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Research Article

Abundance and Infestation of Rice Stem Borer in North Malaysia

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ABSTRACT

The abundance and infestation of rice stem borer were monitored in MADA regions with the influence of weather parameters. The determination of the rice stem borer percentage infestation was recorded by dead heart (DH) and whitehead (WH) symptoms. In four regions of MADA area observations, a higher infestation of rice stem borer was observed during rice planting season one (7.1%) compared to rice planting season two (3.9%) on average. Both damage symptoms of the rice stem borer, DH, and WH were observed higher during the rice planting season one. The highest infestation of rice stem borer during season one was observed in Pendang with 18.60%. From the weather parameters recorded, a high infestation of rice stem borer occurred at 80.0% (RHmax), 8.2 °C of temperature differences (Tdiff), and a lower amount of rainfall (0.6 mm). The high infestation in Pendang in season one was influenced by the lower value of RH, higher range of temperature, and lower amount of rainfall compared to season two. *Chilo polychrysus* was the most abundant species of rice stem borer found in Region 1 and *Scirpophaga incertulas* were abundantly found in Region 2, 3, and 4.

Key words: *Chilo polychrysus*, MADA, Rice pest, *Scirpophaga incertulas*, weather influence

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INTRODUCTION

The stem borer is one of the major insect pests of rice in Asia. As reported by Noorazura (2019), it has caused serious damage to the paddy fields and affected more than 70 percent of the farmers' income during the planting season. The situation once caused the farmers to incur debt due to exceeding the production cost. The infestation of the rice stem borer drastically increased at the beginning of 2017 compared to previous years which was reported to constantly infest the rice field (Emi Faizal, 2019). In 2018, the infestation intensity was 30.30% which involved 7933.76 ha of damaged acreage (Emi Faizal, 2019). Under field conditions, heavy stem borer infestations can cause rice grain yield losses of up to 80% (January *et al*., 2020). However, the abundance, distribution, and damage caused by these stem borer species differ between various stages of crop development, climatic factors, and the geographic location of the rice field (Leonard, 2015).

The damage by rice stem borers has been detected in different growth stages ranging from seedlings to adult rice plants, especially caused by yellow stem borers (Dale, 1994; Hamsein *et al*., 2020). Stem borers can destroy rice at any stage of the plant from seedling to maturity. They feed upon tillers and cause dead hearts or drying of the central tiller, during the vegetative stage; and cause whiteheads at the reproductive stage (Shamik, 2020). The damaged stem is due to the feeding behavior of the rice stem borer larvae has prevented the movement of nutrients from root to leaf (Muralidharan & Pasalu, 2006). As the result, the central

tillers of the paddy seedlings became dry and died or called the dead heart (DH) during the vegetative phase. On the other hand, the panicles become unfilled or known as whiteheads (WH) at the reproductive stage (Bandong & Litsinger, 2005). The severity level of rice stem borer infestation at different stage of paddy plants give a different result to the yield (Pallavi *et al*., 2017). The infestation at the vegetative stage with DH damage lower than 30% could be recovered because it was not affected the yield directly (Rubia *et al*. 1990). However, the yield loss was almost proportional to the WH in the reproductive stage of rice where yield loss was as much as 1-3% higher than the percentage of the whitehead (Suharto & Usyati, 2005).

Other than crop development, biotic and abiotic factors are the causes of the fluctuation of insect population dynamics (Singh *et al*., 2009). The factors such as temperature, rainfall, and relative humidity are the abiotic factors in the insect population outbreak (Heong *et al*., 2007; Hussain *et al*., 2018). Rice stem borer population dynamics are subject to change depending on the dynamic state of its environment (Khaliq, 2014).

In Malaysia, there were four common species of rice stem borer recorded that infesting the rice fields (Gumbek & Hamsein, 2011; Nik Mohd Noor *et al*., 2012). They were yellow-stem borer (*Scirpophaga incertulas*), black-headed stem borer (*Chilo polychrysus*), pink-stem borer (*Sesamia inferens*), and striped stem borer (*Chilo suppressalis*). The rice stem borer species did not assemble in one location and may generate varying levels of infestation. Understanding that, seasonal abundance and population growth trends is essential for timely preparation to deal with threatening pest problems and prevent crop losses (Das *et al*., 2008). The abundance and distribution of rice stem borer species at the specific geographic location provided proper management to the insect pest (Arbab, 2014). Therefore the objective of this study is to determine the abundance of rice stem borer in selected localities of north Peninsular Malaysia, focusing on the damage symptoms in different rice planting seasons.

MATERIALS AND METHODS

Sampling sites

Rice stem borer incidence was recorded in four districts in MADA areas for two rice planting seasons (Figure 1). The first sampling session started in season one (Season 1/2019) which began from June to September 2019 and the second sampling session two (season 2/2019) started from November 2019 until February 2020. The sampling areas followed the regions divided geographically by MADA (Muda Agricultural Development Authority, 2021) where four regions were stated. The regions were divided into Region 1, Region 2, Region 3, and Region 4 which involved several districts (Table 1). From the four regions, ten districts were selected and each district had three replications of sampling sites that were located at least 1 kilometer from each other. The sampling sites were marked as sampling plots one acre in size and planted with rice variety MARDI Siraj 297. Each planting season, a total of thirty sampling plots were recorded for rice stem borer incidence data collection. The paddy fields were maintained in a conventional paddy ecosystem with proper agronomic practices such as good weed management, scheduled fertilizer, and application of pesticides when needed. The data recording was repeated in two planting seasons with another 30 sampling plots.

Experimental layout

Thirty sampling plots were recorded for the rice stem borer incidence in two times per season for the dead heart (DH) and whitehead (WH) symptoms. The sampling time for the DH symptom was taken at 40 days after sowing (DAS) for direct seeding or transplant (DAT) for transplanted rice, while the sampling time for WH symptom was taken at 80 DAS/DAT. The plot in one-acre width was divided into four strata where each stratum was separated into five wards. One ward was divided into five within walking distance of another ward forming ten wards on the left side of the sampling plot, and another ten wards on the right sampling plot. In a ward, four sampling points were randomly selected. The points were selected by throwing a quadrat (25 cm × 25 cm) into the sampling plot. From the quadrat, a total number of tillers and infested tillers with DH or WH symptoms inside the quadrat were counted and recorded. The data collection was continued to the second ward by moving forwards in five walking steps consistently and stopping for another data collection. The data collection was repeated for 20 wards.

Rice stem borer incidence and species abundance

Rice stem borer incidence

The infested tillers with DH symptoms were identified by the whitish color (drying up) of the central shoot of the paddy seedlings during the vegetative stage. The DH and WH can be identified when the central tiller can be easily pulled out from the stem. Four hills of ten tillers paddy seedlings were observed at the sampling point for stem borer infestation data collection. The number of infested tillers (a) and total tiller (b) were recorded to obtain the percentage of stem borer infestation.

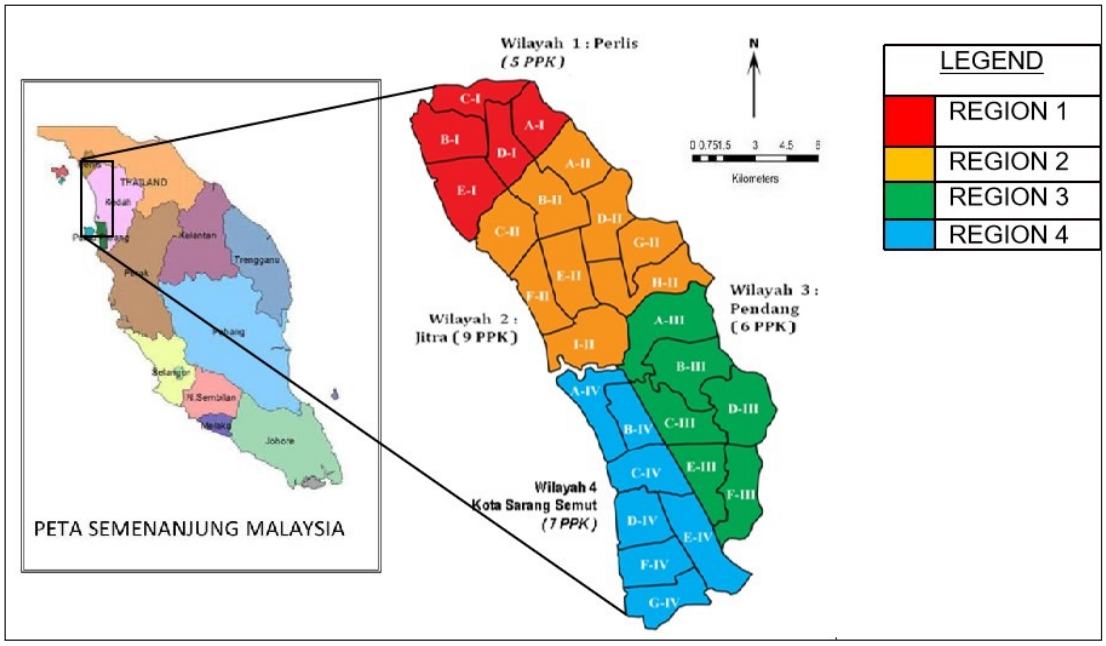

Fig. 1. Location of four MADA Regions in Peninsular Malaysia

Table 1. Thirty sampling sites planted with rice variety MARDI Siraj 297 for rice stem borer incidence data recording per season

No	Region	District	Specific location	Longitude	Latitude
1	R1	Arau	A	6°23'49.0"N	100°15'23.9"E
2	R1	Arau	B	6°24'33.9"N	100°17'00.3"E
3	R1	Arau	C	6°24'50.5"N	100°15'19.7"E
4	R1	Simpang Empat	A	6°16'15.1"N	100°11'31.7"E
5	R1	Simpang Empat	B	6°21'19.5"N	100°11'15.1"E
6	R1	Simpang Empat	C	6°19'40.4"N	100°10'00.7"E
7	R2	Kodiang	A	6°21'03.9"N	100°18'07.5"E
8	R2	Kodiang	B	6°20'50.5"N	100°18'06.1"E
9	R2	Kodiang	C	6°21'32.3"N	100°17'22.4"E
10	R2	Jerlun	A	6°10'28.6"N	100°16'39.5"E
11	R2	Jerlun	B	6°10'50.4"N	100°16'47.9"E
12	R2	Jerlun	C	6°13'18.3"N	100°16'45.7"E
13	R3	Hutan Kampung	A	6°11'24.6"N	100°24'32.3"E
14	R3	Hutan Kampung	B	6°11'00.2"N	100°24'28.9"E
15	R3	Hutan Kampung	C	6°10'37.2"N	100°24'21.8"E
16	R3	Tajar	A	6°04'26.3"N	100°23'22.0"E
17	R3	Tajar	B	6°04'51.9"N	100°23'35.2"E
18	R3	Tajar	C	6°05'09.0"N	100°23'36.6"E
19	R3	Pendang	A	5°58'34.8"N	100°31'15.0"E
20	R3	Pendang	B	5°58'47.7"N	100°29'55.4"E
21	R3	Pendang	C	5°59'01.6"N	100°29'56.6"E
22	R4	Batas Paip	A	6°02'07.9"N	100°20'53.1"E
23	R4	Batas Paip	B	6°01'57.5"N	100°21'03.9"E
24	R4	Batas Paip	C	6°02'29.6"N	100°21'32.6"E
25	R4	Permatang Buluh	A	5°57'08.7"N	100°21'42.1"E
26	R4	Permatang Buluh	B	5°56'45.2"N	100°23'38.9"E
27	R4	Permatang Buluh	C	5°56'48.6"N	100°24'05.1"E
28	R4	Guar Chempedak	A	5°51'28.1"N	100°24'46.7"E
29	R4	Guar Chempedak	B	5°49'56.7"N	100°22'13.0"E
30	R4	Guar Chempedak	C	5°50'20.6"N	100°24'57.8"E

R1 - Region 1
R2 - Region 2
R3 - Region 3
R4 - Region 4

The percentage of DH and WH were calculated using a formula as follows (Satpathi *et al*., 2012):

$$I = \frac{a}{b} \times 100\%$$

I = percentage of stem borer infestation
a = number of infested tillers
b = total tillers

Rice stem borer species abundance

The rice stem borer species abundance was calculated by the larvae identified from the infested tillers. During the DH and WH data collection, the infested tillers were collected from the sampling plot as possible or 50 infested tillers maximum. The infested tillers took apart from the paddy seedlings by pulling out the whole tillers with roots and stored in a plastic bag. The collected tillers were dissected and the larvae were taken out for identification. The larvae species were recorded for species abundance. The identification of the rice stem borer larvae species was guided by following Anderson & Tran-Nguyen, (2012), Mashoor *et al*. (2018), Chang (1981), Nik Mohd Noor *et al*. (2012), and Pathak and Khan (1994). Relative species abundance was calculated according to Rahaman (2014) as follows:

$$\text{Relative abundance (\%)} = \frac{\text{Total no. of individuals of each species}}{\text{Total no. of individuals of all species}} \times 100$$

Weather parameters: Temperature, Relative humidity, and rainfall

Weather parameters including percentage relative humidity (RH), temperature (°C), and rainfall (mm) were obtained from the Malaysian Meteorological Department.

Data analysis

The infestation and species abundance data were analyzed using analysis of variance (ANOVA) Complete Randomized Design (CRD) by IBM® SPSS® Statistics program software version 27 and the means were separated using Duncan's multiple range test (DMRT) at the 5% (p<0.05) level of significance (Gomez & Gomez, 1984).

RESULTS

Rice stem borer infestation at several locations

Data collection from two seasons in four MADA regions (Figure 2) showed that Region 3 was the highest region infested by the rice stem borer. It significantly differed from Region 1, but no significant difference was observed between Region 2 and Region 4.

From the ten districts chosen (Table 2), Pendang showed the greatest infestation of rice stem borer with 13.16% from Region 3. The infestation of rice stem borer in Pendang significantly differed among the six districts; Arau, Simpang Empat, Jerlun, Tajar, Permatang Buluh, and Guar Chempedak. While the other three districts mostly from different regions (Kodiang and Batas Paip) except Hutan Kampung showed no significant difference in the stem borer infestation. From three plots in Pendang (A, B, and C), plot B was infested by a rice stem borer with the maximum infestation (20.53%). It was observed that plot B was planted a month late than the other plots and was surrounded by other agriculture sites which as the palm oil plantation. The high infestation of rice stem borer in Pendang which was planted by direct seeding was observed to show no significance to the transplanted paddy field in Kodiang (7.14%). Jerlun with a similar method of planting to Pendang also showed the lowest infestation (1.69%). However, most of the plots within the districts and regions especially in Pendang and Batas Paip showed a high standard error (SE) indicating various values of the infestation level between the plots were observed. This mean, the high infestation of rice stem borer is not solely influenced by the location but also involved other factors.

Rice stem borer infestation of different planting seasons

The infestation of rice stem borer significantly differed between the two planting seasons. Season one (Nov - Feb) was observed to get higher infestation as compared to season two (Jun - Sept) (Figure 3).

The highest score of rice stem borer infestation during season one was recorded at Pendang with 18.60% (Table 3). Most of the districts showed higher infestation of rice stem borer during season one except Tajar and Jerlun. Both districts presented higher rice stem borer infestation during season two. However, the lowest infestation which occurred at Jerlun also came from season one with a percentage of infestation of 0.48%.

The high infestation in season one in Pendang was observed to have a lower value of maximum RH (RH_{max}), higher temperature differences, and lower rainfall compared to the same location in season two (Table 4). Weather parameters showed high infestation of rice stem borer occurred at 80.0% (RH_{max}) and 8.2 °C temperature differences (T_{diff}). On average, the high level of rice stem borer infestation in season one was influenced by the lower value of RH_{max}, higher range of temperature, and lower amount of rainfall compared to season two (Table 5). The output was in line with the weather parameters recorded in Pendang.

The lowest infestation in season two was recorded in Simpang Empat with a high value of

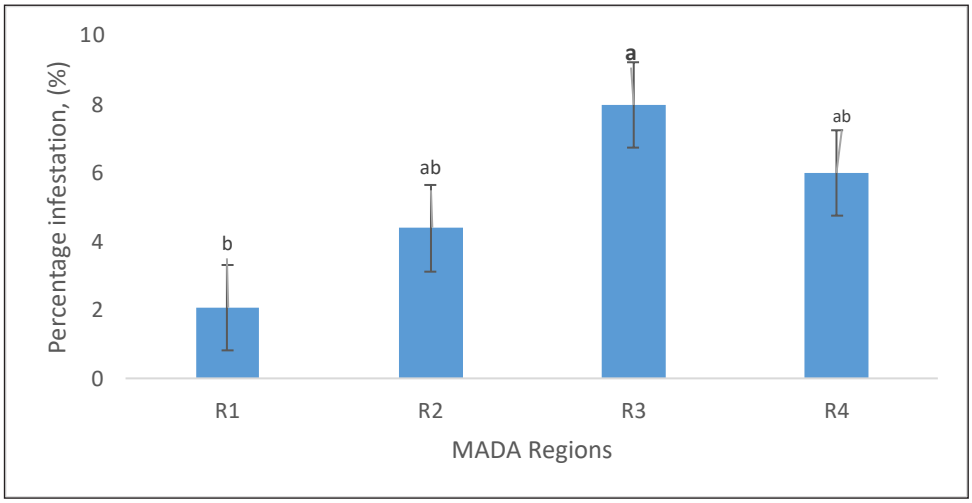

Fig.2. Rice stem borer infestation (%) of four MADA regions in season one and 2 (2019/2020).

Table 2. The level of all rice stem borers infestation at different locations

Region	District	Location	Level of infestation (%)	Mean ± SE
1	Arau	A	4.66	2.2 ± 0.74c
		B	1.13	
		C	0.81	
	Simpang Empat	A	3.22	1.95 ± 0.89c
		B	1.97	
		C	0.66	
2	Kodiang	A	4.53	**7.14 ± 1.39abc**
		B	9.91	
		C	6.97	
	Jerlun	A	1.91	1.69 ± 0.43c
		B	1.31	
		C	1.64	
3	Pendang	A	8.97	**13.16 ± 4.41a**
		B	**20.53**	
		C	9.97	
	Hutan Kampung	A	8.31	8.72 ± 1.76ab
		B	9.13	
		C	8.72	
	Tajar	A	1.56	2.08 ± 0.58c
		B	1.97	
		C	2.72	
4	Batas Paip	A	4.69	9.53 ± 3.44ab
		B	12.97	
		C	10.94	
	Permatang Buluh	A	4.41	6.06 ± 1.56bc
		B	4.97	
		C	8.81	
	Guar Chempedak	A	3.41	2.40 ± 0.44c
		B	2.22	
		C	1.56	

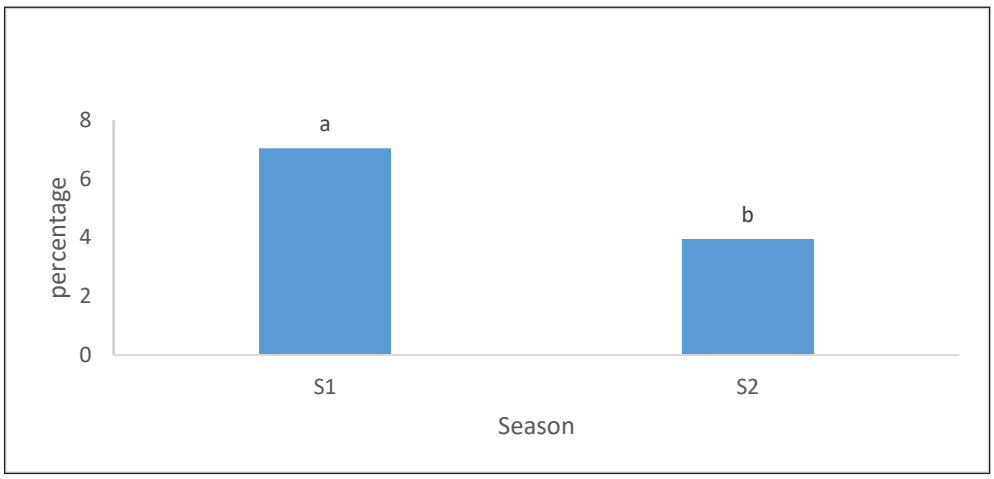

Fig. 3. Percentage infestation of rice stem borer in season one (S1) and season two (S2).

Table 3. The level of rice stem borer infestation of different seasons

Season	Location	Mean ± SE
1	Arau	2.63 ± 1.94
	Simpang Empat	2.94 ± 2.23
	Jerlun	**0.48 ± 0.25**
	Kodiang	9.02 ± 2.51
	Hutan Kampung	10.96 ± 2.94
	Pendang	**18.60 ± 7.37**
	Tajar	1.35 ± 0.63
	Batas paip	14.44 ± 4.45
	Guar Chempedak	1.94 ± 0.69
	Permatang buluh	8.27 ± 4.16
2	Arau	1.77 ± 0.60
	Simpang Empat	0.96 ± 0.15
	Jerlun	2.79 ± 0.41
	Kodiang	5.25 ± 1.85
	Hutan Kampung	6.48 ± 2.16
	Pendang	7.71 ± 3.44
	Tajar	3.21 ± 1.02
	Batas paip	4.63 ± 1.32
	Guar Chempedak	2.8 ± 0.80
	Permatang buluh	3.85 ± 1.27

RH, lower temperature differences, and a higher amount of rainfall. The lowest infestation recorded was 0.96% with the RH_{max} (91.2%), T_{diff} (8.5 °C), and rainfall (7.9 mm). On average, the low level of rice stem borer infestation in season two was influenced by a higher value of RH_{max}, smaller $T_{diff,}$ and more amount of rainfall compared to season one which was similar to the outcomes recorded in Simpang Empat.

Rice stem borer infestation at different level of damage symptoms

The highest percentage of rice stem borer infestation was recorded with DH symptoms with a percentage of infestation of 30.83% during season one in Pendang, Region 3 as illustrated in Table 6. The WH symptoms showed the lowest infestation (1.0%) during season two in Simpang Empat, Region 1. There is no significant difference between the damage symptoms of DH and WH (p=0.649). However, the percentage of DH was observed to have a significant difference between season one and season two (Figure 4).

Rice stem borer species abundance

All stem borer species (Figure 5) were found in all regions (Region 1, Region 2, Region 3, & Region 4). There were three species of rice stem borer found and they were *Chilo polychrysus* (black-headed stem borer) (Figure 6a & 6b), *Sesamia inferens* (pink stem borer) (Figure 6c & 6d) and *Scripophaga incertulas* (yellow stem borer) (Figure 6e & 6f). *Chilo polychrysus* was the most abundant species of rice stem borer found in

Table 4. Influence of weather parameters to the level of rice stem borer infestation

Planting season	Locations	Infestation (Mean ± SE)	Average RH_{max}, %	T_{diff} (Max- Min), °C	Average rainfall (mm)
1	Arau	2.63 ± 1.94	94.7	8.5	0.8
	Batas Paip	14.44 ± 4.45	86	10.7	0
	Guar Chempedak	1.94 ± 0.69	87.8	8.8	0.8
	Hutan Kampung	10.96 ± 2.94	79	12.2	0
	Jerlun	0.48 ± 0.25	79.5	13.7	0
	Kodiang	9.02 ± 2.51	97.5	14.3	0
	Pendang	**18.60 ± 7.37**	**80**	**8.2**	**0**
	Permatang Buluh	8.27 ± 4.16	81.2	9.7	0
	Simpang Empat	*2.94 ± 2.23*	*94.5*	*9.6*	*0*
	Tajar	1.35 ± 0.63	86.5	9.5	10.1
2	Arau	1.77 ± 0.60	92.5	8.7	4.1
	Batas Paip	4.63 ± 1.32	92.3	10.5	3.5
	Guar Chempedak	2.8 ± 0.80	89.7	9.6	1.6
	Hutan Kampung	6.48 ± 2.16	96	7.6	0.1
	Jerlun	2.79 ± 0.41	91	12.3	1.2
	Kodiang	5.25 ± 1.85	90.7	9.9	3
	Pendang	7.71 ± 3.44	89.7	6.6	6.5
	Permatang Buluh	3.85 ± 1.27	91	8.3	5.5
	Simpang Empat	***0.96 ± 0.15***	***91.2***	***8.5***	***7.9***
	Tajar	3.21 ± 1.02	92.5	5.7	24.2

RH_{max} -Maximum Relative humidity (RH), T_{diff} - Differences between temperature (T_{max} - T_{min})

Table 5. Rice stem borer infestation by influence of RH, temperature and rainfall at season one and season two in average

Season	Infestation (%)	$RH_{max\ (\%)}$	T_{diff} (°C)	Rainfall (mm)
S1	7.1	86.7	10.5	0.6
S2	3.9	91.7	8.8	5.7

RH_{max} - maximum value of RH, T_{diff} - Difference between maximum and minimum temperature, S1- season one, S2- season two

Region 1 and significantly differed from Region 2, Region 3, and Region 4 (p=0.014). The pink stem borer, *S. inferens* was more abundant in Region 3 and Region 4 and showed significant differences in Region 1 and Region 2 (p=0.025). On the other hand, the abundance of yellow stem borer was observed to have a high score in Region 2, 3, and 4 and was significantly higher than in Region 1 (p=0.176).

Between the districts (Table 7), *C. polychrysus* was caught abundantly in Simpang Empat, 76.40% followed by Arau, Permatang Buluh, and Pendang with percentage abundance of 59.5%, 55.2%, and 46.0% respectively. No *C. polychrysus* was found in both Hutan Kampung or Tajar. Meanwhile, *S. inferens* species was recorded as the most abundant rice stem borer with 48.8% in Tajar. *S. inferens* also was found abundantly in Guar Chempedak and Permatang Buluh with the percentage of 34.8% and 14.6% respectively. No recorded species of pink stem borer was found in Kodiang and Arau. The most abundant species of rice stem borer, the yellow stem (*S. incertulas*) borer was found in all districts with the highest abundance recorded in Batas Paip with 91.3%. Hutan Kampung and Kodiang also had a high abundance of yellow stem borer which was more than 90%. Simpang Empat was the only district that had lower than 20% of *S. incertulas* abundance.

DISCUSSION

The infestation of rice stem borer in four regions of MADA which are located in the northern part of Peninsula Malaysia is found to be varied. The differences in the level of the rice stem borer infestation between the regions are important information to the stakeholders especially farmers to plan appropriate management of their rice fields. In this study, the rice fields in Region 3 covered the district of Hutan Kampung, Pendang, and Tajar which had been infested heavily with rice stem borers compared to the other three regions. According to the MADA Paddy Cultivation Schedule, Region 3 was arranged at the last phase of the irrigation water inlet for paddy cultivation. Most of the rice cultivation areas in Region 3 were sown late in a month delay and was proved to invite heavy rice stem borer infestation (Baloch *et al*., 2004). The late-planted crop was more susceptible to borers when the

Table 6. The level of rice stem borer infestation at different level of damage symptoms

Rice planting season	Symptom	District	Level of infestation (%)
1	DH	Arau	1.38
		Batas paip	3
		Guar Chempedak	2.58
		Hutan Kampung	14.63
		Jerlun	0.17
		Kodiang	6.42
		Pendang	**30.83**
		Permatang buluh	9.88
		Simpang Empat	4.58
		Tajar	1.17
	WH	Arau	3.88
		Batas paip	**25.88**
		Guar Chempedak	1.29
		Hutan Kampung	7.29
		Jerlun	0.79
		Kodiang	11.63
		Pendang	6.38
		Permatang buluh	6.67
		Simpang Empat	1.29
		Tajar	1.54
2	DH	Arau	1.25
		Batas paip	4.5
		Guar Chempedak	2.92
		Hutan Kampung	2.79
		Jerlun	3.67
		Kodiang	3.46
		Pendang	2.79
		Permatang buluh	3.71
		Simpang Empat	1.21
		Tajar	3.13
	WH	Arau	2.29
		Batas paip	4.75
		Guar Chempedak	2.79
		Hutan Kampung	10.17
		Jerlun	1.92
		Kodiang	7.04
		Pendang	12.63
		Permatang buluh	4
		Simpang Empat	0.71
		Tajar	3.29

neighboring crops were approaching maturity and less susceptible to new infestations (Bhambro, 2000). Among three districts in Region 3, Pendang B was the last sampling plot established during the data collection. The plot became the center of insect focus as the resting moth from the older neighboring plots found new younger host plants to complete its life cycle. A study by Sarwar (2012) on the effects of host plant resistance in early, medium, and late sown showed the late-sown rice field had greater rice stem borer incidence and the least yield production.

Insects population were shown to be influenced by abiotic factors such as temperature, relative humidity, and rainfall (Nag *et al*., 2018). In this study, the weather parameters obtained from the Malaysian Metrological Department revealed that the rice stem borer populations were high during season one (November to February) compared to season two (Jun to September). The differences in infestation between the seasons are mainly because of the fluctuation of the weather patterns during the months of rice planting. In this study, higher infestation was observed during a lower value of maximum RH, high-temperature range, and lower amount of rainfall. High temperatures have caused the life cycle of rice stem borer to be completed in a shorter time. Manikanda *et al.* (2016) revealed yellow stem borer completed its life cycle in a shorter period if exposed to a higher temperature (36 °C). A shorter life cycle promoted the rice stem borer to form a large population and

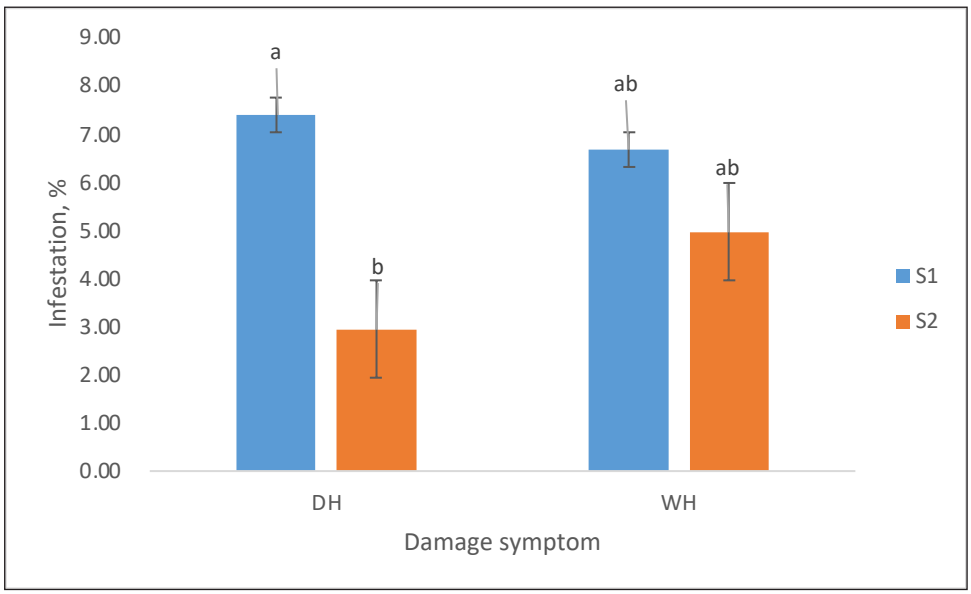

Fig. 4. Rice stem borers infestation at different level of damage symptom

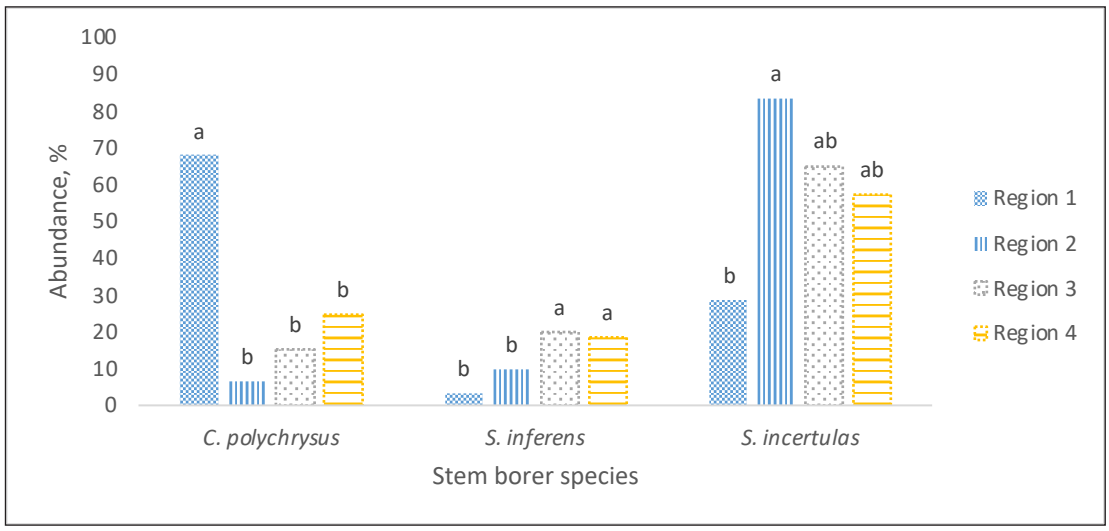

Fig. 5. Species abundance of rice stem borers in four regions in the northern part of Peninsula Malaysia

potentially cause more infestation. On the other hand, the temperature does not affect the incidence of yellow stem borer, while relative humidity and rainfall hurt pest incidence (Jasrotia *et al*., 2019).

Usually, an infestation of rice stem borers that occurs during the vegetative stage (dead heart) had a lower impact on rice yield rather than an infestation that caused a white head during the reproductive stage (Rahman *et al*., 2004). Bandong and Litsinger (2005) reported that the rice stem borer infestation occurred at two susceptible stages which were intermediated by three resistance plant stages, at 'very young rice', 'at mid-growth', and 'after panicle exertion', and also varied by plant maturity. The 30 days delay of the late sown rice field faced earlier infestation due to the availability of early rice cultivation in the surrounding rice field. The very young post-planting rice seedlings from the late sown rice field, with three tillers, were at risk to be severely infested by single-stem borer larvae because the plants were at their peak of susceptibility and weak in defense system (Horgan *et al*., 2018). If early infestation occurred, the number of productive tillers is reduced and leading to a decrease in plant height (Hosseini *et al*., 2010). The plant with decreased height (the survived secondary tillers) later will produce panicles to the primary tillers with different maturity times and this has caused a reduction in grain yield and weight (Ogah & Nwilene, 2017). The whitehead initiated before panicle initiation promoted severe damage to the rice plant and eventually contribute to significant yield loss (Litsinger, 2009).

Damage symptoms of rice stem borer; DH and WH were developed by all types of rice stem

Fig. 6. Rice stem borer species found at four regions in northern part of Peninsular Malaysia

Table 7. Rice stem borer species abundance (%) at different locations

Species	Region	District	Species abundance (%)	Mean ± SE
Chilo polychrysus (Black-headed stem borer)	1	Arau	59.50	**67.95 ± 12.5**
		Simpang Empat	**76.40**	
	2	Kodiang	8.20	6.60 ± 7.35
		Jerlun	5.0	
	3	Hutan Kampung	0.00	15.33 ± 11.3
		Tajar	0.00	
		Pendang	46.00	
	4	Guar Chempedak	15.40	24.50 ± 13.63
		Permatang Buluh	55.20	
		Batas Paip	1.20	
Sesamia inferens (Pink stem borer)	1	Arau	0.00	3.30 ± 2.78
		Simpang Empat	6.60	
	2	Kodiang	0.00	9.95 ± 4.76
		Jerlun	19.90	
	3	Hutan Kampung	9.50	**19.83 ± 19.20**
		Tajar	**48.80**	
		Pendang	1.2	
	4	Guar Chempedak	34.80	18.40 ± 9.71
		Permatang buluh	14.60	
		Batas Paip	5.80	
Scirpophaga incertulas (Yellow stem borer)	1	Arau	40.5	28.75 ± 15.73
		Simpang Empat	17.00	
	2	Kodiang	**91.80**	**83.50 ± 14.08**
		Jerlun	75.2	
	3	Hutan Kampung	90.50	64.83 ± 15.08
		Tajar	51.20	
		Pendang	52.80	
	4	Guar Chempedak	49.80	57.10 ± 15.93
		Permatang Buluh	30.20	
		Batas Paip	**91.30**	

borers, regardless of species. Similar symptoms caused difficulties in distinguishing rice stem borer species that infest the paddy plants. This issue was important to be included in establishing appropriate control strategies and management of the insect pest. The current study discovered that *C. polychrysus* had crossed the border of Region 1 and become the most abundant rice stem borer species in the region. This could be due to some factors that lead to the variation of the rice stem borer species distribution and abundance. The primary factor was the high application of insecticides had encouraged the stem borers to develop high resistance to the insecticide resulting in less effective control (Cheng *et al*., 2010). The high usage of insecticides also probably killed natural enemies such as the parasitoid, *Trichogramma* spp., and the predators resulting in an unstoppable infestation. On the other hand, less insecticide application in rural areas such as Pendang allowed other stem borer species to increase their population and as a result, more species of rice stem borer had been coexisting in all regions.

CONCLUSION

It was understood that different localities, planting seasons, and levels of damage symptoms contributed to a different level of infestations and species abundance of rice stem borers with the influence of the weather parameters such as humidity (RH), temperature differences, and amount of rainfall. . The infestation occurred when the stem borer larval bore rice stem and damaged the plant's center. As a result, applying insecticides to control the pest becomes unsuccessful as other factors have contributed to the population density of the stem borers therefore more detailed information on the rice stem borer was required to understand the mechanism of infestation, including the life cycle, survival rate, development period, and many other factors.

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