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Screening of certain rice varieties and its grain yield on the incidence of *Scirpophaga incertulas* Walker on rainfed rice crop-ecosystem of Manipur valley

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Abstract
Scirpophaga incertulas (Walk.) commonly known as Yellow stem borer (YSB), is one of the most destructive pests and field losses are estimated as 5-8% depending on Rice cultivars. A field experiment was conducted at Rice Research Farm, College of Agriculture, CAU, Imphal during the *Kharif* season, 2020 and 2021. Nineteen certain available rice varieties were tested in the field for their resistance reaction against YSB. Among the entire test varieties, YSB infestation varied from 1.20 to 9.40% Dead Heart (DH) and 1.31 to 7.70% White Ear Head (WEH), which were observed at vegetative and reproductive stages of the crop, respectively. Highest incidence of YSB was recorded on 'TN-1' with 9.40% (DH) and 7.70% (WEH), whereas, the lowest incidence was recorded from *Phouoibiphou* with 1.02% (DH), 1.31% (WEH). The grain yield data revealed that the highest grain yield (8.77 tha^{-1}) was obtained from the plots of *IR-64* as against (2.50 tha^{-1}) in highly susceptible check variety TN-1. It was closely followed by KD-Awangba with 6.57 tha^{-1} and RCM-10 with 6.15 tha^{-1}, whereas Punshiphou, Ereimaphou and WR-11-4 were recorded low yield with 2.91 tha^{-1}, 2.86 tha^{-1} and 2.68 tha^{-1}, respectively and showed non-significant difference with the check variety TN-1.

Keywords: Rice, *Scirpophaga incertulas*, dead heart, white ear head and grain yield

1. Introduction

As we know that rice, *Oryza sativa* is the staple food for more than half of the world's population and this crop is attacked by several 100 species of insect pests during its different cropping stages i.e. from nursery till harvest but only a few of them have gained the status of major importance as far as loss in yield are concerned. Among these major insect pests, rice stem borer (*Scirpophaga incertulas*), is one of the serious pests in our country.

More than 100 species of insects are prone to attack the rice plant of which 20 insect species can cause economic damage (Pathak, 1977; Arora and Dhaliwal, 1996) [10, 1]. Among different insect species associated with rice, yellow stem borer (*S. incertulas*) is one of the most destructive and widely distributed pests in India which is due to impudent cultural practices. Torii (1967) reported *S. incertulas* one of the notorious pest infesting the crop from seedling to maturity stage and distributed from Tropics to temperate regions. While Singh *et al.* (2000) [11] observed a substantial yield losses due to rice gall midge (*O. oryzae*), from the past few years at Manipur, India.

During vegetative stage, *S. incertulas* attack and damage the crop in the form of dead heart (DH) and white ear head (WEH) at reproductive stage. Severe infestation may damage the whole plant and reduces yield and the marketability of the produce. Abiotic factors such as temperature, precipitation, photoperiods etc. directly effects the plant growth and development, yet choosing optimum date of planting also plays an important role in rice grain yield. Although, showing date affect paddy yield due to various favourable environmental condition, sowing date of rice should be adjusted in such a way that reproductive growth stage should not be concide with high temperature stress as it may reduce the number of grains per panicle and resulting in lower grain yield (Safdar, *et al.*, 2013) [13].

Kiritani (1972, 1977 and 1979) [14, 15, 16] revealed that stem borer in rice can be control by application of pesticides, cultivation of resistant varieties and by natural enemies. Waldbauer and Marciano (1979) developed greenhouse screening method to overcome non uniform pest pressure and unpredictability of field population by growing plants in pots inside the greenhouse.

Rao and Padhi (1981) [18] reported the outbreak of yellow stem borer due to the lower amount of rainfall and number of rainy days.

In the vegetative stage, the yellow stem borers' larvae bore into and feed on the leaf sheath causing whitish longitudinal ultimately turn brownish and die resulting to the formation of "dead hearts", during the reproductive stage the larvae *S. incertulas* cut the growing parts resulting to the condition known as "White heads" (Gupta and O' toole, 1986) [4]. Severe infestation by *S. incertulas* often causes complete crop failure (Kushwaha, 1995) [5]. In many Asian countries *viz.*, China, India, Japan, Korea, Malaysia, Sri Lanka and Vietnam, the serious outbreak of rice leaf folder causing severe yield losses (Wada *et al*., 1980; Heong, 1993; Jenita, *et al.*, 2018) [6, 7] due to changes in physical environments, adoption of multiple cropping system, new cultural technologies, use of high levels nitrogenous fertilizer, application of different pesticides which resulted to genetic variability of high yielding rice varieties (Dale, 1994 and De Kraker *et al*., 2000) [8, 9]. The Second instar larvae of leaf folder usually infested on young leaves by folding longitudinally for accommodation and feeds on the green foliage voraciously ultimately formed papery dry leaves. Recently, in few states of India, insect pest complex of rainfed rice crop-ecosystems, rice gall midge damages has been reported as one the major pest of high yielding varieties by damaging the crop at early vegetative stage (Jenita, *et al.*, 2016). The symptom formed by gall midge is popularly known as 'onion shoot' or 'silver shoot'.

Keeping all these in mind, the present study was under taken to explore the efficacy of five new molecules of pesticides, one Neem based insecticide, three available plants extracts with cow-urine, and cow-urine alone against the yellow stem borer.

2. Materials and methods

One month old seedlings were transplanted in Randomized Block Design (RBD) in the plot size of 5m x 4m at 15cm x 20 cm spacing with three replications. Field evaluation of new molecules and cow-urine plant extracts against *S. incertulas* on rice *var.* "Leimaphou (KD-2-6-3)". The experiments were conducted for two consecutive years during *Kharif* season of 2020 and 2021 at the Rice Research Farm, College of Agriculture, Central Agricultural University, (CAU) Imphal.

2.1. Lay out plan of the experimental field

The experiment was laid out in a RBD (Randomized Block Design). There were altogether eleven treatments including one untreated control *viz.*, three new molecules (Thiamethoxam 25 WG, Fipronil 80 WG and Lancergold 51.8 WP), one conventional insecticide (Chlorpyriphos 20 EC), Spinosad 2.5 SC, one neem based insecticide (Nimbecidine 0.03%), three available plants extracts with cow-urine *viz.*, *Artemisia nilagirica* (C.B. Clarke) Pamp, *J*atropha *gossypifolia* L. and *Melia azedirach* Linn. and cow-urine. Each treatment was replicated three times. Each sub-plot measured 5 m x 4 m. Rice variety "Leimaphou (KD-2-6-3)" was sown in the nursery. One month old seedlings were transplanted in the main field at the spacing of 15 cm x 20 cm. The lay out plan of the experiment is presented in Table 1,2,3.

2.2. Preparation of cow-urine indigenous plant extracts

The parts of 3 indigenous plant species (Table 2) were collected from different places of valley districts of Manipur. Two hundred fifty (250) g of fresh parts of each plant samples were weighed and soaked in 1 litre of cow-urine using earthen pots and kept with lid under shade condition for 3 weeks followed by Yumnam *et al.* 2017. The mixture was considered as technical material (stock solution) (Table 1,3).

2.3. Application of insecticides

Six sprayable insecticides, three indigenous cow-urine plant extracts and sole cow-urine were field evaluated at various doses against *S. incertulas*, *C medinalis* and *O. oryzae* infesting the rice var. "Leimaphou (KD-2-6-3)" along with untreated check (Details of the insecticidal treatments are presented in Table 1,3.

All the insecticidal treatments were applied as post transplanting applications in the form of foliar sprays by means of high volume hand compression knapsack sprayer (15 l) using 500 litres of spray solution per hectare to ensure through coverage of the plants during morning around 8.00 pm. The test insecticides were made three times at 15 days intervals commencing from 20 days after transplanting i.e. first spray (20 DAT), second spray (35 DAT) and third spray (50 DAT). Sufficient care was taken to avoid drifting of insecticides while spraying.

2.4. Observations recorded

2.4.1. Yellow Stem borer (*S. incertulas*)

Observations on yellow stem borer infestation were recorded at one day before (1DBA) and ten days after (10 DAA) each application along with total tillers. Twenty (20) hills were selected at random in each plot leaving the border 2 rows. The total number of tillers as well as infested tillers was counted in all the 20 hills under observation. The dead heart (DH) and white ear head (WEH) was recorded as infested tillers depending on the age of the crop. The percentage of the infestation was determined by using the formula (Annon 2004).

$$\% \text{ infestation} = \frac{\text{Number of dead heart (DH) or white ear head (WEH) per 20 hills}}{\text{Total number of tillers or penicles per 20 hills}} \text{X } 100$$

2.4.2. Estimation of grain yield

The crop was harvested when 85% of the grains matured in all treatments (IRRI, Rice Knowledge Bank). The grain yield of each plot was recorded and computed to tonnes per hectare.

2.4.3. Estimation of avoidable yield loss in various insecticidal treatments due to yellow stem borer, *S. incertulas*

The avoidable yield loss was estimated in each of the treatments by using the formula suggested by Pawa *et al.* (1984).

$$\% \text{ Avoidable yield loss} = \frac{T - C}{T} \text{ X } 100$$

Where,
T = Yield in most effective treatment
C = Yield in respective treatment

2.4.4. Determination of cost- benefit ratio

Cost–benefit ratio for each of the insecticidal treatments was determined taking into account the cost of insecticides, labour and pump hiring charges and the price of the additional yield obtained due to the insecticidal treatment, etc.

2.4.5 Statistical Analysis
The data recorded on various aspects of the study were processed to derive the mean values. The mean values after suitable transformation wherever necessary were subjected to statistical analysis to test significance as per Gomez and Gomez (1984) for interpretation of the results.

3. Results and Discussions
The results of present field investigation on the effect of certain new molecules and indigenous cow-urine plant extracts on the incidence of yellow stem borer, *Scirpophaga incertulas* (Walker) was conducted during *Kharif*, 2020 and 2021 season at the Research Farm of the College of Agriculture, Central Agricultural University, Imphal are briefly outlined in the present study.

Three varieties *Leimaphou*, *Tamphaphou* and *KD-Awangba* showed non-significant difference from *Phouoibiphou* at vegetative stage. '*Phouoibiphou*' showed resistance reaction against the borer at vegetative stage, but at reproductive stage, it was recorded with no damage reaction. However, 2 varieties *Leimaphou* (1.14% DH, 2.12% WEH) and *Tamphaphou* (1.33% DH, 2.27% WEH), 5 varieties 'RCM-9 (3.01% DH, 4.82% WEH), *Matamphou* (2.28% DH, 3.39% WEH), Sanapou (2.73% DH, 4.32% WEH), WR-1-9-17 (2.64% DH, 3.63% WEH) and WR-2-3-1(3.23% DH, 5.20% WEH), 3 varieties *Punshiphou* (4.43% DH, 6.48% WEH), *Ereimaphou* (5.44% DH, 6.18% WEH), *CAUS-1* (4.04% DH, 5.94% WEH) and 1 variety *KD-5-2-8* (7.20% DH, 6.82% WEH) reacted resistance, moderately resistance, moderately susceptible and susceptible in both the vegetative and reproductive stages, respectively (Table 6).

Two varieties *IR-64* (3.44% DH, 5.27% WEH) and *RCM-10* (3.65% DH, 5.53% WEH) were observed with moderately resistance reaction at vegetative stage, which turned into moderately susceptible reaction at reproductive stage whereas 2 varieties *Pariphou* (2.03% DH, 2.82% WEH) and *KD-Awangba* (1.73% DH and 2.67% WEH) were reacted moderately resistant at vegetative stage and turned resistant at heading stage. Similar, trends were also observed in case of *TN-1* and *WR-11-4-1* varieties which reacted highly susceptible at vegetative stage turned susceptible at reproductive stage (Table 6).

3.1 Pest status of *S. incertulas* in rainfed rice var. "Leimaphou (KD-2-6-3)"
The rice variety "Leimaphou (KD-2-6-3)" grown in experimental plots during the investigation recorded moderate incidence of all these three insect pests. The infestation due to *S. incertulas* was recorded to vary from 0.37 to 6.46% dead heart and 1.57 to 5.79% white ear head (Table 6).

3.2 Effect of certain new molecules and cow-urine plant extracts against *S. incertulas* in rainfed rice var. "Leimaphou (KD-2-6-3)"
Ten insecticidal treatments comprised of three new molecules *viz*., Thiaomethoxam 25 WG, Fipronil 80 WG and Lancergold 51.8 WP (combination), one conventional insecticide i.e Chlorpyriphos 20 EC, Spinosad 2.5 SC, one neem derivative i.e. Nimbecidine 0.03%, three plant extracts prepared with cow-urine *viz.*, *A. nilagirica*, J. *gossypifolia and M. azedarach* extracts and cow-urine alone was field evaluated against yellow stem borer (*S. incertulas*), in rice var. "Leimaphou (KD-2-6-3)". The test insecticides were applied three times as post transplanting treatment at 20 days interval commencing from the 20 days after transplanting (DAT). The findings of the experimentation on the effect of the insecticidal treatments on the infestation of the insect pest, yield and cost benefit ratio of the treatments are presented in the following paragraphs (Table 5).

3.3 Effect of certain new molecules and cow-urine plant extracts against *S. incertulas* during *Kharif*, 2020 and 2021, in rainfed rice var "Leimaphou (KD-2-6-3)"
The observation on *S. incertulas* recorded in different insecticidal treatments based on three times application on post transplanting revealed that all the treatments based on three times application on post transplanting revealed that all the treatments resulted in significant reduction of the yellow stem borer incidence over untreated control after the application of insecticide in both the experimental years (Table 4). However, cow-urine @ 500 l $ha^{-1}$was least effective as compared to the other remaining treatments.

3.4 Dead heart (DH) incidence recorded during first spray of insecticides
3.4.1 One day before application (1DBA)
The pre-treatment dead heart (DH) counts made at one day before application (1DBA) of first spray indicated that the percentage of DH was non-significantly varied from 1.05 to 2.11%, in various plots during 2020 and similar result was observed during 2021 with DH% varied from 1.06 to 2.88%. Therefore, the pooled mean data based on two years was also resulted with non-significant dead heart per cent in the various plots ranging from 1.15 to 2.38% (Table 4, 5).

3.4.2 Ten days after application (10 DAA)
The data recorded at 10 days after application (10 DAA) of first spray during the experimental year of 2010, on the incidence of *S. incrtulas* showed in Tables 4, 5, revealed that the dead heart (DH) incidence significantly differed ($p<0.05$) among the treatments. Untreated control plots recorded highest per cent dead heart (5.52% DH). The treatment with Fipronil 80 WG @ 50 g ha^{-1} was found to be most effective with minimum DH incidence of 1.55 per cent, closely followed by Thiamethoxam 25 WG @ 100 g ha^{-1} (1.88% DH) which was at par with the plots treated with Lancergold (Acephate 50% + Imidacloprid 1.8%) 51.8 WP @ 750 g ha^{-1} (2.12 per cent DH). The lower dead heart incidence of 2.24, 2.30, 2.34 per cent were observed in the treatments Chlorpyriphos 20 EC @ 1250 ml ha^{-1}, Spinosad 2.5 SC @ 2000 g ha^{-1}, Nimbicidine (Azadirachtin 0.03%) @ 2500 ml ha^{-1}, respectively and these three treatments were at par with each other. The tested three cow-urine and plant extracts *viz.*, J. *gossypifolia*, *M. azedarach* and *A. nilagirica* also resulted significantly lower ($p<0.05$) dead heart incidence against untreated control with 3.62, 3.73 and 3.98 per cent dead heart, respectively and they showed non-significant difference with each other (Table 4, 5).

During 2011, the dead heart (DH) incidence (Table 4, 5) of all the treated plots due to *S. incertulas* were also significantly ($p<0.05$) lower than that of the untreated control plots (6.66%). The lowest DH per cent was recorded from the plots treated with Fipronil 80 WG @ 50 g ha^{-1} (1.42%) and it was at par with Thiamethoxam 25 WG @ 100 g ha^{-1} (1.45%) closely followed by Lancergold (Acephate 50% + Imidacloprid 1.8%) 51.8 WP @ 750 g ha^{-1} (1.98%), Chlorpyriphos 20 EC @ 1250 ml ha^{-1} (2.24 per cent) and Spinosad 2.5 SC @ 2000 g ha^{-1} (2.56% DH). On the other hand, the plots treated with Nimbicidine (Azadirachtin 0.03%) @ 2500 ml ha^{-1} (3.63% DH) showed non-significant difference with cow-urine + *J. gossypifolia*, cow-urine + *M. azedarach* @ 15000 ml ha^{-1} with 3.76 and 3.79%, respectively. Whereas, the plots treated with cow-urine + *A. nilagirica* extracts @ 15000 ml ha^{-1} recorded 4.25% DH. While, the plots received cow-urine alone @ 15000 ml ha^{-1} (5.65% DH) was found to be significantly higher ($p<0.05$) DH incidence than the other treatments (Table 4, 5).

The pooled mean data based on two years presented in (Table 4, 5), further indicated that Fipronil 80 WG @ 50 g ha^{-1} and Thiamethoxam 25 WG @ 100 g ha^{-1} proved to be the most effective insecticidal treatments in reducing dead heart incidence with a record of 1.48 and 1.66%, respectively as against 6.09% in untreated control. These two insecticides were closely followed by Lancergold 51.8 WP @ 750 g ha^{-1} and Chlorpyriphos 20 EC @ 1250 ml ha^{-1} recorded the mean DH 2.05 and 2.24%, respectively but did not differ significantly from each other. The three plant extracts (*A. nilagirica*, *M. azedarach* and *J. gossypifolia* each applied @ 15000 ml ha^{-1}) with cow-urine treatments showed non-significant effect with each other and were found to be least effective treatment against *S. incertulas* which witnessed maximum percentage of dead heart incidence of 4.12, 3.76 and 3.69%, respectively. The plots treated with cow-urine alone recorded 5.26% dead heart. However, all the insecticidal treatments recorded significantly ($p<0.05$) lower dead heart incidence compared to untreated control (Table 4, 5).

3.5 DH incidence recorded during second spray of insecticides

3.5.1. One day before application (1 DBA)

The observation on *S. incertulas* incidence recorded in different insecticidal treatments based on one day before second spray revealed that all the treatments resulted significant ($p<0.05$) reduction of dead heart incidence over untreated control in both the experimental years. According to the data of 2020 (Table 4, 5), Fipronil 80 WG @ 50 g ha^{-1} and Thiamethoxam 25 WG @ 100 g ha^{-1} proved to be the most effective insecticidal treatments in reducing dead heart incidence with a record of 1.62 and 1.80 per cent, respectively as against 7.11% in untreated control, followed by Lancergold 51.8 WP @ 750 g ha^{-1} and Chlorpyriphos 20 EC @ 1250 ml ha^{-1} which showed 1.95 and 2.05% dead heart incidence and these two treatments indicated non-significant effect with Thiamethoxam 25 WG@ 100 g ha^{-1} (Table 4, 5).

Again the plots treated with Spinosad 2.5 SC @ 2000 g ha^{-1} recorded 2.28% dead heart which was at par with the plots treated with Lancergold 51.8 WP @ 750 g ha^{-1} and Chlorpyriphos 20 EC @ 1250 ml ha^{-1}. The highest DH incidence (5.74%) was exhibited from the plots treated with cow-urine alone @ 500 l ha^{-1} which showed significant difference from other insecticidal treatments whereas 4.46% dead heart was exhibited by the plots treated with cow-urine + *A. nilagirica* extract @ 15000 ml ha^{-1}. This treatment showed non-significant effect with rest cow-urine plant extracts i.e. *M. azedarach* and *J. gossypifolia* having 4.35 and 4.31% dead heart, respectively (Table 4, 5).

A similar trend for Fipronil 80 WG @ 50 g ha^{-1} and Thiamethoxam 25 WG @ 100 g ha^{-1} was also observed during *Kharif*, 2021 recording lower mean DH incidence of 1.32 and 1.40%, respectively with non-significant difference from each other (Table 4, 5). The highest DH incidence (4.90%) was observed from cow-urine alone treated plots, followed by the plots treated with cow-urine + *A. nilagirica* extract (4.31%). And all the insecticidal treatments were recorded significantly lower dead heart per cent as against untreated control (5.80%) (Table 4, 5).

The pooled mean incidence data (Table 4, 5) indicated that all the insecticidal treatments varied from 1.47 to 5.32% dead heart incidence which was significantly ($p<0.05$) lower than that of the untreated control plots with a record of 6.46 per cent incidence. The minimum DH incidence of 1.47 and 1.60% were observed in the plots treated with Fipronil 80 WG @ 50 g ha^{-1} and Thiamethoxam 25 WG @ 100 g ha^{-1}, both the treatments were at par with each other which was closely followed by Lancergold 51.8 WP @ 750 g ha^{-1} and Chlorpyriphos 20 EC @ 1250 ml ha^{-1} with 1.86 and 2.14% DH, respectively. Whereas, the maximum incidence of dead heart (5.32 per cent) was marked in the plots treated with cow-urine alone which was significantly differ from the other three cow-urine plant extract treatments (*A. nilagirica* with 4.39%, *M. azedarach* with 4.29% and *J. gossypifolia* with 4.18%) and they had non-significant difference from each other (Table 4, 5).

3.5.2 Ten days after application (10 DAA)

During the experimental period of *Kharif*, 2020 (Table 4, 5), it was recorded that all the tested treatments were significantly superior in controlling yellow stem borer infestation as compared to the untreated control (3.89% DH). However, the Fipronil 80 WG @ 50 g ha^{-1} treated plots was recorded the minimum dead heart incidence with 0.76% which was at par with Thiamethoxam 25 WG @ 100 g ha^{-1} (0.83%). The lowest stem borer incidence was also noticed in the Lancergold 51.8 WP @ 750 g ha^{-1} and Chlorpyriphos 20 EC @ 1250 ml ha^{-1} with 0.88 and 1.16%. While, the maximum yellow stem borer incidence (2.35%) was recorded in cow-urine treatment followed by the plots treated with cow-urine plant extracts with a record of 1.71, 1.63 and 1.56% DH and they showed non-significant effect (Table 4, 5).

Again, it was evident from the data of *Kharif*, 2011, presented in Table 4.5 and illustrated in Fig. 4.3, that the dead heart incidence was gradually declined with the maximum DH per cent recorded from the cow-urine + *A. nilagirica* extract @ 15000 ml ha^{-1} which was significantly ($p<0.05$) inferior from the other two plant extracts *viz.*, cow-urine + *M. azedarach* @15000 ml ha^{-1} (2.80%) and cow-urine + *J. gossypifolia* (2.60%). The minimum DH incidence was recorded from Fipronil 80 WG @ 50 g ha^{-1} (1.12%) treated plots, which was at par with Thaomethoxam 25 WG @ 100 g ha^{-1} (1.18% DH). DH incidences in other insecticidal treatments were varied from 1.71% to 2.18%. All these treatments were significantly superior in controlling yellow stem borer infestation as compared with the untreated control (Table 4, 5).

The pooled mean data based on two years (Table 4, 5) revealed that the lowest dead heart incidence was observed in Fipronil 80 WG @ 50 g ha^{-1} (0.94%) treatment, closely followed by Thiamethoxam 25 WG @ 100 g ha^{-1} (1.00%) and these two treatments were not significantly differ from each other. On the other hand, cow-urine alone @ 500 l ha^{-1} recorded highest dead heart% of 3.03. Other treatments were ranged from 1.30 to 2.50% dead heart incidence. However, all these treatments were significantly superior ($p<0.05$) from the untreated control plots (4.89%) (Table 4, 5).

3.6 DH incidence recorded during third spray of insecticides

3.6.1 One Day before application (1DBA)

In all the treatments during 2020 (Table 4, 5), the magnitude of incidence under different treatments ranged from 0.46 to 2.00% dead heart. Least pest infestation with a record of 0.46 per cent DH incidence was recorded in the plots of Fipronil 80 WG @ 50 g ha^{-1}. Thiamethoxam 25 WG @ 100 g ha^{-1} ranked next to Fipronil 80 WG resulting 0.63% incidence, followed by Lancergold 51.8 WP @ 750 g ha^{-1}, Chlorpyriphos 20 EC @ 1250 ml ha^{-1} and Spinosad 2.5 SC @ 2000 g ha^{-1} recording 0.77, 0.85 and 0.89%, respectively. In order of effectiveness, Nimbecidine @ 2500 ml ha^{-1}, cow-urine + *J. gossypifolia* extract @ 15000 ml ha^{-1}, cow-urine + *M. azedarach* extract @ 15000 ml ha^{-1} and cow-urine + *A. nilagirica* extract @ 15000 ml ha^{-1} and cow-urine alone @ 500 l ha^{-1}. Application of cow-urine alone and cow-urine plant extract formulation resulted in maximum range of infestation, but it was significantly superior to the plots of no pesticide application (2.79%) (Table 4, 5).
Same trend was observed during 2011 (Table 4, 5) also where the dead heart per cent was varied from 0.97 to 3.78% in which the highest incidence was recorded in cow-urine alone @ 500 l ha^{-1} (3.78%), followed by cow-urine + *A. nilagirica* extract @ 15000 ml ha^{-1} (3.01 per cent) and the lowest in the plots of Fepronil 80 WG @ 50 g ha^{-1} (0.97%) as against the untreated control (4.74% DH). Based on two years mean the highest incidence was recorded in the plots treated with cow-urine @ 500 l ha^{-1} where 2.89% dead heart was recorded followed by cow-urine + *A. nilagirica* extract @ 15000 ml ha^{-1} afforded 2.30% DH incidence. Lowest incidence was observed in Fipronil 80 WG @ 50 g ha^{-1} treated plots (0.71%) as against untreated control plots (3.77%) which was significantly ($p<0.05$) higher than all the insecticides treated plots (Table 4, 5).

3.6.2 Ten days after application (10 DAA)

During 2020, the incidence per cent of dead heart at 10 DAA was declined in all the treatments. However, all the insecticides treated plots were significantly ($p<0.05$) lower than that of untreated control plots in which the dead heart per cent was ranged from 0.42 to 2.25 as against untreated control (2.99%). The minimum DH% was recorded in the plots of Fipronil 80 WG @ 50 g ha^{-1} whereas maximum was marked from cow-urine alone applied plots (Table 4, 5). Again it was evident from the data of *Kharif*, 2021, presented in Table 4, 5, that untreated control plots recorded highest ($p<0.05$) dead heart incidence of 4.39% which was significantly higher ($p<0.05$) than that of all the insecticides treated plots in the study. The insecticides treated plots were varied from 2.52 to 0.31% dead heart incidence in which minimum was recorded in Fipronil 80 WG @ 50 g ha^{-1} and maximum in the treatment of cow-urine alone @ 500 ml ha^{-1} (Table 4, 5).
The pooled mean data based on two years (Table 4, 5 and Fig.1) on the incidence of *S. incertulas* revealed that the mean dead heart (DH) incidence significantly differed ($p<0.05$) among the treatments throughout the experimental period where the untreated control plots recorded 3.69 per cent dead heart. The treatment with Fipronil 80 WG @ 50 g ha^{-1} was found to be most effective with minimum DH incidence of 0.37 per cent which was closely followed by the treatments with Thiamethoxam 25 WG @ 100 g ha^{-1}, Lancergold 51.8 WP @ 750 g ha^{-1}and Chlorpyriphos 20 EC @ 1250 ml ha^{-1} with 0.46, 0.73 and 0.85 per cent, respectively which differed significantly ($p<0.05$) from each other. The maximum DH incidence was noticed in the plots treated with cow-urine @ 500 l ha^{-1} (2.39 per cent), followed by the plots treated with cow-urine + plant extract @ 15000 ml ha^{-1} that afforded 1.95 per cent, 1.52 per cent and 1.38 per cent, respectively. The rest two treatments *viz*., Nimbecidine @ 2500 ml ha^{-1} and Spinosad 2.5 SC @ 2000 g ha^{-1} were also showed inferior in reducing the dead heart incidence and each recording the mean DH of 1.03 and 0.92 per cent, respectively in compared with Fipronil 80 WG @ 50 g ha^{-1}, Thiamethoxam 25 WG @ 100 g ha^{-1}, Lancergold 51.8 WP @ 750 g ha^{-1} and Chlorpyriphos 20 EC @ 1250 ml ha^{-1} but superior to the other three cow-urine + plant extracts.

3.7 WEH incidence

During 2020 (Table.4, 5 and Fig. 1), the white ear head incidence was recorded at 90 DAT in which the lowest WEH incidence (2.64%) was recorded in the plots treated with Fipronil 80 WG @ 50 g ha^{-1} as against the untreated control (7.46%), followed by the plots treated with Thiamethoxam 25 WG @ 100 g ha^{-1} (3.01% WEH). The WEH incidence per cent of 3.41, 3.42, 3.47 and 3.57 were marked in the plots treated with Lancergold 51.8 WP @ 750 g ha^{-1} and Chlorpyriphos 20 EC @ 1250 ml ha^{-1}, Spinosad 2.5 SC @ 2000 g ha^{-1} and Nimbecidine @ 2500 ml ha^{-1} which showed non-significant difference between them and they were significantly higher than ($p<0.05$) that of Thiamethoxam 25 WG @ 100 g ha^{-1} treated plots. On the other hand, the maximum WEH incidence was reported from the treatment of cow-urine alone @ 500 l ha^{-1} (5.28% DH), followed by cow-urine + *A. nilagirica* extract @ 15000 ml ha^{-1}, cow-urine + *M. azedarach* extract @ 15000 ml ha^{-1} and cow-urine + *J. gossypifolia* extract @ 15000 ml ha^{-1} with a record of 4.63, 3.91 and 3.75% incidence, respectively and these three treatments were non-significant difference with each other (Table 4, 5, 6).
The mean data on incidence of WEH recorded during *Kharif*, 2011 (Table 4, 5) also indicated that Fipronil 80 WG @ 50 g ha^{-1}, Thiamethoxam 25 WG @ 100 g ha^{-1}, Lancergold 51.8 WP @ 750 g ha^{-1} and Chlorpyriphos 20 EC @ 1250 ml ha^{-1} showed their effectiveness in suppression of YSB with lower WEH incidence of 0.50, 0.99, 1.39 and 1.76%, respectively as against 4.12% in untreated control which showed significant difference ($p<0.05$) from rest of the insecticidal treatments. The WEH incidence recorded in the rest of the insecticidal treatments were varied from 2.17 to 3.34% with maximum being exhibited from cow-urine alone @ 500 l ha^{-1}.
The pooled mean data based on two years revealed that the lowest WEH incidence (1.57 per cent) was recorded in the plots treated with Fipronil 80 WG @ 50 g ha^{-1} as against the untreated control (5.79 per cent), followed by the plots treated with Thiamethoxam 25 WG @ 100 g ha^{-1} (2.00 per cent WEH). The WEH incidence per cent of 2.40, 2.59, 2.82 and 2.94 were marked from the plots treated with Lancergold 51.8 WP @ 750 g ha^{-1}, Chlorpyriphos 20 EC @ 1250 ml ha^{-1},

Spinosad 2.5 SC @ 2000 g ha^{-1} and Nimbecidine @ 2500 ml ha^{-1}, respectively and showed significantly higher than ($p<0.05$) that of the cow-urine and plant extracts @ 15000 ml ha^{-1} treatments. The maximum incidence was marked on the plot treated with cow-urine alone @ 500 l ha^{-1} (4.31% WEH) but significantly superior than the untreated control (Table 4, 5, 6).

3.8 Mean effectiveness of the insecticidal treatments to the yellow stem borer infestation based on two years data (2020-2021).

The mean of two years' infestation data (pooled data) presented in (Table 4, 5) and illustrated in Fig. 1, the mean DH incidence significantly differed ($p<0.05$) among the treatments at 1 DBA and 10 DAA of three sprays and WEH at 90 DAT in both the experimental years. Untreated control plots recorded 3.90 and 4.91 per cent dead heart infestation during *Kharif*, 2020 and 2011, respectively. During 2010, Fipronil 80 WG @ 50 g ha^{-1} treatment was found to be most effective with minimum DH incidence of 1.13% and was closely followed by Thiamethoxam 25 WG @ 100 g ha^{-1} (1.30%) and Lancergold 51.8 WP @ 750 g ha^{-1} (1.27%), which showed non-significant difference from each other. Similarly, during *Kharif* season of 2011 also, Fipronil 80 WG @ 50 g ha^{-1} treatment maintained the most effective treatment with 1.0 4% incidence, followed by Thiamethoxam 25 WG @ 100 g ha^{-1} treatment (1.27%) and Lancergold 51.8 WP @ 750 g ha^{-1} treatment (1.52%) and there were no significant difference between them (Table 4, 5).

Table 1: Details of the insecticidal treatments:

Sl. No.	Dose	Treatment Detail
T_1	15000 ml ha^{-1}	Cow-urine + *Artemisia nilagirica* extract
T_2	15000 ml ha^{-1}	Cow-urine + *Jatropha gossypifolia* extract
T_3	15000 ml ha^{-1}	Cow-urine + *Melia azedarach* extract
T_4	500 l ha^{-1}	Cow-urine
T_5	2500 ml ha^{-1}	Nimbecidine (Azadirachtin) 0.03%
T_6	2000 g ha^{-1}	Spinosad 2.5 SC
T_7	1250 ml ha^{-1}	Chlorpyriphos 20 EC
T_8	100g ha^{-1}	Thiamethoxam 25 WG
T_9	50 g ha^{-1}	Fipronil 80 WG
T_{10}	750 g ha^{-1}	Lancergold 51.8 WP (Acephate 50% + Imidacloprid 1.8%)
T_0	500 l ha^{-1}	Untreated control (Water)

Table 2: List of indigenous plant species evaluated in the present experiment against *S. incertulas* on rainfed rice var. 'Leimaphou (KD-2-3-6)'

Sl. No	Common Name	Scientific Name	Local Name	Family	Plant part use
1	Indian worm wood	*Artemisia nilagirica* (C.B. Clarke) Pamp.	*Leibakngou*	Compositae	Leaves
2	Jatropha	*Jatropha gossypifolia* L.	*Kege-manbi*	Euphorbitaceae	Leaves
3	China Tree	*Melia azedarach* L.	*Seijarak*	Meliaceae	Seed kernel

Table 3: List of insecticides evaluated in the present experiment against *S. incertulas* on rainfed rice

Sl. No	Insecticide	Chemical/Active principle				
		IUPAC Name	Chemical formula	Trade name and formulation	Dose	Manufacturing/ Formulating company
1	Nimbecidine (Azadirachtin 0.03%)	Dimethyl (2a*R*, 3*S*, 4*S*, *R*, *S*, 7a*S*, 8*S*, 10*R*, 10a*S*, 10b*R*)-10-(acetyloxy)-3, 5-dihydroxy-4-[(1*S*, 2*S*, 6*S*, 8*S*, 9*R*, 11*S*)-2-hydroxy-11-methyl-5, 7, 10-trioxatetracyclo[6.3.1.0^{2,6}.0^{9,11}] dodec-3-en-9-yl]-4-methyl-8-{[(2*E*)-2-methylbut-2-enoyl]oxy}octahydro-1*H*-furo[3', 4':4, 4a]naphtho [1, 8-*bc*]furan-5, 10a(8*H*)-dicarboxylate	$C_{35}H_{44}O_{16}$	Nimbecidine EC 0.03%	2500 ml ha^{-1}	T.Stanes &Company Ltd.
2	Spinosad 2.5 SC	*Sccharopolyspora spinosa*	$C_{41}H_{65}NO_{10}$ (A) $C_{42}H_{67}NO_{10}$ (D)	Success 2.5 SC	2000 g ha^{-1}	Dow Agro Sciences, Maharastra
3	Chlorpyriphos 20 EC	o,o-diethyl o- (3, 5, 6- trichloro-2-pyridyl) phosphorothiote	$C_{19}H_{11}Cl_{13}No_3sps$	Chlorovip 20 EC	1250 ml ha^{-1}	Godrej Agrovet Ltd. Highway, Vikhroli (E)Mumbai, Maharastra
	New molecule insecticides					
4	Thiamethoxam 25 WG	3-[(2-Chloro-1,3-thiazol-5-yl) methyl]-5-methyl-N-nitro-1,3,5- Oxadiazinan-4-im	$C_8H_{10}ClN_5O_3S$	Maxima 25WG	100g ha^{-1}	PI Agri Input, Gujarat
5	Fipronil 80 WG	(RS)-5-amino-1-[2, 6-dichloro-4-(trifluoromethyl) phenyl]-4-(trifluoromethylsulfinyl)-1H-pyrazole-3-carbonitrile	$C_{12}H_4Cl_2F_6N_4OS$	Jump 80 WG	50 g ha^{-1}	Bayer Crop Science Ltd. Mumbai
6	Lncergold (Acephate 50% + Imidacloprid 1.8 SP)	*N*-(Methoxy-methylsulfanylphosphoryl)acetamide *N*-{1-[(6-Chloro-3-pyridyl)methyl]-4, 5-dihydroimidazol-2-yl}nitramide	$C_4H_{10}NO_3PS$ $C_9H_{10}ClN_5O_2$	Lncergold 51.8 WP	750 g ha^{-1}	United Phosphrous Ltd.Gujarat

Table 4: Efficacy of certain new molecules and cow-urine plant extracts against *S. incertulas* during *Kharif*, season of 2020 and 2021 (Based on pooled mean data of two years) on rainfed rice var. "Leimaphou (KD-2-6-3)".

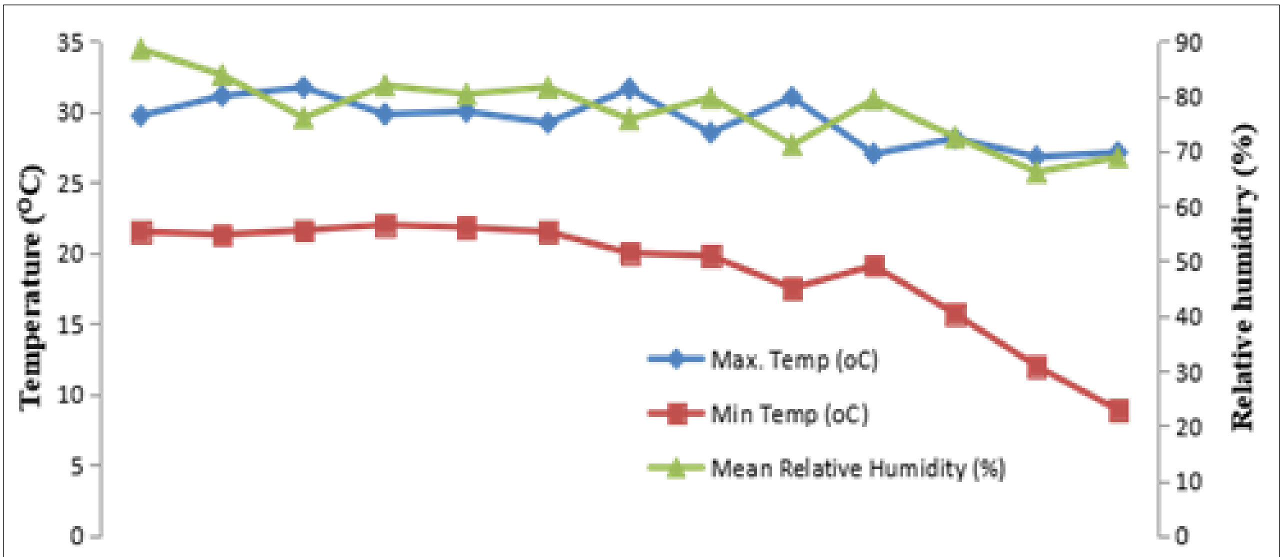
Treatments		Dose	DH%						Mean	WEH% at 90 DAT
			1st Spray at 20 DAT		2nd Spray at 35 DAT		3rd Spray at 50 DAT			
			1DBA	10 DAA	1 DBA	10 DAA	1 DBA	10 DAA		
T_1	Cow-urine + *A. nilagirica* extract	15000 ml ha^{-1}	1.83 (7.62)	4.12 (11.68)	4.39 (12.11)	2.50 (9.05)	2.30 (8.62)	1.95 (8.02)	2.85 (9.52)	3.70 (11.06)
T_2	Cow-urine + *J. gossypifolia* extract	15000 ml ha^{-1}	1.93 (7.97)	3.69 (11.09)	4.18 (11.80)	2.08 (8.23)	1.79 (7.56)	1.38 (6.73)	2.51 (8.89)	3.22 (10.30)
T_3	Cow-urine +*M. azedarach* extract	15000 ml ha^{-1}	1.88 (7.87)	3.76 (11.18)	4.29 (11.99)	2.22 (8.52)	2.03 (8.16)	1.52 (7.04)	2.61 (9.13)	3.33 (10.51)
T_4	Cow-urine	500 l ha^{-1}	1.59 (7.20)	5.26 (13.30)	5.32 (13.34)	3.03 (9.94)	2.89 (9.66)	2.39 (8.88)	3.41 (10.39)	4.31 (11.91)
T_5	Nimbecidine (azadirachtin 0.03%)	2500 ml ha^{-1}	1.15 (5.58)	2.99 (9.94)	3.57 (10.89)	1.71 (7.41)	1.61 (7.22)	1.03 (5.89)	2.01 (7.82)	2.94 (9.81)
T_6	Spinosad 2.5 SC	2000 g ha^{-1}	2.38 (8.57)	2.43 (8.94)	2.38 (8.84)	1.62 (7.21)	1.31 (6.49)	0.92 (5.53)	1.84 (7.60)	2.82 (9.60)
T_7	Chlorpyriphos 20 EC	1250 ml ha^{-1}	1.49 (6.90)	2.24 (8.62)	2.14 (8.39)	1.53 (7.01)	1.20 (6.20)	0.85 (5.30)	1.57 (7.07)	2.59 (9.16)
T_8	Thiamethoxam 25 WG	100g ha^{-1}	2.01 (8.12)	1.66 (7.35)	1.60 (7.23)	1.00 (5.71)	0.94 (5.47)	0.46 (3.89)	1.28 (6.30)	2.00 (7.88)
T_9	Fipronil 80 WG	50 g ha^{-1}	1.53 (7.00)	1.48 (6.98)	1.47 (6.91)	0.94 (5.57)	0.71 (4.80)	0.37 (3.45)	1.09 (5.78)	1.57 (6.73)
T_{10}	Lancergold 51.8 WP (Acephate50%+Imidacloprid 1.8%)	750 g ha^{-1}	1.35 (6.52)	2.05 (8.19)	1.86 (7.84)	1.30 (6.47)	1.08 (5.92)	0.73 (4.89)	1.39 (6.64)	2.40 (8.74)
T_0	Untreated Control (Water)	500 l ha^{-1}	1.53 (7.04)	6.09 (14.28)	6.46 (14.72)	4.89 (12.72)	3.77 (11.12)	3.69 (11.02)	4.40 (11.82)	5.79 (13.78)
	SE(m) ±		0.68	0.27	0.26	0.20	0.11	0.10	0.61	0.13
	CD(p<0.05)		1.43	0.56	0.54	0.42	0.23	0.20	1.22	0.27

Figures in parentheses are angular transformed values
**DH-Dead heart; WEH-White ear head; DBA= Days before application, DAA= Days after application, DAT = Days after transplanting

Table 5: Screening of certain locally available improved varieties for their resistance reaction against *S. incertulas* during *Kharif*, 2020-2021 (based on two years pooled data)

Variety		Percentage Dead Heart (DH) incidence at								Percentage White Ear Head incidence at			
		20 DAT	30 DAT	50 DAT	70 DAT	MEAN	D-value	Damage score	Rating	90 DAT	D-value	Damage score	Rating
V_1=	RCM-9	1.93(1.56)	2.34(1.68)	2.77(1.81)	4.98(2.34)	3.01(1.85)	33.41	3	MR	4.82(2.31)	58.71	3	MR
V_2=	Leimaphou	0.51(1.00)	1.74(1.49)	0.59(1.05)	1.73(1.49)	1.14(1.26)	11.56	1	R	2.12(1.62)	26.47	1	R
V_3=	Pushiphou	2.91(1.85)	2.92(1.84)	4.72(2.28)	7.18(2.77)	4.43(2.19)	50.46	5	MS	6.48(2.64)	71.53	5	MS
V_4=	Matamphou	5.03(2.35)	4.55(1.48)	7.48(2.82)	13.35(3.72)	7.60(2.79)	82.27	9	HS	6.98(2.74)	86.24	7	S
V_5=	IR- 64	2.39(1.70)	2.54(1.74)	3.29(1.95)	5.55(2.46)	3.44(1.96)	38.33	3	MR	5.27(2.40)	62.12	5	MS
V_6=	Phouoibiphou	0.48(0.99)	1.69(2.61)	0.49(0.99)	1.42(1.38)	1.02(1.21)	10.30	1	R	1.31(1.34)	16.48	0	ND
V_7=	WR –11-4	1.51(1.42)	2.12(1.62)	1.73(1.49)	3.77(2.07)	2.28(1.65)	27.57	3	MR	3.39(1.97)	43.88	3	MR
V_8=	Ereimaphou	3.50(2.00)	3.13(2.25)	5.66(2.48)	9.46(3.16)	5.44(2.39)	59.50	5	MS	6.18(2.58)	73.53	5	MS
V_9=	Sanaphou	1.64(1.46)	2.34(1.90)	2.51(1.73)	4.43(2.22)	2.73(1.78)	30.32	3	MR	4.32(2.19)	55.06	3	MR
V_{10}=	CAUS-1	2.87(1.83)	2.79(1.68)	4.32(2.19)	6.17(2.58)	4.04(2.11)	46.68	5	MS	5.94(2.54)	70.59	5	
V_{11}=	Pariphou	1.34(1.36)	2.10(1.81)	1.62(1.45)	3.06(1.89)	2.03(1.58)	23.57	3	MR	2.82(1.82)	33.53	1	R
V_{12}=	WR-1-9-1-1	1.58(1.44)	2.30(1.60)	2.35(1.69)	4.31(2.19)	2.64(1.75)	29.18	3	MR	3.63(2.03)	46.82	3	MR
V_{13}=	RCM-10	2.45(1.72)	2.75(1.67)	3.73(2.05)	5.65(2.48)	3.65(2.01)	39.59	3	MR	5.53(2.46)	64.47	5	MS
V_{14}=	WR -2-3-1	2.09(1.61)	2.43(1.80)	3.08(1.89)	5.33(2.41)	3.23(1.91)	36.50	3	MR	5.20(2.38)	60.46	3	MR
V_{15}=	Akutphou	4.62(2.26)	3.88(1.71)	7.28(2.79)	13.01(3.68)	7.20(2.71)	76.55	7	S	6.82(2.71)	84.71	7	S
V_{16}=	Tamphaphou	0.66(1.07)	1.82(2.09)	0.88(1.17)	1.94(1.56)	1.33(1.33)	14.42	1	R	2.27(1.66)	26.94	1	R
V_{17}=	Ginphou	4.38(2.21)	3.42(1.52)	6.62(2.67)	11.74(3.50)	6.54(2.59)	69.57	7	S	6.35(2.62)	73.53	5	MS
V_{18}=	KD-Awangba	1.25(1.32)	1.97(1.98)	1.21(1.31)	2.47(1.72)	1.73(1.48)	21.17	3	MR	2.67(1.78)	33.53	1	R
V_{19}=	TN – 1 (Check)	6.81(2.70)	6.31(1.57)	9.69(3.19)	14.79(3.91)	9.40(3.10)	100.00	9	HS	7.70(2.86)	100.00	7	S
SE(m) ±		0.06	0.16	0.07	0.05	0.16				0.05			
CD(P<0.05)		0.11	0.31	0.14	0.10	0.32				0.10			

Figure in parentheses are √X+0.5 transformed values, DAT = Days after transplanting; D= Adjusted damaged rating
*ND=No Damage; R= Resistant; MR= Moderately Resistant; MS= Moderately Susceptible; S= Susceptible and HS= Highly Susceptible



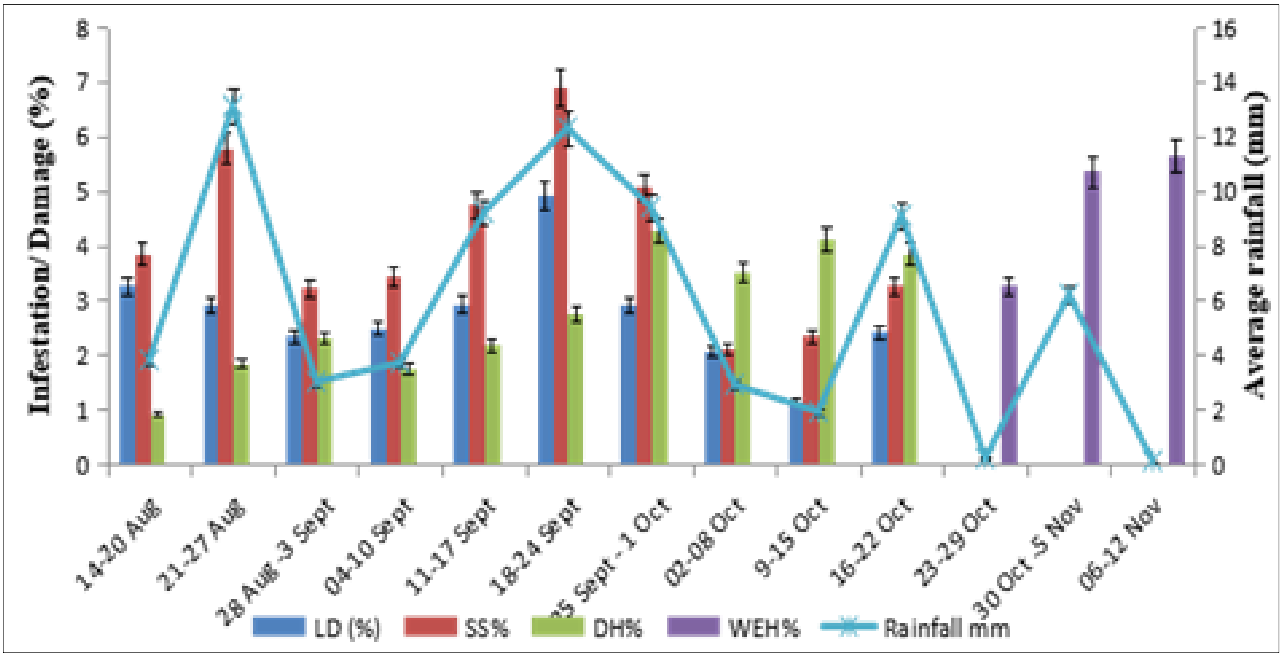


Fig 1: Graphical representation of the effect of abiotic factors on *S. incertulas* on rice var. "Leimaphou (KD-2-6-3)" during *Kharif*, 2020 and 2021 (based on two years pooled mean data)

Table 6: Effect of planting dates on rice var. "Leimaphou (KD-2-6-3)"on the incidence of *S. incertulas* during *Kharif*, 2020 and 2021 (based on two year pooled data)

	Planting date	DH (%)			Mean	WEH (%)
		30 DAT	50 DAT	70 DAT		90 DAT
Early planting	16th May	0.12 (0.78)	1.74 (1.49)	1.48 (1.40)	1.11 (1.23)	0.67 (1.03)
Early planting	31st May	0.52 (0.97)	2.21 (1.64)	2.33 (1.68)	1.65 (1.42)	1.75 (1.49)
Medium planting	15th June	2.19 (1.64)	3.61 (2.03)	2.66 (1.77)	2.82 (1.81)	2.82 (1.82)
Medium planting	30th June	2.63 (1.77)	4.71 (2.28)	3.31 (1.95)	3.55 (2.00)	4.75 (2.29)
Late planting	15th July	6.14 (2.57)	8.53 (3.00)	6.01 (2.55)	6.90 (2.71)	8.39 (2.97)
Late planting	30th July	8.31 (2.96)	10.75 (3.35)	7.53 (2.83)	8.86 (3.05)	10.72 (3.35)
Very late planting	14thAugust	9.76 (3.20)	13.72 (3.77)	11.45 (3.45)	11.64 (3.48)	11.71 (3.49)
	SE(m) ±	0.06	0.04	0.03	0.13	0.04
	CD(P<0.05)	0.14	0.12	0.07	0.29	0.09

Figure in parentheses are √X+0.5 transformed values
** DAT = Days after transplanting, DH = Dead heart and WEH = White ear head

4. Conclusion

Yellow stem borer is one of the most severe pests of rice cultivars in Manipur. Its management practices are very challenging. So, the findings of the present research programme will contribute one of the most valuable control measures of this pest for researchers as well as for the farmers in the future.

5. Author's contribution

ISK designed the study and under his supervision JT, RT and SSS conducted the investigation with field experiments and data analysis. SKP and JT drafted the manuscript and was revised by RT, SSS and ISK. All the authors read the final draft and approved the manuscript.

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7. Conflict of Interests

The authors confirm that they have no conflict of interest with respect to work described in this manuscript.

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