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Research Article

Role of Flowering Plants on Rice Field Bunds in Enhancing Egg Parasitoid Abundance and Parasitism of the Yellow Rice Stem Borer (*Scirpophaga incertulas* Walker)

Peran Tumbuhan Berbunga pada Pematang Sawah dalam Meningkatkan Kelimpahan dan Parasitisme Parasitoid Telur Penggerek Batang Padi Kuning (*Scirpophaga incertulas* Walker)

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ABSTRACT
The yellow rice stem borer (YRSB; *Scirpophaga incertulas* Walker) is a major insect pest of irrigated rice in tropical Asia, capable of reducing yields by 10–30% annually. Conservation biological control through habitat manipulation, particularly the introduction of flowering plants along rice field bunds, has emerged as a promising strategy to enhance natural enemy populations. This study evaluated the effect of flowering plant strips (long bean, soybean, sesame, and cucumber) on egg parasitoid abundance and parasitism rates of YRSB in Karanglo, Polanharjo District, Klaten Regency, Central Java, Indonesia. Two rice fields of equal size (900 m^2) were compared: one with flowering plants on bunds under semi-organic management, and one without flowering plants under conventional management with insecticide applications. Surveys were conducted from October 2014 to January 2015. Two egg parasitoid species, *Telenomus rowani* and *Tetrastichus schoenobii*, were found exclusively in the flowering plant plot, whereas no parasitoids were detected in the control plot. Parasitism rates reached 39.47% per individual egg and 82.39% per egg mass in the flowering plant plot. Mean RSB attack intensity was lower in the flowering plant plot (2.99%) than the control (3.56%). However, these differences should be interpreted cautiously, as the two plots also differed in cultivation practices (semi-organic vs. conventional with insecticides), which constitutes a confounding variable. The findings support the integration of flowering plants, particularly sesame, as a component of ecological engineering strategies to conserve egg parasitoids in rice agroecosystems.
KEYWORDS: biological control; ecological engineering; egg parasitoid; flowering plants; *Scirpophaga incertulas*; *Telenomus rowani*.

ABSTRAK
Penggerek batang padi kuning (PBPK; *Scirpophaga incertulas* Walker) merupakan hama penting padi sawah irigasi di Asia tropis. Penelitian ini mengevaluasi pengaruh penanaman tumbuhan berbunga (kacang panjang, kedelai, wijen, dan mentimun) pada pematang sawah terhadap kelimpahan parasitoid telur dan tingkat parasitisme PBPK di Karanglo, Kecamatan Polanharjo, Kabupaten Klaten, Jawa Tengah. Dua lahan sawah berukuran sama (900 m^2) dibandingkan selama Oktober 2014–Januari 2015. Dua spesies parasitoid telur, *Telenomus rowani* dan *Tetrastichus schoenobii*, ditemukan hanya pada plot berbunga dengan tingkat parasitisme 39,47% per telur individu dan 82,39% per massa telur. Intensitas serangan PBPK lebih rendah pada plot berbunga (2,99%) dibandingkan kontrol (3,56%). Namun, perbedaan praktik budidaya (semi-organik vs. konvensional dengan insektisida) merupakan variabel perancu yang perlu dipertimbangkan. Hasil mendukung integrasi tumbuhan berbunga, khususnya wijen, sebagai komponen rekayasa ekologi untuk konservasi parasitoid telur.
KATA KUNCI: pengendalian hayati; parasitoid telur; rekayasa ekologi; tumbuhan berbunga; *Scirpophaga incertulas*; *Telenomus rowani*.

INTRODUCTION

Rice (*Oryza sativa* L.) is the primary staple crop for over half of the world's population, providing approximately 20% of global dietary energy intake (FAO, 2022). Indonesia, as the third-largest rice producer globally with an annual output exceeding 54 million tonnes, faces persistent yield losses from insect pests that threaten both national food security and the livelihoods of smallholder farmers who constitute the majority of the country's rice producers (Oka, 2005). Among the most damaging insect pests, the yellow rice stem borer (YRSB; *Scirpophaga incertulas* Walker; Lepidoptera: Crambidae) is recognized as one of the most economically important species across tropical and subtropical rice-growing regions. YRSB larvae bore into rice tillers, causing 'dead heart' during the vegetative stage and 'white head' during the

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reproductive stage, with yield losses typically estimated at 10–30% annually but reaching total crop failure (puso) during severe outbreaks (Oka, 2005; Rauf, 2000; Cheng et al., 2023).

Conventional pest management in Indonesian rice systems has relied heavily on synthetic chemical insecticides, including organophosphates and pyrethroids, applied prophylactically or in response to pest outbreaks. While these chemicals can suppress pest populations in the short term, their indiscriminate use carries well-documented ecological consequences, including the elimination of beneficial natural enemies, disruption of trophic cascades, development of insecticide resistance in target pest populations, environmental contamination of soil and water resources, and risks to human health (Untung, 2002; Herlinda & Irsan, 2011). The phenomenon of pest resurgence following insecticide application—wherein pest populations recover rapidly after natural enemy populations are suppressed—has been particularly problematic in tropical rice ecosystems (Heong et al., 2015). These limitations have stimulated increasing emphasis on biologically based pest management strategies that harness natural enemies, including parasitoids, predators, and entomopathogens, to sustainably regulate pest populations within ecologically acceptable thresholds.

Among the natural enemies of YRSB, egg parasitoids are considered particularly valuable because they attack the pest at its earliest and most vulnerable life stage, preventing larval hatching and thereby disrupting the damage cycle before economic injury occurs. Species in the genera *Telenomus* (Hymenoptera: Scelionidae), *Tetrastichus* (Hymenoptera: Eulophidae), and *Trichogramma* (Hymenoptera: Trichogrammatidae) are the principal egg parasitoids of rice stem borers in tropical Asia, with parasitism rates in natural field conditions sometimes exceeding 80% in ecologically favorable habitats (Susiawan & Yuliarti, 2006; Yuliarti et al., 2005). However, the survival, reproduction, and field effectiveness of these parasitoids are strongly influenced by habitat complexity and the availability of supplementary nutritional resources, particularly nectar and pollen, which serve as essential carbohydrate and protein sources for adult parasitoids (Baggen et al., 1999; Gurr et al., 2016). In simplified monoculture rice landscapes, floral resources are scarce, limiting parasitoid longevity and fecundity, especially during periods when host eggs are temporarily unavailable.

Conservation biological control through habitat manipulation has emerged as a promising strategy within the broader framework of ecological engineering for pest management. Flowering plants can provide nectar, shelter from adverse environmental conditions, alternative prey or hosts for parasitoid reproduction, and structurally complex microhabitats that promote natural enemy colonization and retention (Fiedler & Landis, 2007; Gurr et al., 2016). A landmark multi-country study across China, Thailand, and Vietnam demonstrated that sesame-based ecological engineering in rice fields reduced insecticide applications by 70%, enhanced arthropod natural enemy abundance by 40–60%, and maintained or improved rice yields compared to conventional practices (Gurr et al., 2016; Lu et al., 2015). Additional studies from Southeast Asia and the Indian subcontinent have reported similar benefits of floral resource supplementation on parasitoid diversity and pest suppression in rice agroecosystems (Herlina et al., 2011; Settle et al., 1996). Despite these advances, field-level evidence on the specific role of flowering plants in supporting egg parasitoids of YRSB in Indonesian rice fields remains limited, particularly from Central Javanese rice-growing systems where YRSB pressure is consistently high.

To address this knowledge gap, the present study was designed to evaluate how the presence of flowering plant strips along rice field bunds influences the abundance, species composition, and parasitism rates of YRSB egg parasitoids under field conditions in Klaten Regency, Central Java. Specifically, the study aimed to: (1) compare YRSB attack intensity between rice fields with and without flowering plant interventions; (2) identify the species of egg parasitoids present and quantify their parasitism rates; and (3) assess the diversity of parasitoid species associated with different cultivated and wild flowering plant species on the bunds.

MATERIALS AND METHODS

Study Area and Experimental Design

The study was conducted from October 2014 to January 2015 in Karanglo, Polanharjo District, Klaten Regency, Central Java, Indonesia. Parasitoid identification was performed at the Laboratory of Plant Pests and Diseases, Faculty of Agriculture, Universitas Sebelas Maret, Surakarta. The 'Mentikwangi' rice variety was used throughout.

Two rice fields of equal age and size (900 m^2 each) were selected for comparative observation. The treatment plot was established with flowering plants on the bunds: long bean (*Vigna sinensis*), soybean (*Glycine max*), sesame (*Sesamum indicum*), and cucumber (*Cucumis sativus*), sown simultaneously with rice transplanting. This plot was managed semi-organically. The control plot had no flowering plants and was managed conventionally with standard insecticide applications. Weekly observations were conducted from 2 to 10 weeks after transplanting (WAT).

Data Collection

Variables observed included: (1) YRSB attack intensity, assessed using the modified diagonal method on 50 randomly selected rice clumps per plot per observation week, calculated as: Attack Intensity (%) = (damaged tillers / total tillers) × 100; (2) egg parasitoid species identification from collected YRSB egg masses, reared in laboratory vials until emergence and identified using the Goulet and Huber (1993) taxonomic key, cross-referenced with regional descriptions by Susiawan and Yuliarti (2006); (3) parasitism rates, calculated as percentage of parasitized eggs per egg mass; and (4) parasitoid

diversity on flowering plants, assessed through sweep-net sampling at four rice growth stages (early planting, vegetative, generative, and post-harvest).

Data Analysis

Parasitism rates and attack intensity were analyzed descriptively with means and standard deviations. As the study design involved two unreplicated plots differing in both floral resources and cultivation practices, formal inferential statistics were not applied, and results are interpreted as observational comparisons rather than treatment effects. This limitation is acknowledged in the Discussion.

RESULTS

YRSB Attack Intensity

Mean YRSB attack intensity over the observation period was lower in the flowering plant plot (2.99 ± 1.24% per clump) than in the control plot (3.56 ± 1.45% per clump). Attack intensity peaked at 6 WAT in the control plot, coinciding with egg hatching unaffected by insecticide applications and larval feeding on tillers. In both plots, attack intensity declined at 8–10 WAT as larvae pupated and adults emerged and dispersed to new rice fields.

Egg Parasitoid Species and Parasitism Rates

Two egg parasitoid species were identified from YRSB egg masses collected in the flowering plant plot: *Telenomus rowani* (Hymenoptera: Scelionidae) and *Tetrastichus schoenobii* (Hymenoptera: Eulophidae). *T. rowani* was the dominant species. No egg parasitoids were recovered from the control plot; only live larvae were found within egg masses. Parasitism rates in the flowering plant plot reached 39.47% per individual egg and 82.39% per egg mass (Table 1). The highest weekly parasitism was recorded at 6 WAT (75.75% per egg mass), coinciding with peak host egg availability.

Table 1. Summary of YRSB egg parasitism in flowering plant and control plots.

Parameter	Flowering Plot	Control Plot
Egg masses collected	25	20
Total eggs	2,391	2,191
Parasitism (% egg)	39.47	0
Parasitism (% mass)	82.39	0
Live larvae per mass	58.28	121.50
Live parasitoids	662	0
Mean attack (%)	2.99	3.56

Parasitoid Diversity on Flowering Plants

Three YRSB egg parasitoid species were found on flowering plants: *Trichogramma japonicum* (Trichogrammatidae), *T. schoenobii* (Eulophidae), and *T. rowani* (Scelionidae), totaling 9 individuals (Table 2). The highest parasitoid counts were recorded on sesame and *Eclipta prostrata* (3 individuals each). Long bean supported the highest overall parasitoid diversity (4 families). Cucumber attracted no parasitoids, likely due to poor growth from excessive rainfall during the observation period. Parasitoid diversity was highest during the generative phase (12 WAT), dominated by Encyrtidae.

Table 2. YRSB egg parasitoid species found on flowering plants.

Plant	Family	Genus	n
Long bean	Trichogrammatidae	*Trichogramma*	2
Soybean	Trichogrammatidae	*Trichogramma*	1
Sesame	Scelionidae	*Telenomus*	2
	Eulophidae	*Tetrastichus*	1
Eclipta prostrata	Trichogrammatidae	*Trichogramma*	3
Cucumber	–	–	0
Total			9

DISCUSSION

Effect of Flowering Plants on Parasitoid Activity and Pest Suppression

The results of this study provide field-based evidence that rice fields with flowering plant strips on bunds supported substantially higher egg parasitoid abundance and parasitism rates of YRSB compared with fields lacking floral resources. Two egg parasitoid species, *T. rowani* and *T. schoenobii*, were found exclusively in the flowering plant plot, with parasitism reaching 82.39% per egg mass—a rate comparable to or exceeding those reported in other tropical rice systems with habitat management interventions. For instance, Settle et al. (1996) documented parasitism rates of 70–85% in ecologically managed Indonesian rice fields, and Gurr et al. (2016) reported 60–80% parasitism in Chinese rice fields supplemented with sesame strips. The complete absence of parasitoids in the control plot represents a striking contrast that underscores the importance of habitat resources for sustaining natural enemy populations in agricultural landscapes.

These findings are consistent with the theoretical framework of conservation biological control, which predicts that increasing habitat complexity and floral

resource availability in agroecosystems enhances the fitness, longevity, and reproductive output of parasitoid wasps (Landis et al., 2000; Gurr et al., 2016). Adult parasitoids of the order Hymenoptera are generally synovigenic—they continue to mature eggs throughout their adult life—and require carbohydrate-rich food sources such as floral nectar to fuel host-searching behavior, oviposition, and locomotion (Jervis et al., 1993; Wäckers, 2004). In simplified monoculture rice landscapes where flowering plants are absent, parasitoid longevity is reduced and their capacity to locate and parasitize host eggs is compromised, particularly during periods of low host density between cropping cycles.

Parasitoid Species Composition and Dominance Patterns

The dominance of *T. rowani* among egg parasitoids recovered from YRSB egg masses is consistent with its recognized adaptability across diverse rice ecosystems throughout Southeast Asia. Susiawan and Yuliarti (2006) documented *T. rowani* as the most widely distributed and abundant YRSB egg parasitoid across multiple provinces in Indonesia, attributing its success to its broad thermal tolerance, high fecundity, and ability to exploit both cultivated and wild grass hosts. Female *T. rowani* can parasitize 20–40 YRSB eggs per individual and exhibit significantly extended lifespans when nectar sources are available (Yuliarti et al., 2005), which directly explains the higher parasitoid abundance observed in our flowering plant plot. The identification of *T. schoenobii* as a co-occurring species is also noteworthy, as this eulophid parasitoid is a known gregarious endoparasitoid of stem borer eggs and has been reported to complement *Telenomus* parasitism through niche partitioning within egg masses (Rauf, 2000).

The temporal pattern of parasitism, with peak rates occurring at 6 WAT during the early generative stage of rice, closely mirrors the phenology of YRSB oviposition. At this stage, adult moths actively deposit egg masses on rice leaves, providing the highest density of host resources for parasitoids. This synchrony between host availability and parasitoid activity is a critical factor in the success of conservation biological control programs and suggests that the flowering plants were effectively sustaining parasitoid populations until the period of maximum host availability.

Relative Attractiveness of Flowering Plant Species

Among the cultivated and wild flowering plant species evaluated, sesame (*S. indicum*) and the wild composite *E. prostrata* attracted the highest numbers of YRSB egg parasitoids. Sesame is particularly promising for ecological engineering in rice systems because it produces abundant, open-architecture flowers with easily accessible nectar over an extended blooming period, features that are known to favor small-bodied hymenopteran parasitoids (Lu et al., 2015; Gurr et al., 2016). Furthermore, sesame has additional economic value as an oilseed crop, providing farmers with a supplementary income stream that incentivizes adoption of ecological engineering practices. The attractiveness of *E. prostrata* is consistent with findings by Ekawati et al. (2013), who documented this species as one of the most frequently visited wild plants by rice pest parasitoids in Central Javanese agroecosystems. As a spontaneous weed already present on many rice field bunds, *E. prostrata* requires no additional planting investment and represents a cost-free component of conservation biological control. The failure of cucumber to attract parasitoids in this study was attributed to poor growth resulting from excessive rainfall during the observation period, which caused flower abscission and stunted plant development. This observation highlights the importance of selecting flowering plant species that are resilient to local climatic conditions and capable of sustaining floral resource production throughout the rice growing season, including during periods of heavy monsoon rainfall that are typical of tropical rice-growing environments.

Confounding Factors and Study Limitations

A critical limitation of this study that must be acknowledged is the difference in cultivation practices between the two plots. The flowering plant plot was managed semi-organically without synthetic insecticide applications, while the control plot was managed conventionally with regular insecticide use. This introduces a significant confounding variable, as intensive insecticide use in the control plot may have directly suppressed parasitoid populations through lethal and sublethal toxic effects, independently of floral resource availability (Herlinda & Irsan, 2011; Heong et al., 2015). Organophosphate and pyrethroid insecticides are known to be highly toxic to hymenopteran parasitoids, with documented sublethal effects on host-searching behavior, oviposition rate, and offspring sex ratio even at concentrations below lethal thresholds (Desneux et al., 2007). Therefore, the observed differences in parasitoid abundance and parasitism rates between plots likely reflect the combined effect of floral resource provision and the absence of insecticide-induced mortality, rather than the effect of flowering plants alone.

Furthermore, the study employed an unreplicated design comparing two individual fields, which precludes formal statistical testing of treatment effects and limits the generalizability of the findings. The complete absence of parasitoids in the control plot—while striking—could result from factors beyond insecticide use and flowering plant absence, including differences in microclimate, surrounding landscape composition, or stochastic variation in parasitoid colonization. Future research should address these limitations through replicated split-plot or randomized complete block designs in which flowering plant presence and pesticide regime are varied independently as factorial treatments. Multi-season, multi-location studies would further strengthen the evidence base and enable robust quantification of the independent and interactive effects of floral resource provision and insecticide reduction on parasitoid-mediated pest suppression.

Despite these limitations, the magnitude of the observed differences—particularly the 82.39% egg mass parasitism rate in the flowering plant plot versus 0% in the control, and the lower YRSB attack intensity (2.99% vs. 3.56%)—provides compelling observational evidence that warrants further investigation. The findings are broadly consistent with the growing international literature demonstrating that ecological engineering through floral resource supplementation can meaningfully enhance biological control services in rice agroecosystems (Gurr et al., 2016; Settle et al., 1996; Lu et al., 2015).

CONCLUSIONS

This study provides field-based evidence that rice fields with flowering plants on bunds supported exclusively the presence of egg parasitoids (*T. rowani* and *T. schoenobii*) and achieved parasitism rates of 39.47% per egg and 82.39% per egg mass, while control fields yielded no parasitoid activity. Mean YRSB attack intensity was lower in the flowering plant plot (2.99%) than the control (3.56%). However, as the plots differed in both floral resources and insecticide use, these results represent the combined effect of ecological engineering and reduced chemical inputs. Sesame (*S. indicum*) and *E. prostrata* were the most attractive plants for egg parasitoids. These findings support integrating flowering plant strips into rice cultivation as part of ecological engineering strategies for conservation biological control, while highlighting the need for replicated, controlled experiments to quantify the independent contribution of floral resources.

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Conflict of Interest: The authors declare no conflict of interest.

Data Availability Statement: The data supporting the findings of this study are available from the corresponding author upon reasonable request.

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