Indian Journal of Agricultural Sciences **95** (4): 389–394, April 2025/Article
https://doi.org/10.56093/ijas.v95i4.154914

Assessing yellow stem borer (*Scirpophaga incertulas*) incidence patterns in paddy (*Oryza sativa*) cultivation: Implications for climate change adaptation strategies

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Received: 09 August 2024; Accepted: 21 January 2025

ABSTRACT

Rising global food demand and the challenges posed by climate change necessitate sustainable agricultural practices, particularly in staple crop production like rice. The study was carried out during 2022–2023 at College of Agriculture, V C Farm, Mandya, Karnataka to investigate the incidence patterns of the yellow stem borer [*Scirpophaga incertulas* (Walker)], a significant threat to paddy (*Oryza sativa* L.) crops, in the context of climate change. The rice variety Jaya was taken for the study. Correlation analyses between meteorological variables and yellow stem borer infestation were performed to understand climate-driven impacts on pest dynamics. Results revealed varying infestation levels across transplanting dates, with early transplanting showing lower infestation rates. The peak pest incidence was recorded on the 15th of October transplanted crop (14.94%), then 1st of October (13.24%) and 15th of March (11.51%). The lowest incidence was observed in 15th January (0.37%) transplanted crop, followed by 1st January and 1st February transplanted crops. Meteorological factors such as minimum temperature and afternoon relative humidity showed a significant positive correlation and morning relative humidity had a significant negative correlation with dead heart. Meanwhile, maximum and minimum temperatures and rainy days recorded a significant negative correlation with white ears. These findings highlighted the critical need for adaptive agricultural strategies that respond to climate variability. Moving forward, strategies such as developing climate-resilient crop varieties and innovative pest management approaches are essential for sustaining rice production and global food security amidst evolving climatic conditions.

Keywords: Climate adaptation strategies, Climate change, Incidence patterns, Yellow stem borer

Projected population growth and changing consumption patterns in developing countries necessitate an estimated 50% increase in global food grain production (Desa 2019, Pawlak and Kołodziejczak 2020). Agriculture plays a vital role in securing food for billions, with staple crops like rice serving nearly half of the global population (EPA 2017). Climate change impacts agriculture, including pest dynamics, altering both crops and associated pest species through direct and indirect effects. Direct effects influence pest reproduction, development, survival, and dispersal, while indirect effects involve changes in interactions among pests, the environment and other species like natural enemies, competitors, and mutualists, reshaping agricultural ecosystem dynamics (Prakash *et al.* 2014).

In paddy cultivation, pest infestations consistently threaten crop health and yield. Numerous insect species consider the rice plant an ideal host, attacking it at different growth stages and impairing its yield potential (Ali *et al.* 2021). Major pests like stem borers (40%), planthoppers (25%), gall midges (10%) and others (25%) cause significant yield losses (Reddy *et al.* 2010). The yellow stem borer [*Scirpophaga incertulas* (Walker)] is one of the most damaging pests, particularly in Asian rice-growing regions, causing yield losses from 25–87% (Pallavi *et al.* 2017). This pest damages rice at multiple growth stages, with attacks in the vegetative stage causing 'dead hearts' (DHs) and reproductive-stage attacks leading to 'white ears' (WEs). The critical role of rice in global food security highlights the need for effective pest management to ensure sustainable rice production (Deka and Barthakur 2010).

Recent climate changes have impacted the yellow stem borer's physiology, phenology, and distribution (Rahman and Khalequzzaman 2004). Climate change may increase the number of yellow stem borer generations and survival under extreme conditions. Studies in India link changing weather with pest patterns on crops. Evaluating yellow stem borer's future outlook with climate models aids in management planning (Reji *et al.* 2014). Climatic factors like temperature, humidity, and rainfall significantly impact

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insect populations, and research into these factors is essential (Subedi *et al.* 2023). The relationship between climate and pest dynamics is crucial, as warmer, humid conditions favour pests (Morya and Kumar 2021). This study aims to analyse yellow stem borer incidence in the context of climate change, providing insights for resilient pest management strategies (Mandal and Mondal 2018, Jasrotia *et al.* 2019, Skendzic *et al.* 2021).

MATERIALS AND METHODS

The present study was carried out during 2022–2023 at College of Agriculture, V C Farm, Mandya (12°32'N, 76°53'E), Karnataka. A popular and highly susceptible rice variety, Jaya was sown at the fortnightly interval from June 20th to February 20th in a separate block of 1 m × 1 m, the 20–25 day old seedlings of each date of sowing were transplanted in a block of 6 m × 5 m with a spacing of 15 cm × 20 cm, respectively between plants and rows. In each transplanted block of a month, the observations on the per cent dead hearts were recorded in 10-day intervals i.e. at 10, 20, 30, 40, 50, 60, 70 days after transplanting (DAT) and per cent white ears were recorded at 80, 90, 100, 110 and 120 DAT continuously on 10 hills. Likewise, the observations were recorded from 25th July 2022 to 15th July 2023. The crop was raised as per the recommended package of practices, except for the plant protection measures (Anonymous 2017). The per cent dead heart was calculated using the formula i.e. Standard evaluation system for Rice (SES) (IRRI 2013):

$$\text{Dead heart (\%)} = \frac{\text{Total no. of dead heart/10 hills}}{\text{Total no. of tillers}} \times 100$$

Likewise, per cent of white ears was calculated by using the formula:

$$\text{White ears (\%)} = \frac{\text{Total no. of white ears/10 hills}}{\text{Total no. of panicles}} \times 100$$

Further to know the possible influence of meteorological variables on the incidence of yellow stem borer, the weather parameters, viz. maximum and minimum temperature (°C), morning (maximum) and afternoon (minimum) relative humidity (%), sunshine hours, rainfall (mm) and number of rainy days were collected from meteorological observatory unit, V C Farm, Mandya, Karnataka.

The data on the infestation by yellow stem borer was subjected to Microsoft Excel to obtain the mean, further, it was subjected to the arcsine transformation. Similarly, the mean weather data of the previous 10 days of each observation and the data collected on yellow stem borer incidence were subjected to Pearson rank correlation and the correlation coefficient (r) between the incidence of yellow stem borer, mean per cent infestation with mean meteorological variables of the respective period was worked out using SPSS statistical software (SPSS 24 Version) and GraphPad Prism 8.0.2 (263). The correlation coefficient (r) was considered significant at $P<0.05$ and highly significant at $P<0.01$. The results are represented graphically for better interpretation and understanding. The graphs were generated with GraphPad Prism 8.0.2 software.

RESULTS AND DISCUSSION

Among all the transplanting dates from July 15th 2022 to March 15th 2023, the infestation due to yellow stem borer, *S. incertulas* was recorded across all the transplanting. The overall peak incidence was recorded in the 15th October transplanted crop (14.94%), followed by the 1st October and 15th March transplanted crop with 13.24 and 11.51%, respectively. However, the lowest incidence of the pest was recorded on 15th January transplanted crop with 0.37% infestation, followed by the 1st of January and 1st of February transplanted crop. Generally, *S. incertulas* infestation starts from the paddy crop's initial stages, gradually increasing and reaching peak dead heart infestation during the vegetative growth stage. Similarly, the maximum and peak incidence of dead heart caused by yellow stem borer was noticed after 30 and 40 DAT. Meanwhile, the maximum and peak incidence of white ears due to yellow stem borer infestation was recorded at 90 and 100 DAT. So, it is evident that *S. incertulas* infest paddy crop both in the vegetative and reproductive stages. Across all the transplanting dates the peak dead heart (DH) and white ear (WE) (17.30% DH and 11.64% WE) incidence was recorded in the 15th October transplanting followed by the 1st October (14.77% DH and 11.09% WE) and 15th March (12.97% DH and 9.47% WE) transplanting, respectively (Fig. 1). The highest incidence of dead hearts (8.38%) occurred in the second week of October, while the maximum occurrence of white ears (5.02%) was observed during the 49th standard meteorological week (SMW). Similarly, the peak infestation by yellow stem borer was noted in the second and third weeks of October (Seni and Naik 2018). Furthermore, the highest occurrence of dead hearts (10.51%) and white ears (9.38%) was observed during the second week of October and the first week of November (Morshed *et al.* 2020). The studies of Hatwar *et al.* (2021) revealed that the maximum incidence of dead hearts, with an infestation rate of 6.31 ± 2.57%, occurred during the 37th SMW from September 10th to September 16th. Similarly, white ears exhibited a maximum infestation rate of 6.81 ± 2.38% during the 42nd SMW, spanning from October 15th to October 21st.

The dead heart incidence exhibited a significant positive correlation with minimum temperature (0.333**), afternoon relative humidity (0.333**) and rainy days (0.185*). Whereas, morning relative humidity (-0.316**) and bright sunshine hours (-0.204*) showed a significant negative association with the occurrence of dead heart infestation. However, the maximum temperature (-0.131) and rainfall (0.079) showed a non-significant negative and positive association with the dead heart incidence, respectively (Fig. 2). Meanwhile, for the white ear infestation, maximum temperature (-0.392**), minimum temperature (-0.449**), rainfall (-0.250*) and rainy days (-0.326**) showed negative significant association. A non-significant positive correlation was observed for morning relative humidity

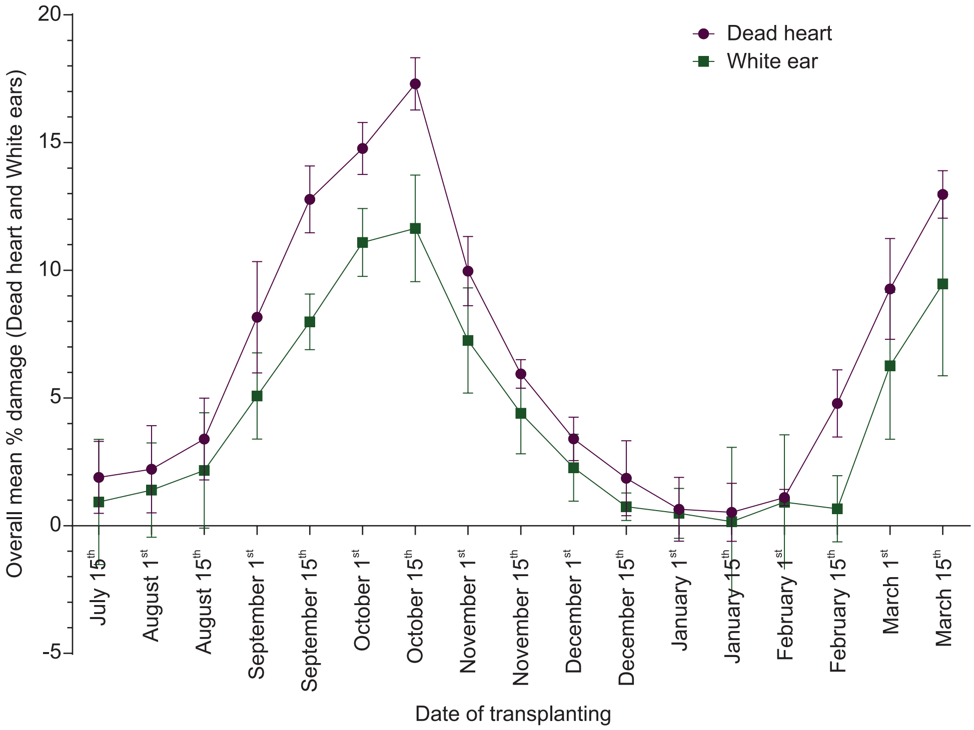

Fig. 1 Mean per cent damage (dead heart and white ears) caused by paddy yellow stem borer at different dates of transplanting.

(0.109), afternoon relative humidity (0.031) and bright sunshine hours (0.028) (Fig. 3) with white ear infestation. Meteorological factors, including temperature and humidity, play a pivotal role in shaping insect activity, dispersal, phenology and survival. These variables directly regulate insect behaviour under diverse weather conditions and indirectly impact insect habitats, plant development, food quality and the activity of natural enemies (Jaworski and Hilszczanski 2013). Temperature, in particular, emerges as a critical environmental determinant for insect phenology, with climate change altering various aspects of crop pest biology, such as range expansion, overwintering patterns, population dynamics, and synchronization with crop cycles (Pareek *et al.* 2017). Correlation analysis indicated a non-significant relationship between yellow stem borer incidence and minimum temperature (r = -0.209), but a significant negative correlation with morning relative humidity (r = -0.506*) and rainfall (r = -0.488), consistent with present results (Seni and Naik 2018). Temperature exhibited a significant negative impact on white ears and a non-significant negative effect on dead hearts, while relative humidity showed a significant positive association with dead hearts but a non-significant negative correlation with white ears. Rainfall displayed a non-significant positive association with dead hearts but a significant negative impact on white ears, contrary to previous findings (Morshed *et al.* 2020). Whereas in the present study, dead hearts exhibited a significant positive correlation with afternoon relative humidity and a non-significant negative correlation with maximum temperature, whereas white ears demonstrated a significant negative correlation with minimum temperature, maximum temperature and rainfall.

Similarly, the 37th and 39th SMW exhibited the highest infestation of dead hearts (14.22%) and white ears (8.91%), respectively, showing a positive correlation with maximum temperature and a significant negative correlation with minimum temperature (Balaji *et al.* 2024). In *rabi* 2022, the 50th and 3rd SMW recorded peak infestations of dead hearts (8.92%) and white ears (7.64%), respectively, with a significant positive association with morning relative humidity and bright sunshine hours, alongside a significant negative association with minimum temperature and afternoon relative humidity. During summer 2023, the highest incidence of dead hearts (29.26%) and white ears (21.74%) occurred in the 16th and 20th SMW, respectively, with a significant positive correlation with minimum temperature, rainy days, rainfall, and afternoon relative humidity (Balaji *et al.* 2024). The peak infestation of dead hearts and white ears was observed between 30–50 DAT and 80–100 DAT, respectively, aligning with current findings. Abiotic factors like temperature, rainfall, sunshine hours and relative humidity significantly influenced yellow stem borer incidence in paddy. Maximum temperatures (25.7–39.5°C) and minimum temperatures (13.8–25.9°C) positively affected dead heart incidence, while white ear incidence showed a positive correlation with minimum temperature (21.6–28.2°C) and evening relative humidity (62–95%). Additionally, rainfall, sunshine hours, and relative humidity impacted dead hearts (r^2 = 0.723) and white ears (r^2 = 0.944) (Prasad and Chatterjee 2022).

Changes in precipitation patterns specifically in amount, intensity, and frequency are critical indicators of climate change. A trend towards decreased precipitation frequency coupled with heightened intensity contributes to more frequent droughts and floods. These patterns have important implications for insect species, particularly those that overwinter in soil, as overlapping rain events can drastically alter their survival and behaviour (Skendzic *et al.* 2021). This is especially relevant for agricultural pests such as the yellow stem borer, whose population dynamics and growth rates are directly affected by temperature and rainfall fluctuations. Increasing temperature and rainfall each positively influence the growth rate of the yellow stem borer individually. However, their combined impact is complex, with high temperatures exerting a negative effect on the insect's abundance under high rainfall conditions, while still promoting growth under intermediate to low rainfall. The yellow stem borer shows a greater growth rate in cooler environments with abundant rainfall, as supported by findings from Ali *et al.* (2020). The relationship between climate variables and pest incidence extends to other abiotic factors, such as relative humidity and sunlight exposure. Dalvi *et al.* (2021) reported a significant positive correlation between evening relative humidity and dead heart incidence, while also noting that maximum temperature and bright sunshine hours were significantly negatively correlated. These findings underscore the sensitivity of pest populations to multiple, interacting climatic elements. Additionally, Sharma and Sharma (2023) observed that minimum temperature and evening relative humidity were both significantly positively correlated with dead heart incidence, reinforcing the influence of microclimatic conditions on pest proliferation. Understanding these interactions is essential for predicting pest outbreaks and developing climate-resilient pest management strategies. The intricate relationship between temperature, precipitation, and humidity highlights the need for adaptive agricultural practices that can mitigate the risks posed by climate change-induced pest dynamics.

The abundance of *S. incertulas* has exhibited a decline from the 1980s to 2010, spanning the past three decades, potentially attributed to mortality induced by elevated temperatures, increased rainfall, and other factors compared to preceding decades (Haq *et al.* 2008, BRRI 2012, Ali *et al.* 2014). Moreover, an examination of peak infestation occurrences by the yellow stem borer from 2000–2023 revealed a discernible shift, corroborated by multiple previous studies. Adiroubane and Raja (2010) documented the highest incidence of yellow stem borer during August, while Mandal *et al.* (2011) reported peak infestation in the fourth week of August. Notably, peak incidences have been observed from August to September and also during January–February (Justin and Preetha 2013). Similar shifts in pest incidence were noted by Kakde and Patel (2014), where infestation peaked in the first week of September, and Mondal and Chakraborty (2017), who recorded peak

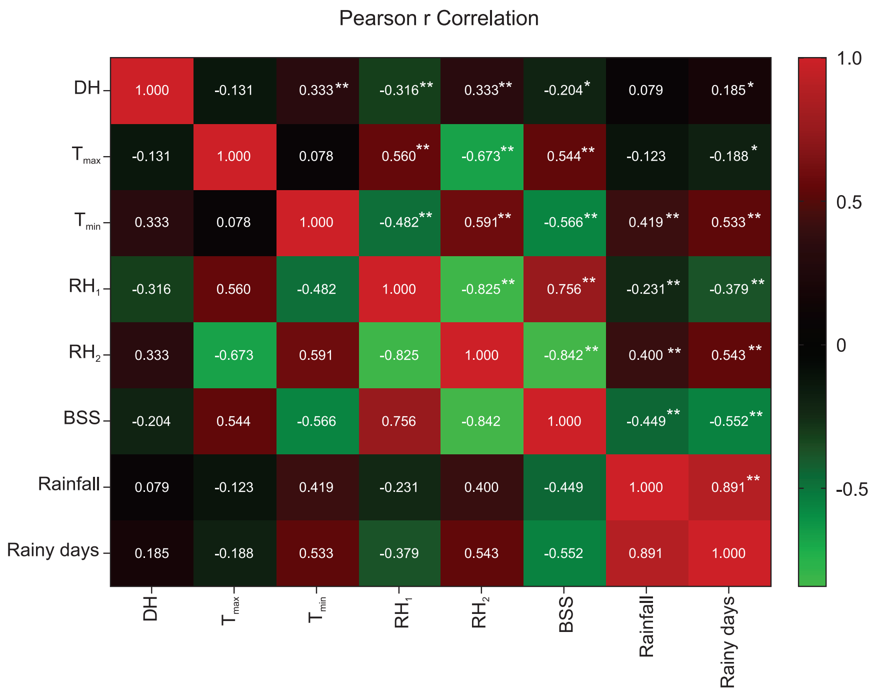

Fig. 2 Pearson correlation matrix heat map between dead heart and meteorological variables. DH, Dead heart; T_{max}, Maximum temperature; T_{min}, Minimum temperature; RH_1, Morning relative humidity; RH_2, Afternoon relative humidity; BSS, Bright sunshine hours.

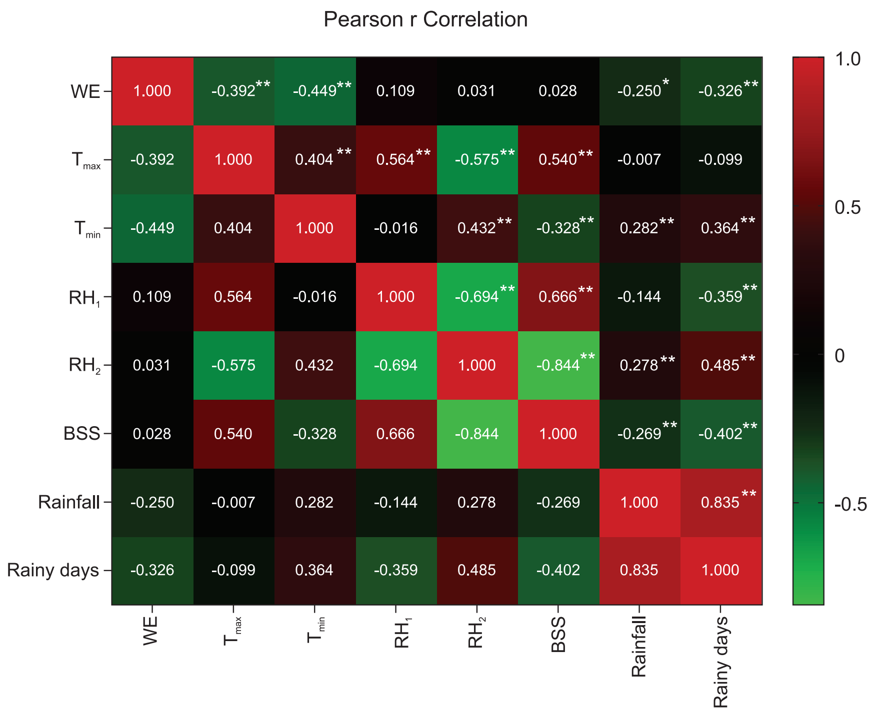

Fig. 3 Pearson correlation matrix heat map between white ears and meteorological variables. WE, White ears; T_{max}, Maximum temperature; T_{min}, Minimum temperature; RH_1, Morning relative humidity; RH_2, Afternoon relative humidity; BSS, Bright sunshine hours.

infestation during the fourth week of September (39th SMW).

Furthermore, the highest percentage of dead hearts, at 10.51%, occurred during the second week of October (Seni and Naik 2018, Morshed *et al.* 2020), aligning with the trends observed in the current study, where peak infestation was noted in the second and third weeks of October. The increase in the yellow stem borer incidence can be attributed to various agronomic and environmental factors, including the extensive use of high-yielding rice varieties, monocropping systems, specific water management practices, high-density planting, overuse of nitrogen fertilizers, and improper agrochemical applications. While these factors contribute to pest proliferation, climate change is a major driver behind the increased incidence, amplifying abiotic stresses that affect crop-pest dynamics and create conducive environments for pest outbreaks. This complex challenge requires integrated solutions that address both agricultural practices and climate adaptation. Strategies must focus on building resilience in farming systems to effectively manage yellow stem borer and similar pests. Raising stakeholder awareness about climate change's effects on pest ecology is crucial, as informed stakeholders are better equipped to implement adaptive measures. Encouraging farmers to participate in research initiatives can enhance adaptive capacity, as their direct involvement enables the tailoring of solutions to local conditions. Moreover, promoting resource conservation technologies, such as precision water management and optimized fertilization, can help mitigate pest pressure (Pareek *et al.* 2017, Skendzic *et al.* 2021). Looking to the future, the research landscape for pest management under climate change should prioritize developing climate-resilient crop varieties capable of withstanding both biotic and abiotic stresses. Adjusting crop calendars based on shifting climatic patterns is another critical measure, as it allows for optimized planting and harvesting times to avoid peak pest incidences. Geographic Information Systems can play a pivotal role in pest risk mapping, enabling predictive analytics for pest outbreaks and facilitating timely interventions. Additionally, exploring new modes of action in pesticide development is essential for effective pest control, especially as pest resistance builds against traditional chemical formulations. Research into environmental friendly pest management practices, such as biological control agents and integrated pest management frameworks, holds promise for sustainable crop protection in the face of climate variability.

In conclusion, ensuring sustainable rice production becomes imperative as global food demand rises amid climate change challenges. This study highlights the intricate relationship between climate dynamics and the incidence patterns of the yellow stem borer, a significant threat to paddy crop. Our findings revealed that the least infestation occurred during July and January transplanted crops. To effectively mitigate pest infestation, early transplanting is recommended. Timely intervention in pest management is crucial, especially as peak infestation typically occurs between 30–40 DAT, emphasizing the need for management practices to commence between 20–25 DAT to prevent significant yield loss. It is important to acknowledge that climate change is a reality, impacting variables such as temperature, rainfall frequency and relative humidity. Our findings underscore the urgency of proactive measures in agricultural practices to mitigate the impacts of climate change on pest dynamics. Moving forward, strategic interventions, including the development of climate-resilient crop varieties and innovative pest management approaches, are essential for safeguarding global food security amidst evolving climatic conditions.

ACKNOWLEDGMENT

Authors acknowledge the support of the KSTePS, Department of Science and Technology, Government of Karnataka for their financial assistance.

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