophaga incertulas* under field conditions.
2. To assess the impact of insecticidal treatments on the yield-related traits of different rice cultivars.
3. To identify the most effective and sustainable pest management strategy for controlling *S. incertulas* in rice cultivation.

2. MATERIALS AND METHODS

The research was based on open field trials with four treatments and three replications of each treatment with each application (foliar application) on rice with a control.

Research area

The research was conducted at Madina colony Meclod gunj, Bahawalnagar during the year of 2020. Experimental site lies between 30.0025° N latitude and 73.2412° E longitude. About 163 m above at sea level. Variety of crops like maize, wheat, cotton, rice, and vegetables are grown throughout the year. These crops are infested by different types of sucking and chewing insect pests like aphid, whitefly, jassid, thrips, cotton bugs, bollworms, sugarcane borers and rice borers, respectively.

Preparation of land

In order to ensure optimal growth and a well-established position of the rice nursery, the land was thoroughly prepared prior to sowing and subsequent transplanting. The selected area was first ploughed using a tractor-mounted cultivator to break up compact soil and improve aeration. This was followed by two cross harrowings to further refine the soil structure and enhance tilth. The land was then leveled using a wooden or laser leveler to ensure uniform water distribution, which is critical for healthy seed germination and seedling development.

Organic matter in the form of well-decomposed farmyard manure (FYM) was incorporated into the soil at a rate of 8–10 tons per hectare during the final ploughing to enhance soil fertility and microbial activity. To ensure proper drainage and ease of management, raised beds and channels were constructed around the nursery area.

Weeds and crop residues were carefully removed manually to eliminate any competition for nutrients and to minimize the risk of pest and disease carryover. After land preparation, the plots were kept free from weeds throughout the nursery period through regular hand weeding. This comprehensive land preparation created an ideal environment for the uniform emergence, vigorous growth, and healthy transplanting of rice seedlings into the main experimental field.

Soil analysis

Before transplanting the rice nursery, soil samples were collected from the experimental field and analyzed at the Soil and Water Testing Laboratory, Bahawalnagar**.** The soil was classified as loam in texture**,** with a pH of 8.5, indicating slightly alkaline conditions. The organic matter content was 6.2%**,** suggesting high fertility and good soil health. Standard tests performed included pH (1:1 soil-water suspension), organic matter (Walkley-Black method), and texture analysis (hydrometer method). This assessment ensured suitable conditions for successful rice transplanting and informed nutrient management strategies.

***Metarhizium anisopliae* culture preparation**

Potato dextrose broth (PDB) media was used for the manipulation of fungus. The distilled water (500ml) was taken in a conical flask. Potato dextrose broth at the rate of 39 g was added in 500 ml water after adding the PDB. The mouth of the conical flask was covered with an aluminum sheet and shaken well. After shaking, the solution was heated at a magnetic stirrer and autoclaved at 121°C for 15-20 minutes at 15psi. The autoclaved conical flask was removed from the autoclave and cooled at room temperature. The flask was placed under the laminar flow hood. Scalpel was heated on the spirit lamp until it became red hot. The process was carried out to remove contamination. A small piece from the fungal *Metarhizium anisopliae* Colony was cut with a red-hot scalpel and inoculated in the autoclaved potato dextrose broth and store at room temperature for 3-5 days for virtuous growth. The grown fungal cultures were centrifuged at 8000 rpm for 15 min at 25°C.

Insecticide collection

Chlorpyrifos 40% EC.

Neem extract preparation

The neem leaves 2.5 kg were chopped into smaller pieces and mixed with 5 litres of fresh water. Water boiled for 30-45 minutes. Solution was kept for 2 hours toward became cool and then filtered.

Experiment

Randomized complete block design (RCBD) was used in this field trails. Rice seeds (PK 1121 Aromatic) was taken from the Rice Research Institute, Kala Shah Kaku, for nursery planting. Primarily, 30 days old rice nursery (PK 1121 Aromatic) was shifted in prepared field immediately, on July12, 2020 at Madina colony Meclod gunj,

Table 1: Germination Percentage of Different Rice Cultivars along with their Common Names.

Cultivars	Common name	Germination %
C_1	Chenab Basmati	97
C_2	PK-386	87
C_3	KSK-133	83
C_4	KSK-434	100
C_5	Super Basmati	60
C_6	KSK-282	77
C_7	Kissan Basmati	83

Bahawalnagar. With the normal spacing of 9 inches @ 2 seedling per hill. Azoxystrobin was used for seed treatments with the help of hand sprayer. Research area was 2 meter square and three replications for each treatment. Four treatments T_1 (Neem extract), T_2 (Chlorpyrifos), T_3 (*Metarhizium anisopliae*) and T_4 (Control) was used in this research study. Botanical extracts (neem) 30 ml/liter of water was used. Biopesticide (*M. anisopliae*, 2 ml/liter of water) and Chlorpyrifos at rate of 1 ml/L of water was used. A hand sprayer with a capacity of about 2 litres for the application of pesticides was used. Treatments were applied by foliar application. Each treatment had 9 plants. Treatments was applied three times with the interval of 40, 60, 70 days after nursery transplanting.

Table 2: This soil analysis report evaluates two rice fields with loamy soil texture, showing slightly alkaline conditions (EC ~0.54–0.55 dS/m) and high organic matter content (6.2–6.6%). Available phosphorus is low (6–7.6 ppm), while potassium levels vary significantly (32–110 ppm). The report recommends gypsum application, acid-forming fertilizers, and organic amendments to improve soil fertility and crop productivity.

Sr. No.	**Field No.**	**Depth (inches)**	**Area (Acre)**	**EC (dS/m)**	**Organic Matter (%)**	**Available P (ppm)**	**Available K (ppm)**	**Soil Texture**
1	T1	6–12	2	0.54	6.2	6	110	Loam
2	T2	6–12	2.4	0.55	6.6	7.6	32	Loam

Table 3: Soil analysis report of agricultural fields showing physico-chemical properties at two soil depths, including pH, EC, organic matter, available phosphorus and potassium, saturation percentage, and gypsum.

Sr. No.	**Depth (inches)**	**Square / Acre No.**	**EC (dS/m)**	**pH**	**Organic %**	**Av. P (ppm)**	**Av. K (ppm)**	**Saturation %age**	**Textural Class**	**Gypsum (Bags/Acre)**
1	0 to 6	T1	1.6	8.6	0.62	7.9	116	38	Loam	9
2	6 to 12	T2	2.4	8.5	0.54	6.6	110	32	Loam	

For assessment of yield related traits, seven cultivars; i.e., C_1 (Chenab Basmati), C_2 (PK-386), C_3 (KSK-133), C_4 (KSK-434), C_5 (Super Basmati), C_6 (KSK-282), C7 (Kissan Basmati) were used. Research area was 2 meter square and three replications for each cultivar. All varieties were obtained from the Institute of Rice, Kala Shah Kaku. Seed germination ratio was determined before sowing. Ten randomly selected hills in each plot were calculated for no. of spikelet/panicle, no. of fertile spikelets/ panicle, no. of grains/plant (with the help of seed counter), yield/ plant (gram), 100 grain weight (gram), panicle weight (g) (Electronic scale was used), days to maturity, root length (centi meter), root wt. (fresh and dry) (g), and harvest index after harvesting. All treatments were same like irrigation, fertilizer applications and kept unsprayed throughout the season. To evaluate the efficacy of different pesticides against rice stem borer observation was done at the vegetative and reproductive periods, the white head (%) and dead heart (%). And number of insects were counted from each treatment plot.

Seed germination percentage

Seed was soaked for 24 hours in container and 30 seeds of each variety was kept in wet cloth. Seed was started germination after 40 hours. Note the germination percentage by using formula GP = seeds germinated/total seeds x 100.

Data collection

Development parameter data (plant height) was taken from the 3 plants during the rice crop's mid-grain filling stage from every treatment plot by using measuring tape. There was a variety of panicles and numbers of whiteheads counted at harvest. As defined by Suresh *et al* (2009), the incidence of YSB is determined using following formula:

Incidence of stem borer (percent) = (Number of dead hearts or whiteheads ÷Total number of productive tillers) ×100.

Pretreatment data was recorded

White heads:

The white heads data were recorded from 10 randomly selected plants. The percentage of white heads was determined after the milking stage. The recorded data were converted into percentage by using the following formula:

$$WH\% = \frac{\text{Number of the White heads (WH)}}{\text{Total Number of tillers with panicels}} \times 100$$

Grains yield (kg ha-1):

Grain yields were recorded in each plot from three key rows and then converted into kg ha-1 by using the following formula,

$$Grains\ yield\ (kg\ ha^{-1}) = \frac{\text{Grains yield in three main rows in each plot}}{\text{Row to row distance x number of rows x row length}} \times 10000m^2$$

Calculation of 1000-grains weight (g):

Thousand grain weight was determined by counting 1000 grain in each plot, and then weighting with a digital balance.

Biological efficacy:

The biological efficacy of treatments for pest infestation was calculated by the following formula.

$$\text{Percent (\%)decrease over the control} = \frac{A-B}{A} \times 100$$

A: Total number of dead hearts and white heads in control plot; **B:** Total number of dead hearts and white heads in treated plot.

Statistical Analysis

After data collection, Statistix 8.1 software was used for data analysis.

3. RESULTS

Three experiments were performed in order to investigate the effect of different rice varieties and synthetic insecticides on Yellow stem borer (*Scirpophaga incertulas*) population at University of Agriculture Faisalabad during summer 2020, illustrated the various results.

Dead Hearts at 7 Days after First Application

After 7 days of the first insecticidal application, the highest average number of dead hearts (4.33) was recorded in the untreated control (T4), which was significantly different from all other treatments. The lowest number of dead hearts (2.33) was observed in T2 (Chlorpyriphos), indicating its superior effectiveness. T1 (Neem extract) resulted in 3.66 dead hearts, significantly different from T2 but statistically similar to T3 (*Metarhizium anisopliae*), which recorded 3.00 dead hearts (figure 1).

Dead Hearts at 14 Days after First Application

All treatments had a significant impact on dead heart formation 14 days' post-treatment. T2 (Chlorpyriphos) once again showed the most effective control with the minimum number of dead hearts (2.00), which was significantly different from all other treatments. T1 (Neem extract) recorded 2.99, and T3 (*Metarhizium anisopliae*) 2.66 dead hearts, both statistically similar. The control group (T4) recorded the highest number of dead hearts (3.66), significantly different from T2 (figure 2).

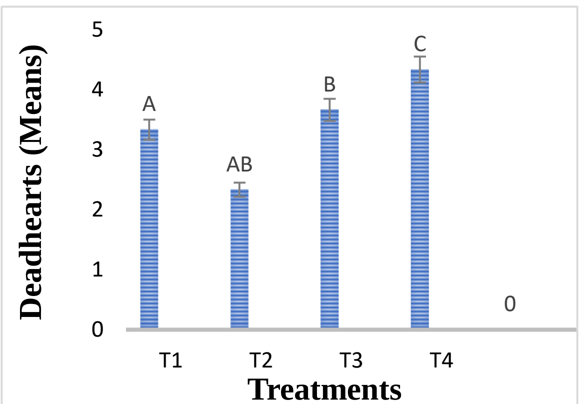

Figure. 1: Average number of dead hearts in rice crop after 7 days of post treatments of 1st application Where T1: Neem extract, T2: Chlorpyriphos, T3: Metarhizium anisopliae, T4: Control.

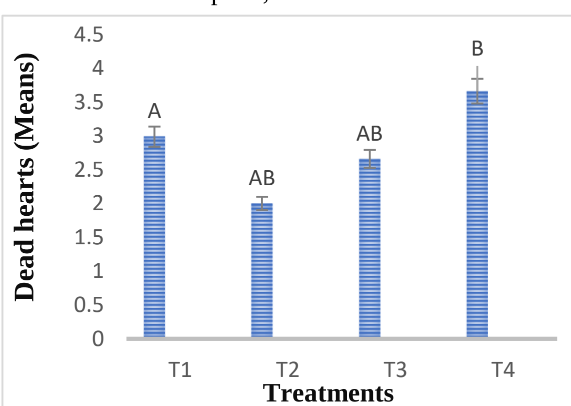

Figure 2: Average number of dead hearts in rice crop after 14 days of post treatments of 1st application. Where T1: Neem extract, T2: Chlorpyriphos, T3: *Metarhizium anisopliae*, T4: Control.

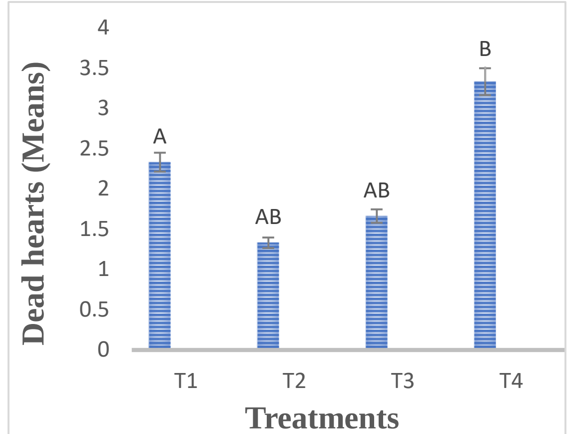

Figure.3: Average dead hearts in rice crop after 28 days of post treatments of 2nd application. Where T1: Neem extract, T2: Chlorpyriphos, T3: *Metarhizium anisopliae*, T4: Control.

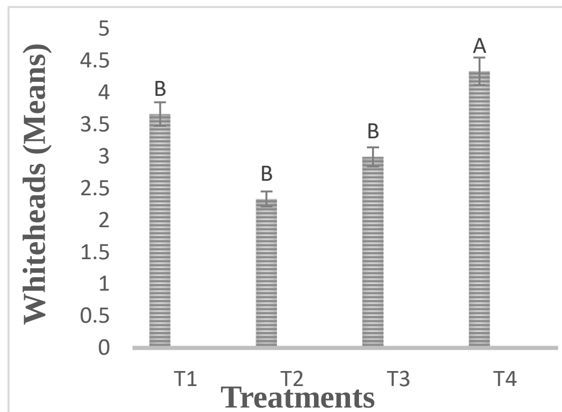

Figure. 4: Average whiteheads in rice crop after 21 days of post treatments of 3rd application. Where T1: Neem extract, T2: Chlorpyriphos, T3: *Metarhizium anisopliae*, T4: Control.

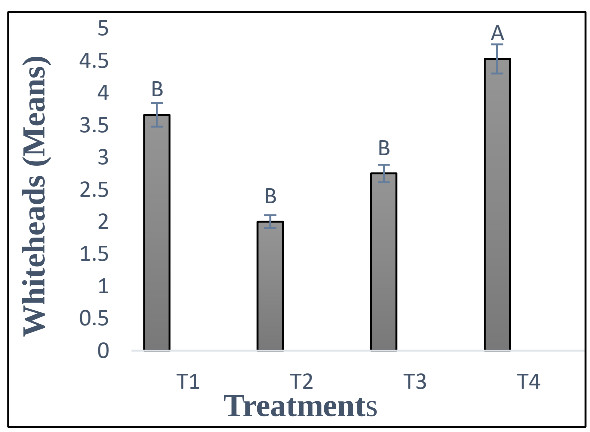

Figure. 5: Average whiteheads in rice crop after 28 days of post treatments**.**

Cultivars	No. of grains/ panicles	Panicles weight (g)	No. Grains/ plants	Root Length (cm)	Root Fresh weight (g)	Root dry weight (g)	Tillers/ plant	100 Grain Weight (g)	Panicle length (cm)
C7	134^{A}.67 ±6.1	2^{B}.38± 0.5	1955^{A}.3 ±50	15^{A}.28±0 .45	15^{E}.48 ±0.42	6^{C}.12± 0.35	26^{A}. 00±	3^{A}.37 ±0.22	12^{A}.50 ±0.39
C3	126^{AB}.3 3±5.01	2^{A}.98± 0.6	1838^{C}.7 ±45	19^{AB}.33± 0.48	25^{B}.52 ±0.76	8^{B}.48± 0.40	24^{B}. 33±	2^{B}.75 ±0.21	12^{A}.40 ±0.36
C6	113^{CD}.0 0±4.89	2^{AB}.66 ±0.65	1291^{G}± 35	18^{ABCD}.1 2±0.42	17^{D}.97 ±0.43	5^{C}.90± 0.33	23^{C}. 33±	2^{B}.74 ±0.20	11^{BC}.70 ±0.42
C4	102^{D}.33 ±3.22	2^{B}.38± 0.36	1809^{D}.0 ±47	16$^{BCD.06}$ ±0.41	26^{B}.01 ±0.72	11^{A}.15 ±0.42	21^{A}. 10±	2^{B}.63 ±0.23	11^{C}.67± 0.41
C1	101^{BC}.3 6±3.11	2^{AB}.47 ±0.46	1847^{B}.3 ±47	20^{A}.16±0 .51	30^{A}.35 ±0.78	8^{B}.18± 0.32	20^{B}. 66±	2^{B}.57 ±0.27	11^{C}.36± 0.35
C5	98^{E}01±2 .67	2^{B}.42± 0.43	1502^{F}.3 ±41	15^{CD}.78± 0.46	19^{A}.91 ±0.55	11^{A}.22 ±0.41	19^{A}. 23±	2^{B}.43 ±0.24	11^{CD}.18 ±0.39
C2	96^{D}.00± 2.56	2^{AB}.90 ±0.80	1572^{E}.7 ±40	19^{ABC}.03 ± 0.47	20^{C}.07 ±0.57	8.^{B}15± 0.34	18^{A}. 22±	2^{B}.39 ±0.21	11^{C}.15± 0.32

Table 2. Comparative analysis of yield-contributing and root morphological traits among different rice (*Oryza sativa* L.) cultivars

Dead Hearts 28 Days after Second Application

After 28 days of the second application, T2 (Chlorpyriphos) maintained its effectiveness with the lowest average number of dead hearts (1.33), significantly different from all other treatments. The highest incidence (3.33) was recorded in T4 (Control). T1 (Neem extract) and T3 (*Metarhizium anisopliae*) recorded 2.33 and 1.66 dead hearts respectively. T2 and T3 were statistically similar, while T1 and T4 differed significantly from each other (figure 3).

Effect of Treatments on Whiteheads

Whiteheads at 21 Days after Third Application

At 21 days after the third application, all treatments showed significant effects on whitehead formation. T2 (Chlorpyriphos) resulted in the minimum average whiteheads (2.33), which was not significantly different from T1 (3.66) and T3 (*Metarhizium anisopliae*, 2.99). However, T2 and T4 (Control: 4.33) were highly significantly different. This indicates that T2 was more effective in minimizing damage (figure 4).

Whiteheads at 28 Days after Third Application

At 28 days' post-treatment, T2 (Chlorpyriphos) once again showed the lowest number of whiteheads (2.00), significantly different from T4 (Control:

4.53). However, the difference between T2 and T1 (3.05) or T3 (2.75) was statistically non-significant. T1 and T3 were also statistically similar. The highest number of whiteheads was recorded in the untreated control group (figure 5).

These traits were positive relation with yield of plant (table 2). Among seven cultivars C7 (Kissan basmati) performed better than other cultivars. Average number of grains/panicle ($134^{A}.67\pm6.1$), grains/plant ($1955^{A}.3\pm50$), number of tillers/plant ($26^{A}.00\pm2.1$), 100 grain weight ($3^{A}.37\pm0.22$) and panicle length ($12^{A}.50\pm0.39$) were recorded maximum in C7 cultivar as compare to other cultivars. Day-to-head, number of productive tillers and plant height have all been shown to reduce rice grain production. A favorable correlation exists between panicle length, number of grains /panicle, and grain weight, as well. To better understand the connections between rice yield and yield-related factors, this study was conducted. Assuming significance at the level of 0.000, grain yield was significantly correlated with the number of spikelets/panicle (134.67), number of fertile tillers/plant (26.61), and 100 grain weight (26.01). (2.36 g). According to previous study, panicle length, number of reproductive tillers and grain amount per panicle have a positive and significant relationship with one another. The number of tillers per plant, the number of filled grains per panicle, and the weight of 1000 grains are all factors that affect grain production.

Plant yields were positively relation with the number of tillers per plant (26.00). Rice's most important agronomic feature is the tiller number, which affects the panicle number, a critical component of grain output. Number of reproductive tillers /plant is positively associated with grain yield in this research ($p = 0.611$), as does plant height. Its prolific tillers, full grains/ panicle and Where C7: Kissan Basmati, C3: KSK-133, C6: KSK-282, C4:KSK434, C1: Chenab Basmati, C5: Super Basmati, C2: PK-386.

100 grain weight (g) are the primary factors that increase rice output potential. Grain yield was significantly related to panicle length (12.5). Numerical grain production is positively relating with the number of grains/panicle and the weight (g) of grains per panicle Moreover, panicle weight was positively and significantly related to plant height ($p = 0.206$). Plant height was determined by measuring the distance between the plant's base and the tip of its longest panicle. Longer panicles contribute to plant height in the investigated rice varieties. Significantly positive correlations were found between panicle weight and the number of spikelets per panicle (134.67, $p = 0.721$), the number of fertile spikelets per panicle ($p = 0.616$), the filled grain percent, and the 100 grain weight ($p = 0.592$). Rice panicle weight is directly related to the quantity of loaded grains. Numerical correlations between the number of grains per panicle and the 100-grain weight have been established. The proportion of filled grain was positively and strongly linked with yield/plant. There is a strong link between filled grains/panicles and grain yield. Rice grain filling is a key and dynamic factor that affects grain output. Climate, soil, variety, fertilizer application, and insect and pest infestations all have an impact on filled grain percentage. There is a significant and positive relationship between grain yield and panicle weights, number of fertile spikelets/panicle, filled grain %, No. of fertile tillers per plant, and total number of tillers per plant. However, 100 grain weights or plant height have little effect on production. Accordingly, rice cultivars can be selected for breeding projects based on factors such as fertile spikelet/panicle, panicle weight (g), spikelet count, filled grain %, and number of fertile tillers per plant. Number of tillers / plant and viable spikelets per panicle all contribute to

higher yields in rice, although not as much as other factors.

DISCUSSION

The present study was conducted to evaluate yield-related traits among various rice (*Oryza sativa* L.) cultivars and to assess the efficacy of different pest control treatments- *Metarhizium anisopliae*, neem extract (*Azadirachta indica*), and Chlorpyriphos- against the yellow stem borer (*Scirpophaga incertulas*). The analysis of yield-contributing traits highlighted that the number of tillers per plant, grains per panicle, 100-grain weight (g), and spike length (cm) were significantly associated with grain yield. These findings are consistent with those reported by Rajeswari and Nadarajan (2004), who emphasized the importance of productive tillers, panicle length, grains per panicle, and grain weight as key yield indicators. Similarly, Akhi *et al*., (2016) confirmed that the number of tillers per plant and grains per panicle have a strong and direct effect on overall yield and should be prioritized in breeding programs.

The correlation between yield traits was further supported by Ranawake and Amara singhe (2014), who observed a significant relationship between the number of spikelets per panicle and grain yield in rice varieties. In this study, the cultivar C7 (134A) exhibited the highest spikelet count, affirming Laza *et al.*, (2015), who identified spikelets per panicle as one of the most stable yield predictors.

In evaluating pest management efficacy, Chlorpyriphos-treated plots showed the least damage symptoms (dead hearts and whiteheads), indicating its superior performance against *S. incertulas*. This aligns with the results of Neelakanth *et al.*, (2017) and Sawant *et al.*, (2019), who reported high efficacy and increased yields following Chlorpyriphos application. Although chemical control proved highly effective, the integration of biopesticides and botanicals showed promising results. *Metarhizium anisopliae* and neem extract substantially reduced pest infestation and improved grain yield, with minimal environmental impact. These outcomes agree with Shahid *et al*. (2003) and Bhojane *et al.*, (2020), who highlighted the efficacy of biopesticides and neem-based products in reducing stem borer populations.

Furthermore, the current findings revealed that *M. anisopliae* treatments resulted in the lowest average number of dead hearts and whiteheads (1.66), while also achieving a respectable grain yield (30.533 g), just slightly below that of Chlorpyriphos-treated plots (32.700 g). Neem extract also demonstrated effective control, as supported by Rahman *et al*. (2020), reducing dead heart incidence by over 15%. The results reinforce the assertion by January *et al*., (2018) that biopesticides and botanicals can effectively reduce damage incidence, increase pest mortality, and enhance rice yield with lower ecological risk.

Conclusively, while Chlorpyriphos remains the most effective in managing *S. incertulas*, *M. anisopliae* and neem extract represent viable, eco-friendly alternatives for sustainable pest management in rice ecosystems. These biocontrol agents can be integrated into IPM strategies to reduce chemical dependency and support environmental conservation efforts.

CONCLUSION

The present study, conducted in Madina Colony, McLeod Ganj, Bahawalnagar in 2020, aimed to evaluate yield-related traits in rice cultivars and assess the efficacy of different pest control treatments—Chlorpyrifos, Neem extract, and *Metarhizium anisopliae*—against the yellow stem borer (*Scirpophaga incertulas*), a major pest of rice. The results demonstrated that critical yield traits such as number of tillers per plant, number of grains per panicle, spike length, and 100-grain weight were positively correlated with overall grain yield. Among the treatments, Chlorpyrifos (T2) proved to be the most effective in reducing pest infestation symptoms such as dead hearts and whiteheads, leading to the highest grain yield. However, Neem extract (T1) and M. anisopliae (T3) also showed notable efficacy and contributed to yield improvement over the untreated control. These biopesticides offered eco-friendly alternatives, significantly reducing damage across three foliar applications as the pest population breached ETL thresholds. Overall, this study concludes that while Chlorpyrifos remains the most potent, both botanical and biological controls are promising, sustainable tools in integrated pest management (IPM) for rice cultivation.

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Author's Contributions

Fazeela Zarin and Muhammad Asif: Conduct the experiment.

Muhammad Asif and Dr. Ahmad Nawaz: Designed the experiment, technical and language checked.

Fazeela Zarin: Analyzed data and wrote the manuscript.

Dr. Amjad Bashir: Revised the manuscript.

Conflict of interest

The authors declare that they have no conflict of interest.

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