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# Seasonal incidence of insect pests in Proso Millet (*Panicum miliaceum* L.) under coastal conditions of Karaikal, India

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**Abstract**
Field experiments were conducted during Summer and *Kharif* 2024 at PAJANCOA & RI, Karaikal to investigate the seasonal incidence of insect pests of proso millet and their relationship with meteorological parameters. The peak incidence of shoot fly (12th MSW), pink stem borer (13th MSW), leaf folder and flea beetle (12th MSW), aphids (14th MSW), and earhead bugs (16th MSW) was observed during Summer 2024. In *Kharif* 2024, peak incidence occurred at 38th - 43rd MSW depending on the pest species. Correlation studies revealed that, in Summer, shoot fly, leaf folder, and flea beetle populations were negatively associated with minimum temperature, while pink stem borer and aphids showed negative correlation with evening relative humidity. Earhead bugs exhibited a positive correlation with both maximum and minimum temperature. During *Kharif,* shoot fly showed positive correlation with temperature and negative association with relative humidity. Minimum temperature positively influenced pink stem borer, leaf folder, and flea beetle, whereas earhead bugs were positively associated with relative humidity and negatively with maximum temperature. Multiple linear regression analysis indicated that weather parameters significantly influenced pest incidence, explaining about 56–94% of variation in summer and 59–80% in *Kharif*. The study enumerated the strong influence of climatic factors on the regulation of pest dynamics in proso millet, providing a basis for developing weather-based pest management strategies.

**Keywords:** Proso millet, insect pests, seasonal incidence, weather parameters, correlation, multiple regression, pest dynamics

## Introduction

Proso millet (*Panicum miliaceum* L.) is an important minor cereal crop widely cultivated in India and other parts of the world. It is one of the oldest domesticated small-grain cereals and is known by various names, including common millet and broomcorn millet (Prabhakar *et al.*, 2017) [20]. The grain is nutritionally rich, containing high levels of carbohydrates, protein, dietary fibre, and essential minerals, making it a valuable component of food and nutritional security.

India is the leading producer of millets globally, and their importance has been increasingly recognized due to their resilience to climate variability and nutritional benefits. Initiatives such as the designation of 2018 as the National Year of Millets and 2023 as the International Year of Millets have further promoted millet cultivation (Karthick *et al.*, 2023) [10]. Despite this, millet productivity is constrained by several biotic factors, among which insect pests are a major limitation.

More than 60 insect species are reported to infest millets, including seedling pests, foliage feeders, sucking pests, earhead feeders, and storage pests (Chava *et al.*, 2023) [5]. In proso millet, key pests include shoot fly (*Atherigona pulla*), stem borers (*Sesamia inferens* and *Chilo partellus*), leaf folder (*Cnaphalocrocis medinalis*), aphids (*Hysteroneura setariae* and *Rhopalosiphum maidis*), and termites (Kalaisekar *et al.*, 2016) [9]. Pest incidence varies with season and agro-climatic conditions, often causing yield losses of 10–20% (Prasad *et al.*, 2023) [21]. In Tamil Nadu, proso millet is cultivated in limited pockets, often with minimal or no use of synthetic insecticides. With the recent increase in consumer awareness and demand for millets, there is a growing need for sustainable pest management strategies. In this context, understanding seasonal pest dynamics and their relationship with weather parameters is essential for developing eco-friendly management approaches. Therefore, the present study was undertaken to investigate the seasonal incidence of major insect pests of proso millet and their association with weather factors.

## Materials and Methods

### 1. Seasonal incidence of insect pests

The seasonal incidence of insect pests of proso millet was studied in an unsprayed field plot (96 m²) during Summer and *Kharif* 2024. The crop was raised following recommended agronomic practices without insecticidal application to allow natural pest build-up.

Observations were recorded at weekly intervals from germination to harvest. Ten plants were randomly selected from five locations and tagged for repeated observations. Major pests, including shoot fly, stem borers, leaf folder, flea beetle, aphids, and earhead bugs were monitored. Shoot fly incidence was assessed based on maggot count and percentage of dead hearts. Stem borer damage was recorded as dead hearts and white ear symptoms. Leaf folder incidence was assessed by larval counts and folded leaves, while flea beetle infestation was estimated based on adult population and feeding damage. Aphids were counted per plant, and earhead bugs per earhead. Natural enemies, particularly coccinellid beetles and spiders, were also recorded weekly from the same sampling units.

### 2. Influence of meteorological parameters on pest incidence

Daily meteorological data on maximum and minimum temperature (°C), morning and evening relative humidity (%), and rainfall (mm) were obtained from the meteorological observatory of PAJANCOA & RI, Karaikal.

Weekly averages were computed to correspond with pest observations.

The relationship between pest incidence and weather parameters was analyzed using Pearson's correlation coefficient:

$r = \Sigma[(xi - \bar{x})(yi - \bar{y})] / \sqrt{[\Sigma(xi - \bar{x})^2 \times \Sigma(yi - \bar{y})^2]}$

where $r$ is the correlation coefficient, $x$ and $y$ are individual observations of weather parameters and pest population, and $\bar{x}$ and $\bar{y}$ are their respective means.

To determine the combined effect of weather variables on pest incidence, multiple linear regression analysis was performed:

$Y=a+b1X1+b2X2+b3X3+\cdots+bnXn$

where $Y$ represents pest population, $a$ is the intercept, $b_1, b_2, \ldots b_n$ are regression coefficients, and $X_1, X_2, \ldots X_n$ represent independent variables such as temperature, relative humidity, and rainfall.

The coefficient of determination ($R^2$) was used to quantify the proportion of variation in pest incidence explained by the independent variables. Statistical significance was tested at the 5% probability level using standard statistical procedures.

## Results and Discussion

### 1. The shoot fly, *Atherigona pulla* (Wiedemann)

Shoot fly incidence commenced during the 9th MSW (fourth week of February) with 11 maggots per 50 plants in Summer and during the 36th MSW (first week of September) with 17 maggots per 50 plants in *Kharif*. The peak incidence was recorded during the 12th MSW (fourth week of March) with 49 maggots per 50 plants, declining to 14 maggots per 50 plants by the 14th MSW in Summer. In *Kharif*, the peak occurred during the 38th MSW (third week of September) with 47 maggots per 50 plants, followed by a decline to 21 maggots per 50 plants by the 41st MSW. These findings corroborate earlier reports of peak shoot fly activity during March and higher infestation in post-rainy season crops sown during September–October (Biradar *et al.* 2011; Taneja *et al.* 1986) [2, 26] (Table 1) (Fig 1).

Correlation analysis indicated that shoot fly exhibited a significant negative association with minimum temperature (r = −0.61) and non-significant negative correlations with other weather parameters during Summer 2024, whereas in *Kharif* 2024, it showed a significant positive correlation with maximum (r = 0.72) and minimum temperature (r = 0.70) and a significant negative correlation with morning (r = −0.71) and evening RH (r = −0.62). These results are in line with earlier reports (Khan *et al.*, 2024; Pawar *et al.*, 2015; Swathi *et al.*, 2022) [11, 19, 25] (Table 2) (Plate 1).

### 2. The pink stem borer, *Sesamia inferens* (Walker)

The incidence of pink stem borer was first observed during the 10th MSW (first week of March) with 24 larvae per 50 plants in Summer and during the 37th MSW (second week of September) with 21 larvae per 50 plants in *Kharif*. Peak populations were recorded during the 13th MSW (fourth week of March) with 49 larvae per 50 plants, declining to 15 larvae per 50 plants by the 18th MSW in Summer. In *Kharif*, the maximum population occurred during the 39th MSW (fourth week of September) with 49 larvae per 50 plants and declined to 10 larvae per 50 plants by the 43rd MSW. These observations are in agreement with earlier studies reporting peak activity in March, higher infestation in crops sown during late February to early March, and maximum damage during September followed by a decline towards late October (Zafar and Chaudhry 1979; Mahadevan and Chelliah 1986; Savithri and Prakash 2023) [16, 24, 27] (Table 1) (Fig 1).

Pink stem borer showed a significant negative correlation with evening RH (r = −0.58) during Summer and a significant positive correlation with minimum temperature (r = 0.62) during Kharif, while other relationships remained non-significant. Similar trends have been reported previously (Choudhary *et al.*, 2018; Savithri and Prakash, 2023) [24] (Table 2) (Plate 1).

### 3. The leaf folder, *Cnaphalocrocis medinalis* (Guenee) & The flea beetle, *Chaetocnema pusaensis* (Melsheimer)

Leaf folder incidence reached its peak during the 12th MSW (fourth week of March) with 115 larvae per 50 plants and declined to 14 larvae per 50 plants by the 17th MSW during Summer. In *Kharif*, the population increased gradually, reaching 102 larvae per 50 plants during the 39th MSW (fourth week of September), and declined to 10 larvae per 50 plants by the 43rd MSW. These results are consistent with earlier reports indicating peak incidence during September–October and around the 39th MSW, with higher infestation during *Rabi*/Summer and lower incidence during *Kharif* (Patnaik 2001; Chakraborty *et al.* 2011; Lingappa 1972) [4, 14, 18] (Table 1) (Fig 1).

Flea beetle incidence was observed from the 9th MSW (fourth week of February) with 40 beetles per 50 plants, reaching a peak during the 12th MSW (fourth week of March) with 135 beetles per 50 plants and declining to 20 beetles per 50 plants by the 17th MSW in Summer. In *Kharif*, the population peaked during the 39th MSW (fourth week of September) with 102 beetles per 50 plants and declined to 13 beetles per 50 plants by the 43rd MSW. These findings are supported by earlier studies reporting higher infestation during February–May and September–October (Hossain *et al.* 2012; Praveenkumar and Kandibane 2022) [8, 22] (Table 1) (Fig 1).

Leaf folder and flea beetle exhibited significant negative correlations with minimum temperature during Summer (r = −0.57 and −0.58, respectively) and significant positive correlations during *Kharif* (r = 0.69 and 0.61, respectively), with other parameters showing non-significant associations. These findings agree with earlier studies (Bhatnagar and Saxena, 1999; Raghavendra *et al.*, 2023) [1, 23] (Table 2 ) (Plate 1 & 2).

### 4. The bean aphids, *Aphis craccivora* (Koch)

Aphid population appeared during the 10th MSW (first week of March) with 78 aphids per 50 plants in Summer and during the 37th MSW with 63 aphids per 50 plants in Kharif. The population peaked during the 14th MSW (first week of April) with 276 aphids per 50 plants and declined to 79 aphids per 50 plants by the 18th MSW in Summer. In Kharif, peak population was recorded during the 40th MSW (first week of October) with 220 aphids per 50 plants, declining to 68 aphids per 50 plants by the 44th MSW. These results are in accordance with earlier findings reporting aphid incidence from March–April in Summer and August–November in *Kharif* (Borad *et al.* 2020; Kore *et al.* 2013) [3, 12] (Table 1) (Fig 1).

Aphid population showed a significant negative correlation with evening RH (r = −0.60) during Summer, while no significant relationships were observed during Kharif. These results are consistent with previous reports indicating weak or non-significant associations with weather parameters

(Patil *et al.*, 2015; Savithri and Prakash, 2023) [17, 24] (Table 2) (Plate 2).

**5. The earhead bugs, *Leptocorisa acuta* (Thunberg)**

The incidence of earhead bugs peaked during the 16th MSW (third week of April) with 156 bugs per 50 plants in Summer and during the 43rd MSW (fourth week of October) with 126 bugs per 50 plants in *Kharif*. The lowest populations were recorded during the 19th MSW (second week of May) with 36 bugs per 50 plants and the 45th MSW (second week of November) with 41 bugs per 50 plants, respectively. These observations are consistent with earlier reports indicating peak populations during September–October in *Kharif* and March–April in Summer, followed by a decline towards November and May (Kumar *et al.* 2023a; Ghule *et al.* 2005) [7] (Table 1) (Fig 1).

Earhead bugs exhibited significant positive correlations with maximum (r = 0.68) and minimum temperature (r = 0.67) during Summer, whereas during *Kharif,* they showed significant positive correlations with morning (r = 0.69) and evening RH (r = 0.72) and a significant negative correlation with maximum temperature (r = −0.65). These findings are supported by earlier studies (Das *et al.,* 2023; Lisha *et al.,* 2020) [6, 15] (Table 2) (Plate 2).

Multiple linear regression analysis indicated that weather parameters collectively explained a substantial proportion of variation in pest incidence in proso millet across seasons. During Summer 2024, the model accounted for 94% (shoot fly), 59% (pink stem borer), 81% (leaf folder), 80% (flea beetle), 56% (aphids) and 60% (earhead bugs), while in *Kharif* 2024, the corresponding values were 80, 61, 74, 65, 59 and 80%, respectively. The higher coefficient of determination observed for shoot fly, leaf folder and flea beetle indicate a strong dependence on prevailing weather conditions, particularly temperature and relative humidity, which are known to regulate insect development, survival and activity. In contrast, the relatively moderate variation explained in pink stem borer and aphids suggests that their population dynamics are influenced not only by weather factors but also by host plant phenology, crop stage and biotic interactions. The consistently high explanatory power for shoot fly across seasons further highlights its sensitivity to climatic variability, while the moderate response of stem borer may be attributed to its internal feeding habit, which buffers it from external environmental fluctuations. Overall, the results emphasize that weather-based models are highly effective in predicting the incidence of certain pests, whereas incorporation of additional ecological factors is necessary for improving prediction accuracy in others, thereby aiding in the development of more reliable pest forecasting and management strategies (Table 3).

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

| Meteorological standard week (MSW) | Proso millet pests | | | | | |
|---|---|---|---|---|---|---|
| | Shoot fly | Pink stem borer | Leaf folder | Flea beetle | Aphids | Earhead bugs |
| **Summer 2024** | | | | | | |
| 8th (Feb 22-25) | 0 | 0 | 0 | 0 | 0 | 0 |
| 9th (Feb 26- Mar 04) | 11 | 0 | 32 | 40 | 0 | 0 |
| 10th (Mar 05- 11) | 24 | 24 | 67 | 79 | 78 | 0 |
| 11th (Mar 12-18) | 47 | 37 | 95 | 110 | 176 | 0 |
| 12th (Mar 19-25) | 49 | 43 | 115 | 135 | 200 | 0 |
| 13th (Mar 26-Apr 1) | 38 | 49 | 94 | 102 | 236 | 40 |
| 14th (Apr 2-8) | 14 | 44 | 76 | 88 | 276 | 79 |
| 15th (Apr 9-15) | 0 | 37 | 58 | 67 | 187 | 98 |
| 16th (Apr 16-22) | 0 | 31 | 25 | 38 | 121 | 156 |
| 17th (Apr 23-29) | 0 | 25 | 14 | 20 | 110 | 102 |
| 18th (Apr 30- May 6) | 0 | 15 | 0 | 0 | 79 | 84 |
| 19th (May 7- 13) | 0 | 0 | 0 | 0 | 0 | 36 |
| ***Kharif* 2024** | | | | | | |
| 35th (Aug 29- Sep 2) | 0 | 0 | 0 | 0 | 0 | 0 |
| 36th (Sep 3-9) | 17 | 0 | 13 | 18 | 0 | 0 |
| 37th (Sep 10-16) | 30 | 21 | 45 | 43 | 63 | 0 |
| 38th (Sep 17-23) | 47 | 34 | 72 | 81 | 160 | 0 |
| 39th (Sep 24-30) | 42 | 49 | 102 | 102 | 181 | 0 |
| 40th (Oct 1-7) | 39 | 35 | 85 | 89 | 220 | 35 |
| 41st (Oct 8-14) | 21 | 23 | 57 | 58 | 170 | 79 |
| 42nd (Oct 15-21) | 0 | 16 | 24 | 30 | 103 | 103 |
| 43rd (Oct 22-28) | 0 | 10 | 10 | 13 | 92 | 126 |
| 44th (Oct 29- Nov 4) | 0 | 0 | 0 | 0 | 68 | 98 |
| 45th (Nov 5-11) | 0 | 0 | 0 | 0 | 0 | 41 |

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

| Sl. No. | Insects | Summer 2024 | | | | | *Kharif* 2024 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Temperature (°C) | | Relative humidity (%) | | Rainfall (mm) | Temperature (°C) | | Relative humidity(%) | | Rainfall (mm) |
| | | Maximum | Minimum | Morning | Evening | | Maximum | Minimum | Morning | Evening | |
| 1. | *A. pulla* | -0.39 | -0.61* | -0.01 | -0.28 | -0.31 | 0.72* | 0.70* | -0.71* | -0.62* | -0.41 |
| 2. | *S. inferens* | 0.11 | -0.17 | -0.36 | -0.58* | -0.41 | 0.46 | 0.62* | -0.43 | -0.35 | -0.20 |
| 3. | *C. medinalis* | -0.33 | -0.57* | -0.02 | -0.36 | -0.34 | 0.53 | 0.69* | -0.51 | -0.42 | -0.22 |
| 4. | *C. pusaensis* | -0.33 | -0.58* | -0.01 | -0.36 | -0.36 | 0.50 | 0.61* | -0.49 | -0.39 | -0.20 |
| 5. | *A. craccivora* | 0.19 | -0.10 | -0.38 | -0.60* | -0.36 | 0.16 | 0.29 | -0.12 | 0.01 | 0.10 |
| 6. | *L. acuta* | 0.68* | 0.67* | -0.49 | -0.25 | -0.02 | -0.65* | -0.56 | 0.69* | 0.72* | 0.47 |

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

**Table 3:** Multiple linear regression between meteorological parameters and the population of proso millet pests during Summer and *Kharif* 2024

| | | Summer 2024 | | *Kharif* 2024 | |
|---|---|---|---|---|---|
| Sl.N. | Variables(Y) | Regression equation | $R^2$ value | Regression equation | $R^2$ value |
| 1. | *A. pulla* | $Y= 1101.62+0.50X_1-2.07X_2-1.35X_3+0.54X_4-0.02X_5$ | 0.94** | $Y= -371.77+1.33X_1+0.24X_2-0.86X_3+1.16X_4+0.54X_5$ | 0.80** |
| 2. | *S. inferens* | $Y= 651.83+0.65X_1-1.37X_2-0.87X_3+0.10X_4-0.08X_5$ | 0.59* | $Y= -457.15+0.57X_1+0.92X_2-0.73X_3+1.21X_4+0.48X_5$ | 0.61* |
| 3. | *C. medinalis* | $Y= 2037.98+0.54X_1-1.90X_2-1.08X_3+0.27X_4-0.07X_5$ | 0.81** | $Y= -1750.95+0.48X_1+0.94X_2-0.59X_3+0.73X_4+0.70X_5$ | 0.74** |
| 4. | *C. pusaensis* | $Y= 2220.77+0.58X_1-1.91X_2-1.06X_3+0.29X_4-0.04X_5$ | 0.80** | $Y= -908.21+0.83X_1+0.67X_2-0.83X_3+1.21X_4+0.58X_5$ | 0.65* |
| 5. | *A. craccivora* | $Y= 2557.19+0.84X_1-1.37X_2-0.65X_3-0.05X_4+0.06X_5$ | 0.56* | $Y= -2183.61+1.33X_1+0.49X_2-1.18X_3+2.48X_4+0.34X_5$ | 0.59* |
| 6. | *L. acuta* | $Y= -1136.0-0.08X_1+1.15X_2+0.45X_3-0.38X_4-0.16X_5$ | 0.60* | $Y= -175.62+0.25X_1-0.09X_2-0.49X_3+2.06X_4-0.68X_5$ | 0.80** |

* Significance at 0.05 per cent level ** Significance at 0.01 per cent level; X1 - Maximum temperature (ºC) X2 - Minimum temperature (ºC) X3 - Morning relative humidity (%) X4 - Evening relative humidity (%); X5 - Rainfall (mm)

PUPA ADULT

The shoot fly, *Atherigona pulla* (Wiedemann)

LARVA PUPA ADULT

The pink stem borer, *Sesamia inferens* (Walker)

The leaf folder, *Cnaphalocrocis medinalis* (Guenee)

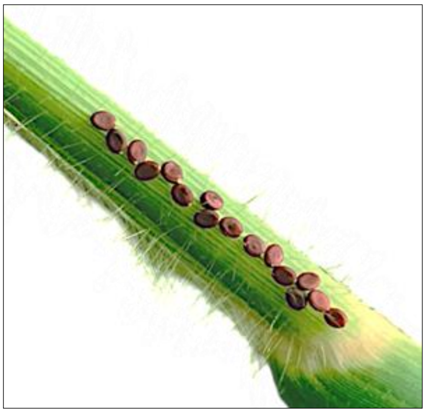
**Plate 1:** Pests of proso millet at PAJANCOA and RI, Karaikal, U.T. of Puducherry

GRUB ADULT

The flea beetle, *Chaetocnema pusaensis* (Melsheimer)

NYMPH ADULT

The bean aphids, *Aphis craccivora* (Koch)



EGG ADULT

The earhead bugs, *Leptocorisa acuta* (Thunberg)

**Plate 2:** Pests of proso millet at PAJANCOA and RI, Karaikal, U.T. of Puducherry

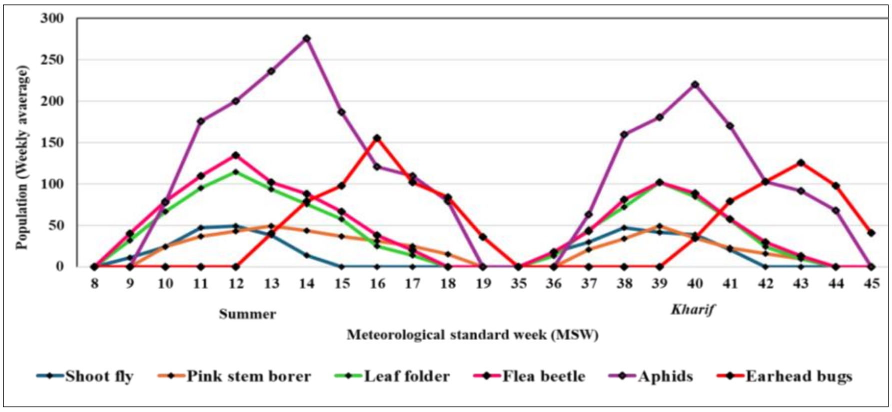



**Fig 1:** Population trend of proso millet pests during Summer and *Kharif* 2024

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