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Seasonal dynamics of insect pests in Little Millet (*Panicum sumatrense*) in relation to weather parameters in coastal agroecosystems of Karaikal

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Abstract
Investigation on the seasonal incidence of major insect pests of little millet (*Panicum sumatrense*) was carried out in field experiments during Summer and Kharif 2024. The dominant pests observed were shoot fly (*Atherigona pulla*), pink stem borer (*Sesamia inferens*), flea beetle (*Chaetocnema pusaensis*), leaf folder (*Cnaphalocrocis medinalis*), earhead bug (*Leptocorisa acuta*), and aphid (*Aphis craccivora*). Pest incidence exhibited distinct seasonal patterns, with peak populations occurring during the 10th–14th SMW in Summer 2024 and 27th–32nd SMW in Kharif 2024. Aphids and leaf folder were recorded relatively higher population levels. Correlation analysis indicated that most pests showed negative associations with relative humidity, particularly evening RH, while temperature exerted variable effects. Significant relationships were observed between key pests and selected weather parameters. Multiple linear regression analysis revealed that weather factors accounted for 53–71 per cent and 55–67 per cent variation in pest populations during Summer and Kharif, respectively.

Keywords: Little millet, seasonal incidence, insect pests, weather parameters, regression analysis, *Aphis craccivora*, *Cnaphalocrocis medinalis, Atherigona pulla, Sesamia inferens*

Introduction

Little millet, *Panicum sumatrense* Roth ex Roem. & Schult is a minor coarse cereal crop that belongs to the family Poaceae or Graminae. These grains are used as food in Africa and Asia and are generally planted on marginal ground in arid regions of subtropical and tropical climates (Tonapi *et al*., 2013) [21]. This crop has become recognized as a nutri-cereal, due to its nutritional content (Kundra *et al*.,2020a). In India, the most common minor millet, little millet can be used as a superior substitute for wheat and rice because they are gluten-free and offer a rich supply of carbohydrates, protein, vitamins, and minerals (Chava *et al*., 2023) [1]. Considering this, greater emphasis is being placed on maximizing efforts to increase the amounts of millets produced domestically (Kumar *et al*., 2023) [9].

Millets have been shown to host at least 150 different insect species worldwide. Of these, India has been reported to include 116 species. Due to lower crop productivity, grain quality, and fodder yield, insects that feed on different plant sections at various stages of plant growth cause economic losses (Swathi *et al*., 2022) [20]. Seedling pests, such as shoot flies and stem borers; foliage pests, namely hairy caterpillar, cutworms, and armyworms, grasshoppers, ash weevils, and flea beetle; sucking pests, such as spider mites, aphids, and shoot bug; earhead pests, such as head caterpillars, earhead bug, and grain midge; insects of the soil, such as white grubs, termites, or white ants (Chava *et al*., 2023) [1]. Even though little millets are tolerant to insect pests *viz*., shoot fly, pink stem borer, earhead bug, thrips, head caterpillars and gall midge, which cause major yield loss in addition to army worms, leaf beetles and grasshoppers as an occasional pest (Kumar *et al*., 2023; Kamakshi *et al*., 2021; Prasad *et al*., 2023; Gahukar and Reddy, 2019) [1, 4, 7]. In view of the above, in the present investigation, seasonal incidence of major insect pests and the effect of different meteorological parameters like maximum and minimum temperature, morning and evening relative humidity, rainfall on development and survival of the insect pests and natural enemies was studied.

Materials and Methods

The field experiments were conducted in Summer and *Kharif* 2024 at the Eastern farm of the Pandit Jawaharlal Nehru College of Agriculture and Research Institute (PAJANCOA and RI), Karaikal, U.T. of Puducherry, India. Climate of this region is classified as tropical maritime, characterized by consistently high temperature and humidity throughout the year. The region experiences hot and humid summers, while winters are mild and comparatively dry due to the moderating influence of the adjoining sea.

The mean monthly morning relative humidity generally exceeds 85–89%, whereas the mean monthly evening relative humidity ranges from 75 to 80% during the year. The average monthly maximum and minimum temperatures vary between 28–36 °C and 20–26 °C, respectively. The area receives substantial rainfall, primarily during the Northeast monsoon season (October–December), which plays a crucial role in determining the agro-climatic conditions of the region. The experiment was laid out in a randomized block design (RBD) with eight treatments replicated thrice, and the ruling variety used was ATL 1. The variety was raised in the nursery on 15. 02. 2024, and 20 days after sowing (DAS), the seedlings were transplanted in the main field in 5 x 5 square meter plots with a spacing of 25 cm x 10 cm. The blanket recommendation of fertilizers of 44: 22 kg/ha N: P_2O_5 were applied as per the crop production guide 2020 of Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu. About 100 per cent N andP_2O_5, 12.5t/ha FYM/compost, were applied at basal stage.

Method of observations

Observations on shoot fly and pink stem borer incidence were recorded at regular intervals, with damage assessed as

dead hearts at the vegetative stage and white ears at the reproductive stage on ten randomly selected plants per plot. Flea beetle and leaf folder damage were evaluated based on the proportion of damaged or folded leaves from ten sampled plants/hills per plot. Populations of ear head bugs and aphids were estimated by counting nymphs and adults on ten randomly selected hills per plot.

Meteorological factors and their association

Meteorological parameters, namely maximum and minimum temperature, morning and evening relative humidity (RH), and rainfall (RF) were recorded daily in both the seasons at the meteorological observatory in the Agronomy department, PAJANCOA and RI, Karaikal, U.T. of Puducherry. To study the influence of meteorological factors on the population build up, correlation studies were carried out with major insect pests of little millets.

Results and Discussion

During the period of investigation, the population of insect pests was fluctuating and present throughout the crop season. Seasonal incidence of insect pests of little millet during Summer and *Kharif* 2024 (Weekly average) were presented in the Table 1. Simple correlation and Multiple linear regression of major insect pests with maximum and minimum temperature, morning and evening relative humidity and rainfall during Summer and *Kharif*, 2024 are presented in the Table 2 to 5 (Fig.1).

Shoot fly, *Atherigona pulla*, (Wiedemann) (Diptera: Muscidae)

In Summer 2024, shoot flies first appeared during the 8th SMW in the third week of February (12 maggots/50 plants), and in *Kharif* 2024, during the 24th SMW in the second week of June (21 maggots/50 plants). Shoot fly incidence peaked on the 10th SMW in second week of March (43 maggots/50 plants), during the Summer 2024. In *Kharif* 2024, the highest incidence was observed on 27thSMW, first week of July (49 maggots/50 plants), while the lowest incidence was observed on 29thSMW, third week of July with 4 maggots/50 plants.

These present findings are in conformity with the results of Saxena *et al*. (2022) [18], who stated that the earliest incidence of *A. soccata* in sorghum was 4.12 per cent dead heart during the 27th SMW and the highest damage percentage of dead hearts (55.43%) was recorded during the 30th SMW (*i.e*., 23-29 July) and the damage decreased from the 30th SMW to zero during the 35th SMW (27th August-2nd September 2019). Kundra *et al*. (2020b) studied that a gradual increase in dead heart in little millet was noticed from one week after germination, and maximum infestation of *A. pulla* was observed in the 3rd week after germination (July) which varied from 16.86 to 24.66 dead hearts/10 plants.

A. pulla recorded a significant negative correlation with minimum temperature (-0.67) and non-significant negative correlation with maximum temperature (-0.52), evening relative humidity (RH) (-0.13) and rainfall (-0.29), non-significant positive correlation with morning RH (0.39) during Summer 2024. It was found that shoot fly registered a non-significant negative correlation (-0.30, -0.31) with evening RH and rainfall during *Kharif* 2024. The present results are in accordance with the findings of Swathi *et al*. (2022) [20] who expressed that, there was a significant negative correlation with minimum temperature (r = -0.51) and evening RH (r = -0.47) for little millet shoot fly and a significant negative correlation with minimum temperature (r = -0.50), evening RH (r = -0.46) and maximum temperature (r = -0.30) for proso millet shoot fly (Fig.2).

Pink stem borer, *Sesamia inferens,* (Walker) (Lepidoptera: Noctuidae)

Pink stem borer larvae initially appeared in the fourth week of February on the 9th SMW (10 larvae/50 plants) in Summer 2024, and in the fourth week of June on the 26th SMW (21 larvae/50 plants) in *Kharif* 2024. Throughout the Summer 2024, there were two separate peak incidences of pink stem borer: one on the 11thSMW in the second week of March (46 larvae/50 plants), and another on the 14thSMW in the first week of April (45 larvae/50 plants). In *Kharif* 2024, the incidence peaked on the 29thSMW, during third week of July, with 48 larvae/50 plants. The incidence declined on the 33rdSMW, during the fourth week of August, with 8 larvae/50 plants. Deole *et al*. (2013) [2] observed that, during last week of February, highest larval population of *S. inferens* on maize was recorded, and the peak activity of adults was observed during mid of March.

S. inferens indicated a significant negative correlation (-0.58) with evening RH and a non-significant negative correlation with all remaining factors, while flea beetle, *C. pusaensis* showed a non-significant negative correlation with all parameters, during the Summer2024. During *Kharif* 2024, there was a significant negative correlation among maximum temperature, morning and evening RH,with pink stem borer (-0.58, -0.71, -0.66) and flea beetle (-0.59, -0.68, -0.70), respectively. Raghvani *et al*. (2008) [16] revealed that maximum temperature was significantly negatively correlated with the population of stem borer. Joshi *et al*. (2009) [6] observed a negative correlation between the evening RH and pink stem borer incidence (Fig.3).

Flea beetle, *Chaetocnema pusaensis*, (Marsh.) (Coleoptera: Chrysomelidae)

The peak incidence of flea beetle was recorded on the 13thSMW in the fourth week of March (104 beetles/50 plants) and 29thSMW in the third week of July (92 beetles/50 plants) during Summer and *Kharif* 2024, respectively. The lowest incidence was recorded in the 18thSMW (12 beetles/50 plants) in the first week of May in Summer 2024 and 33rdSMW (19 beetles/50 plants) in the third week of August in *Kharif* 2024, respectively.

Prodhan *et al*. (2008) [15] observed that the flea beetle incidence was high in mid of August and September during 2007 at Bangladesh. According to Hossain *et al*. (2012) [5], the largest peak infestation of the striped flea beetle, *Phyllotreta striolata*(Fabricius), was observed in February, April, and May, with varying dates of planting in green gram during *Kharif* 2009 [6] in Bangladesh, with corresponding percentages of leaf damage of 7.67, 10.33, and 11.60 per cent. These results are in support with the present findings. Praveenkumar and Kandibane (2022) [14] reported that black gram flea beetle recorded a non-significant negative correlation with maximum (-0.15) and minimum relative humidity (-0.47) during *Rabi* 2020-2021. These reports are in agreement with the current findings (Fig.4).

Leaf folder, *Cnaphalocrocis medinalis*, (Guenée) (Lepidoptera: Crambidae)

The leaf folder larvae recorded peak incidence on the 11thSMW in the third week of March (86 larvae/ 50 plants) and30thSMW in the fourth week of July (102 larvae/50 plants) during Summer and *Kharif* 2024, respectively. The lowest incidence was recorded in the 17thSMW (13 larvae/50 plants) in the fourth week of April in Summer 2024 and 34thSMW (11 larvae/50 plants) in the fourth week of August in *Kharif* 2024.

Gadekar (2022) [3] studied that the incidence of damaged leaves by rice leaf folder (0.45%) first appeared during 10th SMW *i.e*., second week of March. Thereafter, the per cent folded leaves or damaged leaves gradually increased till 11th SMW *i.e*., third week of March. The peak infestation 2.97 per cent damaged leaves was observed at the 12th SMW *i.e*., fourth week of March. The above results are in accordance with the present findings.

The leaf folder, *C. medinalis* indicated a significant negative correlation (-0.57) with evening RH and a non-significant negative correlation with minimum temperature, morning RH and rainfall throughout the Summer 2024, and a significant negative correlation (-0.62) with evening RH, significant positive correlation (0.63) with the maximum temperature, non-significant negative correlation with morning RH during *Kharif* 2024.

According to Khan and Ramamurthy (2004) [8], there was a significant and negative correlation between the amount of leaf damage of the rice leaf folder and all the weather parameters, including the maximum and minimum temperatures, rainfall, and relative humidity. Patil *et al*. (2020) [12] revealed that the correlation analysis of rice leaf folder indicated a significant positive correlation with maximum temperature (r = 0.529) and a non-significant negative correlation minimum temperature (r = -0.0179), evening RH (r = -0.314), morning RH (r = -0.281) and rainfall (r = -0.337) (Fig.5).

Earhead bug, *Leptocorisa acuta*, (Thunberg) (Hemiptera: Miridae)

The peak incidence of earhead bug was recorded on the 14thSMWwith 101 earhead bugs/50 plants in the first week of April and 32ndSMW in the second week of August (97 earhead bugs/50 plants) during Summer and *Kharif* 2024, respectively. The lowest incidence was recorded in the 19thSMW (7 earhead bugs/50 plants) in the second week of May in Summer 2024 and 35thSMW (14 earhead bugs/50 plants) in the first week of September in *Kharif* 2024.

The present findings are in close conformity with the reports of Gadekar (2022) [3], who reported that the incidence of nymphs and adults of gundhi bug (earhead bug) (0.73 /hill) first appeared during 13th SMW *i.e*., last week of March, at panicle formation stage. Thereafter, number of nymphs and adults gradually increased till the14th SMW *i.e*., first week of April. The peak population 3.88 nymphs and adults per hill of gundhi bug was recorded at 15th SMW *i.e*., second week of April, at milking stage.

A significant negative correlation (-0.59) with evening RH and non-significant negative correlation with morning RH during Summer 2024 and significant positive correlation (0.63) with rainfall, a non-significant negative correlation with minimum temperature, morning and evening RH, was recorded in earhead bug, *L. acuta* during *Kharif* 2024. These results are in close conformity with the results obtained by Sharma *et al*. (2019) [19] who expressed that the correlation analysis with rice earhead bug had a non-significant negative correlation with minimum temperature (r = -0.397), average temperature (r = -0.255), evening relative humidity (r = -0.040), and average relative humidity (r = -0.086) (Fig.6).

Aphids, *Aphis craccivora*, (Koch) (Hemiptera: Aphididae)

The aphid population recorded its peak incidence on the 13thSMW in the fourth week of March (280 aphids/50 plants) and 30thSMW in the fourth week of July (372 aphids/50 plants) during Summer and *Kharif* 2024, respectively. The lowest incidence was recorded in the18thSMW (12 aphids/50 plants) in the first week of May in Summer 2024 and 34thSMW (17 aphids/50 plants) in the fourth week of August in *Kharif* 2024.

Praveenkumar and Kandibane (2022) [14] stated that aphids appeared at 12th SW (March) (38 aphids/50 plants) and reached the highest peak at 16th SW (April) (305 aphids/ 50 plants) in black gram. These findings are in agreement with the present findings.

A significant negative correlation (-0.55) recorded in aphids, *A. craccivora* with evening RH and non-significant negative correlation with remaining factors during Summer 2024 and significant negative correlation (-0.66, -0.56) with morning and evening RH, significant positive correlation (0.57) with maximum temperature during *Kharif* 2024. Similar findings were given by Ramkumar *et al*. (2023) [9] recorded that the aphid populations had a negative correlation (r = -0.108) with evening relative humidity and a positive correlation (r = 0.57) with minimum temperature (Fig.7).

The multiple linear regression analysis indicated that all the weather parameters together was responsible for significant variation of 53, 70, 53, 71, 59 and 54 per cent on the incidence of shoot fly, pink stem borer, flea beetle, leaf folder, ear head bug and aphids population respectively, in little millet during Summer 2024 (Table 4) and significant variation of 56, 60, 58, 63, 67 and 55 per cent on the incidence of shoot fly, pink stem borer, flea beetle, leaf folder, ear head bug and aphids population respectively, in little millet during *Kharif* 2024 (Table 5).

Table 1: Seasonal incidence of insect pests of little millet during Summer and *Kharif* 2024 (Weekly average)

Standard Meteorological Week	Little millet pests					
	Shoot fly	Pink stem borer	Flea beetle	Leaf folder	Earhead bug	Aphids
Summer 2024						
7th (Feb 12-18)	0	0	0	0	0	0
8th (Feb19-25)	12	0	13	8	0	9
9th (Feb 26- Mar 4)	24	10	47	12	0	28
10th (Mar 5- 11)	43	20	13	49	0	42
11th (Mar 12-18)	39	46	54	86	11	200
12th (Mar 19-25)	23	39	87	52	22	170

13th (Mar 26-Apr 1)	19	28	104	31	50	280
14th (Apr 2-8)	0	45	38	53	101	190
15th (Apr 9-15)	0	26	68	21	28	210
16th (Apr 16-22)	0	18	39	18	30	110
17th (Apr 23-29)	0	8	22	13	42	54
18th (Apr 30-May6)	0	0	12	0	29	12
19th (May 7-13)	0	0	0	0	7	0
Kharif 2024						
23rd (Jun 4-10)	0	0	0	0	0	0
24th (Jun 11-17)	21	0	12	0	0	11
25th (Jun 18-24)	44	0	17	0	0	0
26th (Jun 25- Jul 1)	16	21	31	21	0	87
27th (Jul 2-8)	49	33	59	53	0	203
28th (Jul 9-15)	21	37	72	77	18	151
29th (Jul 16-22)	4	48	92	35	47	250
30th (Jul 23-29)	0	47	73	102	68	372
31st (Jul 30-Aug 5)	0	41	69	98	84	170
32nd (Aug 6-12)	0	10	13	45	97	21
33rd (Aug 13-19)	0	8	19	21	41	87
34th (Aug 20-26)	0	0	0	11	28	17
35th (Aug 27-Sep 2)	0	0	0	0	14	0

Table 2: Correlation between meteorological parameters and the population of little millet pests during Summer 2024

Sl. No.	Insects	Temperature (ºC)		Relative humidity (%)		Rainfall (mm)
		Maximum	Minimum	Morning	Evening	
1.	*A. pulla*	-0.52	-0.67*	0.39	-0.13	-0.29
2.	*S. inferens*	-0.52	-0.35	-0.05	-0.58*	-0.33
3.	*C. pusaensis*	-0.11	-0.20	-0.20	-0.40	-0.27
4.	*C. medinalis*	0.17	-0.33	-0.12	-0.57*	-0.33
5.	*L. acuta*	0.55	0.28	-0.45	-0.59*	-0.21
6.	*A. craccivora*	0.76	-0.13	-0.29	-0.55*	-0.23

* Significance at 0.05 per cent level ** Significance at 0.01 per cent level

Table 3: Correlation between meteorological parameters and the population of little millet pests during Kharif 2024

S.N	Insects	Temperature (ºC)		Relative humidity (%)		Rainfall (mm)
		Maximum	Minimum	Morning	Evening	
1.	*A. pulla*	0.41	0.01	0.04	-0.30	-0.31
2.	*S. inferens*	-0.58*	0.36	-0.71**	-0.66*	-0.19
3.	*C. pusaensis*	-0.59*	0.34	-0.68**	-0.70**	-0.26
4.	*C. medinalis*	0.63*	0.19	-0.54	-0.62*	0.08
5.	*L. acuta*	0.14	-0.31	-0.26	-0.22	0.63*
6.	*A. craccivora*	0.57*	0.48	-0.66*	-0.56*	-0.31

* Significance at 0.05 per cent level ** Significance at 0.01 per cent level

Table 4: Multiple linear regression between meteorological parameters and the population of little millet pests during Summer 2024

S.N	Variables(Y)	Regression equation	R^2 value
1.	*A. pulla*	$Y=314.64+0.70X_1-0.95X_2-0.06X_3-0.37X_4+0.32X_5$	0.53*
2.	*S. inferens*	$Y=356.32+0.77X_1-1.47X_2-0.13X_3-0.68X_4+0.56X_5$	0.70**
3.	*C. pusaensis*	$Y=2353.36-1.76X_1+0.54X_2-0.81X_3-0.92X_4+0.31X_5$	0.53*
4.	*C. medinalis*	$Y=455.07+1.12X_1-1.85X_2-0.33X_3-0.40X_4-0.46X_5$	0.71**
5.	*L. acuta*	$Y=-650.82+1.96X_1-1.40X_2+0.13X_3-0.42X_4+0.19X_5$	0.59*
6.	*A. craccivora*	$Y=4953.50-0.48X_1-0.43X_2-0.57X_3-0.86X_4+0.52X_5$	0.54*

* Significance at 0.05 per cent level ** Significance at 0.01 per cent level

Table 5: Multiple linear regression between meteorological parameters and the population of little millet pests during Kharif 2024

S. N	Variables(Y)	Regression equation	R^2 value
1.	*A. pulla*	$Y=-225.29+0.61X_1-0.48X_2+0.67X_3-0.22X_4-0.67X_5$	0.56*
2.	*S. inferens*	$Y=47.09-0.16X_1+0.47X_2-0.32X_3-0.55X_4+0.35X_5$	0.60*
3.	*C. pusaensis*	$Y=296.00-0.25X_1+0.35X_2-0.17X_3-0.76X_4+0.16X_5$	0.58*
4.	*C. medinalis*	$Y=-876.20+0.25X_1+0.61X_2-0.02X_3-0.43X_4+0.73X_5$	0.63*
5.	*L. acuta*	$Y=-101.97+0.13X_1+0.32X_2-0.40X_3+0.06X_4+1.02X_5$	0.67**
6.	*A. craccivora*	$Y=-1481.07+0.17X_1+0.45X_2-0.37X_3-0.08X_4+0.23X_5$	0.55*

* Significance at 0.05 per cent level ** Significance at 0.01 per cent level

X_1 - Maximum temperature (ºC) X_2 - Minimum temperature (ºC)

X_3 - Morning relative humidity (%) X_4 - Evening relative humidity (%)

X_5 - Rainfall (mm)

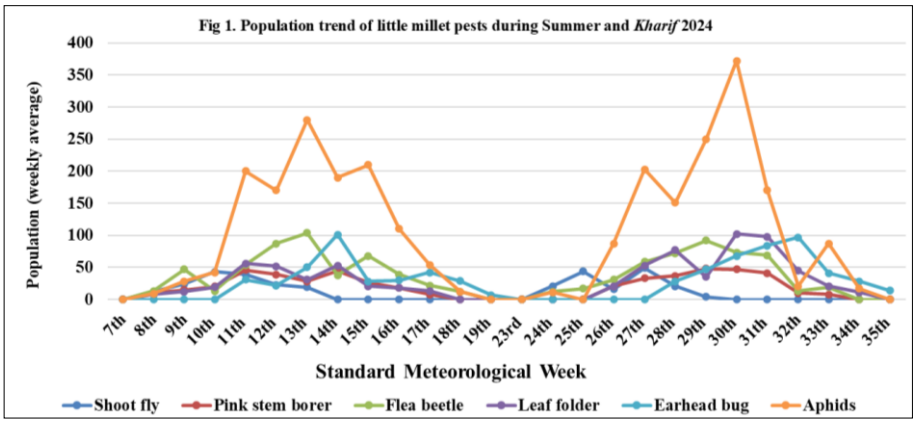


Fig 1: Population trend of little millet pests during Summer and *Kharif* 2024

Maggot Pupa Adult

Fig 2: The shoot fly, *Atherigona pulla* (Wiedemann)

Larvae Pupa Adult

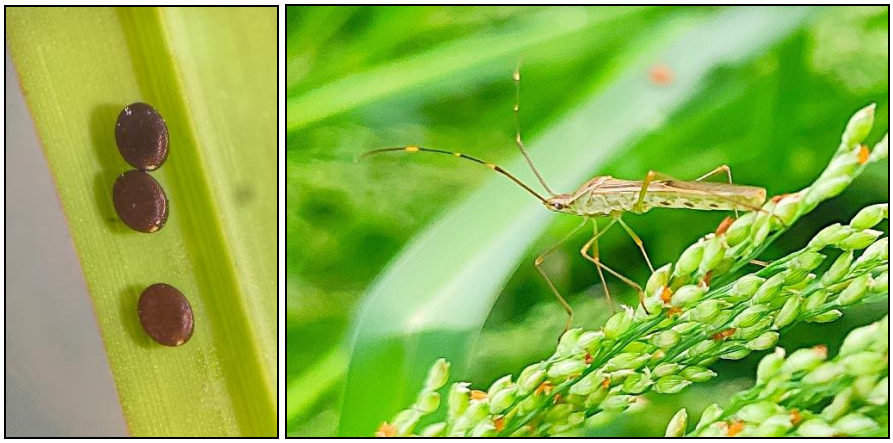
Fig 3: The pink stem borer, *Sesamia inferens* (Walker)

Larvae Adult

Fig 4: The flea beetle, *Chaetocnema pusaensis* (Melsheimer)

Larvae Pupa Adult

Fig 5: The leaf folder, *Cnaphalocrocis medinalis* (Guenee)



Egg Adult

Fig 6: The earhead bug, *Leptocorisa acuta* (Thunberg)

Nymph Adult

Fig 7: The bean aphid, *Aphis craccivora* (Koch)

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