RESEARCH ARTICLE

Comparative Evaluation of the Impact of Different Cultivation Methods on Infestation of Insect Pests of Rice on the Konkan Coast of Maharashtra

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Abstract

Rice is an important cereal staple food for the majority of the world's population. The choice of cultivation methods plays a key role in influencing insect pest infestation, which ultimately affect the crop yield. Hence, a field experiment was carried out to comparatively evaluate a total of eleven rice cultivation methods for their impact on infestation level of yellow stem borer, leaf folder and case worm. Among the cultivation methods evaluated, the lowest incidence of dead heart as well as white ear head was recorded in the char sutri method with no significant difference compared to the recommended rice cultivation method. In the system of rice intensification method, the least occurrence of leaf folder and case worm was observed, with a statistically significant difference in incidence compared to the recommended rice cultivation method. These findings underscore the importance of adopting environmentally friendly and resource-efficient cultivation practices to mitigate pest damage while ensuring the long-term sustainability of rice production.

Highlights

- The Char sutri method showed promising results in reducing dead heart and white ear head incidence in rice cultivation.
- The system of rice intensification demonstrated a significant reduction in leaf folder and case worm occurrences compared to traditional methods.
- Environmentally friendly cultivation practices hold potential for mitigating pest damage in rice production.
- Sustainable approaches are crucial for securing long-term rice production.

Keywords: Char sutri, system of rice intensification, yellow stem borer, leaf folder, case worm

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Introduction

Rice is a way of life, a symbol of sustenance and comfort. According to the *Vedas*, one of the earliest cereals known to humanity is rice, which is simply referred to as "Annam," meaning food. Rice has been recognized as an essential staple food from ancient India to modern India. It serves as a primary food source for nearly half of the global population, with India being the second largest producer and consumer after China (Chandel *et al*., 2022; Rabara *et al*., 2018). Projections indicate that, to fulfill the growing rice demand of the expanding global population, there is a need for an increase in global rice production. Currently standing at 524 million tons, it is anticipated to reach 700 million tons by the year 2025 (Papademetriou, 2000). Among the constraints in rice production, insect pests are the most important biological factors affecting rice production systems, leading to a reduction in both quantity and quality.

Diverse cultivation practices are employed across the country, spanning from North to South and East to West. The traditional method of rice cultivation demands substantial resources and degrades soil health, increasing the incidence of insect pests. Soni and Tiwari (2016) found a higher infestation of rice stem borer in transplanted rice than in directly seeded rice. Dendup and Chhogyel (2018) highlighted the comparative advantage of direct seeding, either through a drum seeder or broadcasting, over transplanted rice. According to Pathak *et al*., (2012), the system of rice intensification (SRI) resulted in a lower prevalence of stem borer, case worm, and leaf folder compared to traditional methods. Karthikeyan *et al*., (2010)

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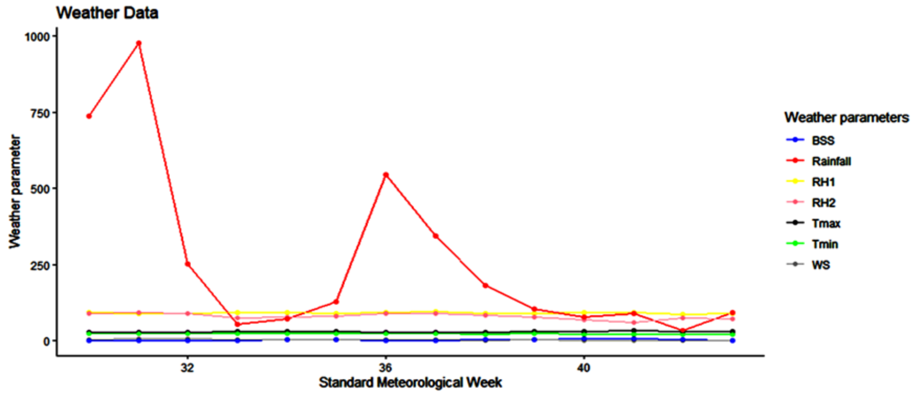

Fig. 1: Meteorological data trends throughout the crop season. BSS- Bright sunshine hours, RH- Relative Humidity, T- Temperature, WS- Wind speed

reported a significantly lower incidence of stem borer during the vegetative phase in SRI compared to the standard rice cultivation method. The occurrence of case worms was also lower in the SRI system, with a higher presence of natural enemies such as spiders and larval parasitoids. Padmavathi *et al*., (2009) observed reduced yellow stem borer damage, particularly at the maximum tillering stage, in the cultivar Shanti grown under SRI compared to conventional methods. Ravi *et al*., (2007) noted less damage of white ear heads in different rice varieties under the SRI method due to vigorous plant growth and wider spacing. Muralidharan *et al*., (2015) conducted field trials in Kuttanad and revealed the significant impact of drum seeding on paddy growth and yield parameters compared to broadcasted plots. The drum seeder contributed to an optimal plant population, effective tillering, and reduced pest and disease incidence, enhancing the microclimate. Hence, there is an urge to shift from the traditional method of cultivation to an advanced, efficient method of rice cultivation that uses all resources efficiently while lowering the incidence of insect pests. However, comparative evaluation of traditional and modern rice cultivation methods and their impact on rice insect pest incidence remains limited. Recognizing the significance of this issue, our current investigation focused on implementing different cultivation methods that optimize resource utilization while ensuring sustainable pest management practices.

Materials and Methods

Experimental Details

The field experiment was carried out in the Kharif season of 2019 at the Regional Agriculture Research Station (RARS), Karjat, Maharashtra. The location is situated at a latitude of 18°55′ N and longitude of 71°18′ E, with an altitude of 51 m above sea level. The topography of the experimental plots was uniform. The selection of the site was based on the suitability of the land for the cultivation of the crop and the resources available for rice cultivation in the Kharif season. The soil type was medium black. The experimental plots were laid out according to the study requirements, using normal agronomic practices. Meteorological observations prevailing at the experimental site were recorded during the crop season (Fig. 1).

The field experiment was conducted with randomized block design (RBD), with 3 replications and a total of eleven cultivation methods (10+1(recommended rice cultivation methods)) (Table 1). The recommended rice cultivation method was used to compare the incidence of insect pests with that of other cultivation methods. The Karjat 3 variety, collected from RARS, Karjat, was used for the experiment. The gross plot size was 9 m × 4.5 m, and the total experimental area was 49.5 m × 27 m. Agricultural practices were implemented following the recommended package of practices, with the exception of the measures related to plant protection.

Methods of recording observations

Ten rice hills were randomly selected for observation. Weekly observations were documented for stem borers, leaf folders and caseworms. Damage from the yellow rice stem borer was assessed by counting dead hearts (DH) during the vegetative stage and white ear heads (WEH) during the panicle initiation

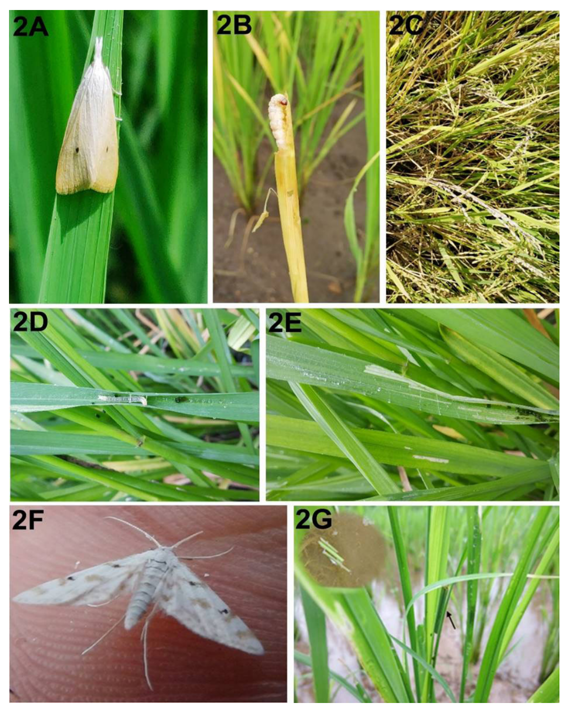

Fig. 2: Rice insect pests: 2A) Yellow stem borer female moth; 2B) Dead Heart with larva; 2C) White ear head infestation; 2D) Leaf folder larva; 2E) Leaf folder infestation; 2F) Case worm adult; 2G) case worm larvae preparing tubular cases (black arrow), floating tubular cases (left side up)

Table 1: Details of Cultivation methods

Name of method	*Details*
SRI method (System of rice intensification)	A mat nursery prepared 10-to-12-day-old seedlings, each having 3 to 4 leaves, which were transplanted individually at a shallow depth of 25 cm × 25 cm. Flooding should be avoided at an early stage. (Sinha and Talati, 2007; Berkelaar, 2001).
Char sutri method	In this paddy cultivation method, *Gliricidia* leaves were buried in the soil during puddling. Using the marked rope for uniform planting, transplanting of 21-25-day-old seedlings was done at the first hill and second hill (2-3 seedlings per hill), predicting an approximate 15 cm distance in front of the first and second hills and third and fourth hills planted (2-3 seedlings per hill). The sutras for this method include **Sutra 1:** Reuse and incorporate paddy residue in the field. **Sutra 2:** Application of *Gliricidia* leaves. **Sutra 3:** Transplanting the four hills uniformly by using improved and hybrid varieties. **Sutra 4:** On the same day, after uniform transplanting, 2.7 grams of urea briquette was placed at a 7-10 cm dip in the middle of the square formed by four hills (Jadhav *et al*., 2022; Kashid *et al.,* 2022).
Mechanical Transplanting (MT)	Mechanical transplanting of rice using *Yanji-Shakti* transplanter was conducted. A mat nursery was prepared for growing seedlings for mechanical transplanting following the method described by Modi *et al*., (2022). After 21–22 days of nursery, the seedlings were ready for mechanical transplanting. The mat was cut into pieces of the required size using a knife and taken into the field to be placed on the feeding tray of the transplanter. A well-leveled field with 3–4 cm water level was used for mechanical transplanting at 20 cm × 15 cm spacing (Guru *et al*., 2018).
Broadcasting of sprouted seeds in puddle condition (BSS) **(***Rahu***)**	The seeds were initially soaked in water for 24 hours and then placed in a moist gunny bag for an additional 24 hours. The sprouted seeds were subsequently spread across a puddled field. (Thakur *et al*., 2004)
Drum seeding of sprouted seed (DSSS)	Sprouted seeds were manually sown in the field using a four-colter drum seeder at a depth of 3 to 5 cm with row spacing of 20 cm on a puddled field (Singh, 2008).
Drum seeding of dry seed (DSDS)	This approach mirrors drum seeding with sprouted seeds, differing only in the use of dry seeds. After sowing, the seeds are covered with soil (Ali *et al*., 2006)
Conservation method	Sprouted seeds were manually sown in a prepared field at a spacing of 20 cm ×15 cm by making holes. After sowing, the seeds were covered with soil.
SRT method (Saguna rice technique)	The procedure followed as per Kashid *et al*., (2022) and Jadhav *et al*., (2022). Depression holes were made with SRT iron forma (SRT Tool) on the raised beds with a spacing of 25 cm × 25cm. Sprouted seeds were manually sown in holes and covered with soil. This system made the crop ready for harvesting 8 to 10 days earlier.
Farmer Practice-Mulching (FP-M)	This method involved the application of 25-micron silver-black polythene mulch for poly mulch treatment, with rice seeds dibbled on raised beds at a spacing of 30 cm × 30 cm (1′ × 1′).
Recommended Mulching Method (RM)	A similar approach was followed as in FP-M, utilizing 25-micron silver-black polythene mulch for polymulch treatment. However, in this case, the rice seeds were dibbled on raised beds at a spacing of 20 cm × 15 cm. (Gao *et al*.,2023; Kasirajan and Ngouajio, 2012).
Recommended Rice cultivation method (RRC)	21- to 25-day-old seedlings (raised in a wet nursery bed) were transplanted at 20 cm × 15 cm into a manured and fertilized puddled field with the help of rope for uniform planting.

stage. Leaf folder and case worm damage were recorded based on the total number of leaves and damaged leaves (Fig. 2A-G). The percentage of damage was calculated using the formula:

$$\text{Stem borer} = \frac{\text{Number of dead hearts/white ear head}}{\text{Total number of tillers/panicles per hill}} \text{ X } 100$$

$$\text{Leaf folder and case worm} = \frac{\text{Number of damaged leaves}}{\text{Total number of leaves per hill}} \text{ X } 100$$

Statistical analysis

The data from various observations were systematically tabulated and subjected to statistical analysis through analysis of variance (ANOVA) within a randomized block design. To ensure uniformity, an arcsine transformation was applied. A graphical representation of the data was created using R Software.

Results

Impact of different cultivation methods on insect pests infesting rice

Yellow stem borer (dead heart)

The dead heart infestation started from the 30th SMW up to the 40th SMW. The infestation increased up to the 34th SMW and from the 35th SMW, the incidence decreased until the end of infestation in SRI, MT, BSS and RRC methods. In char sutri, FP-M and RM, infestation increased up to 35th SMW. In DSSS, DSDS, conservations and SRT, variations were observed in infestation. The overall mean percent dead heart infestation ranged from 2.75 to 3.67. Among all cultivation methods, the lowest mean percent infestation was observed in Char sutri (2.75%), which was at par with RRC (3.03%). The mean percent infestation in SRI

Table 2: Effect of different cultivation methods on a rice yellow stem borer (DH) and White ear head (WEH) infestation

Sr. No.	SMW	Percent infestation of rice yellow stem borer: Dead Heart												White Ear Head				
		30	31	32	33	34	35	36	37	38	39	40	M. I.	40	41	42	43	M. I.
	Methods:																	
1	SRI	0.00 (0.00)	3.84 (11.29)*	3.49 (10.75)	4.10 (11.66)	5.92 (14.08)	4.34 (12.**0**2)	4.22 (11.84)	3.53 (10.82)	2.76 (9.54)	1.81 (7.72)	0.85 (5.20)	3.17 (10.25)	0.69 (4.74)*	3.19 (10.27)	4.24 (11.85)	5.11 (13.07)	3.31 (10.47)
2	Char sutri	0.00 (0.00)	1.70 (7.41)	3.81 (11.25)	4.11 (11.69)	4.26 (11.92)	4.80 (12.66)	4.32 (11.99)	3.53 (10.82)	2.17 (8.46)	1.42 (6.83)	0.12 (1.16)	2.75 (9.55)	0.98 (5.68)	3.29 (10.45)	3.94 (11.45)	3.12 (10.12)	2.84 (9.69)
3	MT	0.95 (4.56)	2.37 (8.83)	3.00 (9.96)	4.17 (11.78)	5.90 (14.06)	5.72 (13.83)	5.33 (13.34)	3.16 (10.24)	2.99 (9.96)	1.63 (7.34)	0.58 (4.32)	3.25 (10.39)	0.70 (4.80)	3.58 (10.91)	4.87 (12.74)	4.15 (11.74)	3.33 (10.51)
4	BSS	0.00 (0.00)	2.31 (8.66)	4.12 (11.69)	4.34 (12.01)	5.48 (13.54)	5.27 (13.26)	4.63 (12.38)	4.38 (12.08)	4.48 (12.22)	2.89 (9.76)	0.90 (5.37)	3.53 (10.82)	1.16 (6.12)	4.29 (11.94)	4.19 (11.78)	5.68 (13.79)	3.83 (11.28)
5	DSSS	0.00 (0.00)	3.72 (11.09)	4.77 (12.60)	3.58 (10.87)	5.17 (13.12)	4.54 (12.27)	4.11 (11.69)	4.83 (12.69)	5.08 (13.01)	3.53 (10.79)	0.61 (4.47)	3.63 (10.99)	1.68 (7.34)	5.41 (13.41)	4.75 (12.58)	5.09 (13.01)	4.23 (11.87)
6	DSDS	0.00 (0.00)	3.17 (10.15)	4.67 (12.46)	5.44 (13.47)	4.58 (12.33)	4.51 (12.25)	4.78 (12.62)	4.85 (12.71)	3.61 (10.95)	1.21 (6.23)	0.95 (5.53)	3.43 (10.67)	1.09 (5.91)	3.04 (10.02)	5.68 (13.79)	4.89 (12.77)	3.68 (11.06)
7	Conservation	0.00 (0.00)	3.70 (11.05)	2.78 (9.54)	5.08 (12.99)	5.01 (12.91)	4.85 (12.71)	5.14 (13.10)	5.02 (12.94)	4.30 (11.93)	3.70 (10.85)	0.75 (4.91)	3.67 (11.04)	1.10 (6.00)	3.92 (11.40)	5.46 (13.52)	5.57 (13.65)	4.01 (11.55)
8	SRT	0.42 (2.14)	2.21 (8.38)	4.11 (11.69)	3.68 (11.04)	5.14 (13.10)	5.61 (13.68)	4.51 (12.27)	3.31 (10.48)	5.11 (13.07)	2.99 (9.95)	0.95 (5.59)	3.46 (10.71)	0.91 (5.47)	2.81 (9.64)	5.61 (13.70)	5.81 (13.94)	3.78 (11.21)
9	FP-M	0.89 (4.42)	2.26 (8.64)	3.10 (10.13)	4.51 (12.25)	5.94 (14.10)	6.16 (14.37)	4.67 (12.47)	3.12 (10.17)	2.77 (9.57)	2.54 (9.16)	0.96 (5.61)	3.36 (10.56)	0.99 (5.66)	3.06 (10.06)	4.77 (12.60)	5.11 (13.06)	3.48 (10.76)
10	RM	1.36 (6.70)	3.38 (10.54)	3.48 (10.71)	4.26 (11.90)	5.23 (13.22)	5.36 (13.39)	5.24 (13.23)	4.31 (11.97)	3.01 (9.99)	2.66 (9.36)	1.11 (6.04)	3.58 (10.91)	0.95 (5.56)	3.80 (11.23)	5.40 (13.43)	5.51 (13.55)	3.92 (11.41)
11	RRC	0.00 (0.00)	2.84 (9.69)	3.05 (10.05)	4.02 (11.57)	5.63 (13.71)	4.95 (12.85)	4.26 (11.91)	2.96 (9.86)	2.56 (9.19)	1.89 (7.83)	1.16 (6.15)	3.03 (10.02)	0.85 (5.26)	3.12 (10.14)	4.55 (12.31)	4.19 (11.80)	3.18 (10.27)
	SE (m±)	1.19	0.73	0.46	0.45	0.33	0.37	0.36	0.31	0.38	0.70	0.55	0.17	0.46	0.44	0.37	0.37	0.20
	C.D. 5%	3.52	2.14	1.35	1.32	0.98	1.10	1.05	0.92	1.13	2.07	1.63	0.50	1.35	1.30	1.09	1.09	0.58

*Figures in parenthesis are arc sine values, M. I.- Mean Infestation (%)

Table 3: Effect of different cultivation methods on rice leaf folder and rice case worm infestation

Sr. No.	SMW	Percent infestation of rice leaf folder												Percent infestation of rice case worm								
		30	31	32	33	34	35	36	37	38	39	40	M. I.	30	31	32	33	34	35	36	37	M. I.
	Methods:																					
1	SRI	0.00 (0.00)*	0.15 (1.81)	0.08 (0.92)	0.17 (1.91)	0.27 (2.99)	0.11 (1.90)	0.08 (1.29)	0.03 (0.57)	0.00 (0.00)	0.03 (0.60)	0.00 (0.00)	0.07 (1.44)	0.00 (0.00)*	0.08 (0.96)	0.15 (1.83)	0.13 (1.71)	0.08 (1.35)	0.07 (1.26)	0.03 (0.60)	0.00 (0.00)	0.04 (1.14)
2	Char sutri	0.13 (1.18)	0.25 (2.87)	0.23 (2.73)	0.43 (3.73)	0.16 (2.28)	0.26 (2.94)	0.17 (2.36)	0.09 (1.75)	0.10 (1.78)	0.00 (0.00)	0.07 (1.21)	0.14 (2.12)	0.00 (0.00)	0.25 (2.85)	0.14 (1.77)	0.17 (2.32)	0.14 (1.69)	0.21 (2.59)	0.10 (1.45)	0.06 (1.11)	0.07 (1.54)
3	MT	0.00 (0.00)	0.07 (0.90)	0.25 (2.88)	0.34 (3.31)	0.66 (4.64)	0.39 (3.44)	0.22 (2.66)	0.06 (1.18)	0.18 (2.38)	0.12 (2.01)	0.00 (0.00)	0.16 (2.32)	0.00 (0.00)	0.23 (2.75)	0.24 (2.79)	0.25 (2.86)	0.30 (3.14)	0.16 (2.29)	0.15 (2.24)	0.06 (1.18)	0.10 (1.81)
4	BSS	0.00 (0.00)	0.29 (3.09)	0.36 (3.45)	0.57 (4.31)	0.74 (4.91)	0.60 (4.41)	0.22 (2.66)	0.15 (2.22)	0.09 (1.38)	0.05 (0.74)	0.12 (1.60)	0.23 (2.75)	0.16 (1.31)	0.22 (2.20)	0.34 (3.36)	0.39 (3.59)	0.28 (3.03)	0.36 (3.44)	0.17 (2.36)	0.00 (0.00)	0.14 (2.12)
5	DSSS	0.00 (0.00)	0.26 (2.92)	0.48 (3.94)	0.63 (4.53)	0.72 (4.86)	0.71 (4.79)	0.35 (3.28)	0.20 (2.51)	0.05 (0.74)	0.00 (0.00)	0.10 (1.05)	0.25 (2.88)	0.00 (0.00)	0.09 (0.99)	0.40 (3.62)	0.44 (3.79)	0.32 (3.21)	0.35 (3.39)	0.29 (3.07)	0.00 (0.00)	0.14 (2.12)
6	DSDS	0.00 (0.00)	0.11 (1.10)	0.39 (3.56)	0.76 (5.01)	0.55 (4.25)	0.62 (4.49)	0.20 (2.54)	0.12 (1.62)	0.06 (0.83)	0.00 (0.00)	0.00 (0.00)	0.20 (2.56)	0.00 (0.00)	0.12 (1.13)	0.41 (3.67)	0.29 (3.10)	0.30 (3.14)	0.35 (3.39)	0.15 (1.79)	0.00 (0.00)	0.12 (1.95)
7	Conservation	0.00 (0.00)	0.25 (2.88)	0.29 (3.10)	0.52 (4.11)	0.71 (4.84)	0.67 (4.70)	0.32 (3.23)	0.13 (2.04)	0.10 (1.81)	0.03 (0.60)	0.00 (0.00)	0.21 (2.65)	0.00 (0.00)	0.25 (2.88)	0.36 (3.37)	0.27 (2.99)	0.34 (3.36)	0.34 (3.32)	0.19 (2.47)	0.00 (0.00)	0.13 (2.04)
8	SRT	0.00 (0.00)	0.10 (1.06)	0.26 (2.92)	0.36 (3.41)	0.30 (3.10)	0.12 (1.95)	0.19 (2.43)	0.12 (1.95)	0.12 (1.99)	0.08 (1.35)	0.00 (0.00)	0.12 (1.98)	0.00 (0.00)	0.00 (0.00)	0.23 (2.74)	0.21 (2.65)	0.29 (3.09)	0.12 (1.98)	0.09 (1.38)	0.00 (0.00)	0.07 (1.48)
9	FP-M	0.33 (2.66)	0.29 (3.08)	0.14 (1.77)	0.46 (3.62)	0.59 (4.41)	0.37 (3.39)	0.14 (2.12)	0.10 (1.78)	0.08 (1.65)	0.00 (0.00)	0.12 (1.98)	0.19 (2.47)	0.17 (1.93)	0.26 (2.92)	0.10 (1.50)	0.14 (1.76)	0.08 (1.30)	0.00 (0.00)	0.07 (0.85)	0.00 (0.00)	0.06 (1.39)
10	RM	0.25 (2.34)	0.26 (2.92)	0.23 (2.73)	0.48 (3.95)	0.68 (4.71)	0.54 (4.19)	0.43 (3.75)	0.19 (2.47)	0.09 (1.72)	0.13 (1.66)	0.11 (1.52)	0.24 (2.82)	0.19 (2.02)	0.26 (2.92)	0.21 (2.63)	0.17 (2.36)	0.33 (3.31)	0.14 (1.69)	0.00 (0.00)	0.00 (0.00)	0.09 (1.74)
11	RRC	0.00 (0.00)	0.18 (2.45)	0.17 (2.36)	0.18 (2,40)	0.36 (3.41)	0.20 (2.49)	0.10 (1.78)	0.12 (1.95)	0.11 (1.90)	0.10 (1.78)	0.00 (0.00)	0.11 (1.90)	0.00 (0.00)	0.20 (2.54)	0.22 (2.66)	0.28 (3.03)	0.31 (3.19)	0.33 (3.29)	0.16 (2.32)	0.03 (0.60)	0.11 (1.90)
	SE (m±)	0.63	0.58	0.39	0.47	0.26	0.37	0.32	0.35	0.41	0.46	0.52	0.10	0.54	0.63	0.49	0.36	0.41	0.36	0.49	0.29	0.08
	C.D. 5%	1.86	1.71	1.15	1.40	0.76	1.09	0.95	1.04	1.22	1.35	1.52	0.29	1.59	1.86	1.44	1.05	1.21	1.06	1.44	0.84	0.23

*Figures in parenthesis are arc sine values, M. I.- Mean Infestation (%)

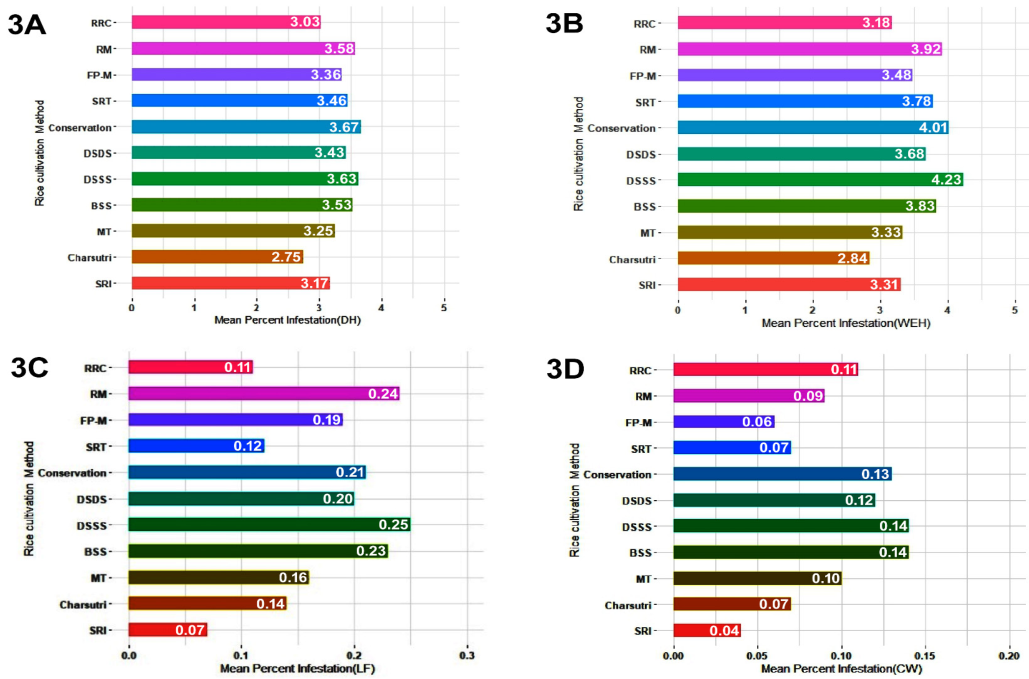

Fig. 3: Effects of different Cultivation methods on rice yellow stem borer [3A) DH-Dead Heart, 3B) WEH-White Ear Head], 3C) Leaf folder (LF) and 3D) Case worm (CW) infestation

(3.17%) was on par with MT (3.25%), FP-M (3.36%), DSDS (3.43%), SRT (3.46%), followed by BSS (3.53%), RM (3.58%), DSSS (3.63%) and conservation (3.67%) (Table 2, Fig. 3A).

Yellow stem borer (white ear head)

The percentage of white ear head infestation started at the 40th SMW and continued up to the 43rd SMW. The incidence of white ear head increased up to 42nd SMW in char sutri, MT, DSDS and RRC and for the remaining methods, the incidence increased up to the 43rd SMW. The overall mean percentage of white ear head infestations due to yellow stem borers from the 40th SMW to the 43rd SMW significantly differed between the treatments, ranging from 2.84 to 4.23%. The lowest mean percentage infestation was observed in char sutri (2.84%), which was on par with RRC (3.18%). The mean percent infestation in SRI (3.31%) was on par with MT (3.33%), FP- M (3.48%) followed by DSDS (3.68%), SRT (3.78%), BSS (3.83%), RM (3.92%), conservation (4.01%) and DSSS (4.23%) (Table 2, Fig. 3B).

Leaf folder

Leaf folder infestation started at the 30th SMW and continued up to the 40th SMW. No infestations were recorded from the 41st to the 43rd SMW. Leaf folder incidence was observed only in char sutri, FP-M and RM at the 30th SMW. Overall, the maximum leaf folder incidence was observed in SRI, MT, BSS, DSSS, conservation, FM-P, RM and RRC during the 34th SMW and in Char sutri, DSDS, SRT during the 33rd SMW. Data indicated that the mean percentage leaf folder infestation from 30th SMW to 43rd SMW ranged from 0.07 to 0.25%. The lowest mean percentage of infestation was observed in SRI (0.07%). The mean percentage infestation in RRC (0.11%) was on par with SRT (0.12%), and char sutri (0.14%). The mean percentage infestation in MT (0.16%) was on par with FP-M with (0.19%), DSDS (0.20%) followed by conservation (0.21%), BSS (0.23%), RM (0.24%), DSSS (0.25%) (Table 3, Fig. 3C).

Case worm

Rice case worm infestations were observed from the 30th SMW to the 37th SMW. No infestations were recorded from the 38th to the 43rd SMW. No incidences were observed in SRI, Char sutri, MT, DSSS, DSDS, Conservation, SRT and RRC during the 30th SMW. The overall maximum incidence was in char sutri, FM-P during 31st SMW, in SRI, DSDS and Conservation during 32nd SMW, in BSS and DSSS during 33rd SMW, in MT, SRT and RM during 34th SMW and in RRC during 35th SMW. The overall mean percentage of case worm infestation ranged from 0.04 to 0.14 from the 30th SMW to the 43rd SMW. The lowest mean percentage of infestation was observed in SRI (0.04%). The mean percentage infestation in FP-M (0.06%) was on par with SRT (0.07%) and char sutri (0.07%). The mean percentage infestation in RM (0.09%) was at par with MT (0.10%), RRC (0.11%), DSDS (0.12%) followed by conservation (0.13%), BSS (0.14%) and DSSS (0.14%) (Table 3, Fig. 3D).

Discussion

In the present study, we evaluated the effects of eleven cultivation methods, including the recommended rice cultivation method for comparison, on three major rice pests: rice stem borer, leaf folder, and case worm. Among the cultivation methods assessed, the lowest incidences of both dead heart and white ear head were observed in the char sutri method, followed by RRC and SRI methods. There was no significant difference in stem borer incidence between the char sutri and RRC methods. In the char sutri method, the incorporation of paddy residue and *Gliricidia* during field puddling was employed. Rice residue management practices may also influence the bioavailability of silicon in rice fields (Hughes *et al*., 2020). Silicon plays a crucial role in enhancing plant resistance to various stressors, including nutrient depletion, drought stress, pathogens, and pest attacks. Previous studies have demonstrated that silicon application imparts resistance to rice insect pests, such as the African striped borer, yellow rice stem borer, striped stem borer and leaf folder (Jeer *et al*., 2018). While *Gliricidia* is known for its use as a green manuring crop and reported insecticidal properties against various pests (Krishnappa *et al*., 2012). The results of our studies align with Kashid (2017), who reported that the char sutri method of rice cultivation is effective for controlling the rice stem borers while also increasing crop production. Khade and Roy (2020) reported that factor share analysis revealed that the char sutri method had the highest contribution (i.e., 32.84 %) to paddy yield.

Our study's findings indicate a significantly lower incidence of rice leaf folders and case worms in fields utilizing the SRI method compared to the RRC method. The SRI method is dedicated to improving the overall environment for rice plants, both above and below ground. The health and vitality of rice plants cultivated through SRI practices enable them to resist pest attacks and potential diseases. The success of SRI in minimizing pest incidence in rice is attributed to several factors, including vigorous plant growth, wider plant spacing, mechanical weed control, absence of stagnant water, and a reliance on organic nutrition to enhance soil health and fertility (Karthikeyan *et al*., 2010; Visalakshmi *et al*., 2014; Kesh *et al*., 2017; Nath and Das (2018); Chintalapati *et al*., 2023). This factor increases airflow within the crop canopy, greater exposure to sunlight, and subsequently reduces pest incidence. Furthermore, the study discovered that SRI plots exhibited increased silica content, a factor known to enhance plant resistance against pests and reduce damage caused by insect pests, pathogens, and non-insect pests. The accumulation of silica in plant tissues serves as a physical deterrent for leaf-chewing pests, influencing the regulation of defense-related enzymes and plant hormone signaling, as well as the modification of volatile blends in plants. The result of our study, supported by Padmavathi *et al*., (2009), indicates that SRI methods foster greater biodiversity of natural enemies, such as predators and parasitoids, resulting in a lower occurrence of leaf folder, case worm, and stem borer compared to other cultivation techniques. Similar findings were reported by Karthikeyan *et al*., (2007) and Pathak *et al*., (2012), underscoring the lower incidences of stem borer, leaf folder, and case worm in SRI, along with increased populations of natural enemies like spiders.

Conclusion

The results of the experiment indicate that, in comparison to conventional farming techniques (RRC method), the Char Sutri approach exhibited the least occurrence of stem borers (Dead Heart and White Ear Head). Moreover, the System of Rice Intensification (SRI) method demonstrated the lowest incidence of leaf folders and case worms. It is believed that its establishment method is what made it successful in combating insect pests. This underscores the importance of understanding and optimizing cultivation practices to enhance pest resistance in rice crops. By adopting innovative cultivation techniques, farmers can effectively manage the insect pest population while promoting sustainable rice production. This research contributes to the ongoing effort to develop environmentally friendly and economically viable pest management strategies, ensuring the long-term sustainability of rice production systems worldwide.

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Conflicts of Interest

The authors have no conflicts of interest.

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