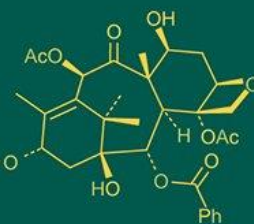
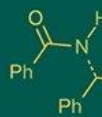
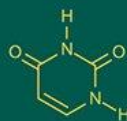
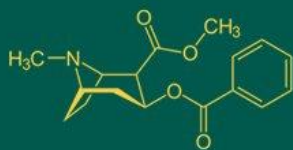


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Amruth S

Department of Agricultural
Entomology, University of
Agricultural Sciences, GKVK,
Bengaluru, Karnataka, India

Prabhu C Ganiger

PC unit, ICAR-AICRP on
Small millets, Zonal
Agricultural Research Station,
UAS, GKVK, Bengaluru,
Karnataka, India

Krishana

Department of Agricultural
Entomology, University of
Agricultural Sciences, GKVK,
Bengaluru, Karnataka, India

Corresponding Author:**Amruth S**

Department of Agricultural
Entomology, University of
Agricultural Sciences, GKVK,
Bengaluru, Karnataka, India

The population dynamics of insect pests of little millet, *Panicum sumatrense* and their natural enemies

Amruth S, Prabhu C Ganiger and Krishana

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Abstract

The study on the population dynamics of insect pests and their natural enemies in little millet was conducted at the Zonal Agricultural Research Station (ZARS), UAS, GKVK, Bengaluru, Karnataka, during the *Kharif* season of 2023 and 2024. Insect pest populations and their natural enemies were monitored from September to November, 2023 and July to September, 2024, with a correlation established between dead-heart caused by major pest *i.e* shoot fly and the corresponding weather data collected during the study period. During *Kharif* 2023 and 2024, the population dynamics of insect pests and their natural enemies in little millet were monitored from germination to harvest. In 2023, shoot fly (*Atherigona pulla*) caused dead-heart damage ranging from 0.00% to 31.11%, peaking in mid-September (38th SMW) and declining to 11.11% by late October (43rd SMW). Other pests, including weevils, grasshoppers and aphids, exhibited similar population trends. Weevils peaked at 0.89 per plant in September (39th SMW), while grasshoppers and aphids reached their highest populations of 0.67 per metre row and 0.56 per leaf, respectively, in early to mid-September, declining by harvest. Natural enemies, including coccinellids and spiders, remained active throughout the season, with peaks of 0.56 per plant for coccinellids and 0.89 per plant for spiders. Correlation analysis revealed that shoot fly infestation had a significant positive relationship with minimum temperature ($r = 0.778$), while correlations with other environmental factors, such as relative humidity, rainfall and sunshine hours, were non-significant. In 2024, shoot fly infestation peaked at 38.89% in mid-July (30th SMW) and declined to 17.78% by late August. Similar trends were observed for weevils, grasshoppers and aphids, while coccinellids and spiders peaked at 0.44 and 0.56 per plant, respectively. Correlation analysis in 2024 showed a significant negative relationship between shoot fly infestation and minimum temperature ($r = -0.690^*$), with other factors exhibiting non-significant correlations.

Keywords: Little millet, shoot fly (*Atherigona pulla*), population dynamics, insect pests

Introduction

Little millet (*Panicum sumatrense*) (*miliare*) is a key cereal crop belonging to the Poaceae family, especially in the arid and semi-arid regions of Asia and Africa, where it serves as a staple food for many communities. Known for its resilience to drought and poor soil conditions (Sharma *et al.*, 2016) ^[14]. As global food security becomes increasingly important, enhancing the cultivation of resilient crops like little millet is essential for sustaining rural livelihoods and improving nutritional outcomes. It is known by various local names: Saame or Savi in Kannada, Kutki in Hindi, Samai in Tamil, Samulla in Telugu and Channa in Malayalam (Kundra *et al.*, 2019) ^[10].

Furthermore, to integrate millets into the mainstream, highlight their nutritional benefits, and encourage their cultivation, the Government of India has designated 2018 as the "Year of Millets." Additionally, the FAO Committee on Agriculture forum has proclaimed 2023 as the "International Year of Millets."

Kishore (1996) ^[8] reported 116 pests that infest pearl millet, in which major pest includes shoot fly (*Atherigona approximata*), stem borer (*Chilo partellus*), grey weevil (*Mylocerus* spp.), leaf roller (*Marasmia trapezalis*), sugarcane leaf hopper (*Pyrilla perpusilla*), fulgorid (*Peregrinus maidis*), hairy caterpillars (*Amsacta* spp.), ear-head caterpillars (*Eublemma silicula* and *Cryptoblades gnidiella*), white grub (*Holotrichia consanguinea*) and midge (*Geromyia penniseti*), pose significant challenges in the field. The shoot fly alone can cause grain losses up to 20-50 per cent. Whereas Ganiger *et al.* 2024 ^[5], worked on taxonomic identification of maggot and adult stages of kodomillet shoot fly, *Atherigona simplex*.

The highly diverse agro-ecosystem in millet-growing regions directly and indirectly affects grain yield through various biotic and abiotic factors that serve as significant constraints to production. A survey of pest incidence on millets indicated that crops are impacted by 50 to 55 different pest species across various regions and seasons, from sowing to harvesting and storage. Within this complex pest landscape, shoot flies from the genus *Atherigona* (Muscidae) are particularly harmful, leading to considerable yield losses, especially in little millet during the 4 to 5 leaf stage (Nageshchandra and Ali, 1983) [11]. Fletcher (1914) [3] was the first to report the incidence of shoot flies in South India.

Population dynamics refers to the study of how pest populations change over time in response to environmental factors and agricultural practices (Ghosh *et al.*, 2018) [6]. By analyzing these dynamics, patterns can be identified and potential outbreaks can be predicted, allowing farmers to implement timely and effective pest control measures.

Materials and Methods

The research was conducted to collect data on the occurrence of insect pests at various growth stages of little millet and their natural predators during the *Kharif* season of 2023 and 2024 at ZARS, UAS, GKVK, Bengaluru. The little millet variety TNAU-186 was sown in 3 x 4 m plot with a plant spacing of 30 x 10 cm.

Observations recorded

Observation was recorded every week after 15 days of sowing, where in 10 plants are considered for each observation, such three observations was recorded for dead-hearts and natural enemies like predators and parasitoids. The observations were recorded till harvesting stage of the crop. Data obtained on population dynamics of insect pests and their natural enemies in little millet and infestation of major pest was correlated with Standard Meteorological Week (SMW).

Method of observation

1. Shoot fly: The observations were recorded from 30 plants within the net plot by counting the number of dead hearts to total number of plants selected and the results were expressed as a percentage using the following formula

$$\text{Per cent dead-heart} = \frac{\text{Number of plants showing dead-heart symptoms}}{\text{Total number of plants in each plot}} \times 100$$

2. Grasshoppers: The population of grasshoppers was observed as the number of grasshoppers per one metre row in a plot.

3. Weevils: The weevil population was recorded as number of weevils per plant on 10 randomly selected plants.

4. Aphids: The aphid population was recorded as number of aphids per leaf on 10 randomly selected plants.

5. Natural enemies: The population of predators *i.e.*, coccinellids and spiders was counted from 10 randomly selected plants at weekly intervals and expressed as number of natural enemies per plant.

Results and Discussion

The population dynamics of insect pests of little millet and their natural enemies during *Kharif* 2023 and 2024

1. Shoot fly, *Atherigona pulla* (Wiedemann)

During *kharif* 2023, the shoot fly infestation in little millet ranged from 0.00 to 31.11% dead-hearts, starting in the 36th SMW with 21.11% incidence. It peaked at 31.11% in the 38th SMW (third week of September) and declined to 11.11% by the 43rd SMW (last week of October). The present findings are in corroborates with Saxena *et al.* (2022) [13], they revealed that the peak incidence of shoot fly infestation was observed during 29th and 30th standard meteorological week (SMW). Whereas, Choudhary *et al.* (2018) [1], who revealed that infestations of shoot fly began on the 31st standard meteorological week (SMW) and lasted throughout the crop season. Later, it gradually increased, reaching a peak in the 33rd (2014) and 34th (2015) SMWs with plant infestations of 16.67 and 20.00 per cent, respectively. The variations may be due to change in the time of sowing.

During *kharif* 2024, the shoot fly infestation in little millet ranged from 0.00 to 38.89% dead-hearts, starting in the 28th SMW (first week of July) with 27.78% incidence. The infestation peaked at 38.89% in the 30th SMW (third week of July) and declined to 17.78% by the 35th SMW (last week of August). The present findings were more or less similar to that of Choudhary *et al.* (2018) [1], who revealed that infestations of shoot fly began on the 31st Standard Meteorological Week (SMW) and lasted throughout the crop season. Later, it gradually increased, reaching a peak in the 33rd (2014) and 34th (2015) SMWs with plant infestations of 16.67 per cent and 20.00 per cent, respectively. The present findings corroborate with Saxena *et al.* (2022) [13], they revealed that the peak incidence was observed during 29th and 30th Standard Meteorological Week (SMW).

2. Weevil, *Mylocherus discolor* (Schoenherr) and *Mylocherus viridanus* (Fabricius)

During *kharif* 2023, the weevil populations started at 0.33 per plant in the 37th SMW (second week of September). The peak population of 0.89 per plant was observed during the 39th SMW (fourth week of September). The population gradually declined to 0.11 per plant by the 42nd SMW (third week of October). Whereas in 2024, Weevil populations began at 0.11 per plant in the 28th SMW (first week of July), peaking at 0.56 per plant during the 30th SMW (third week of July). The population gradually declined and reached a minimum of 0.11 per plant by the 33rd SMW (second week of August).

3. Grasshopper, *Oxya hyla* (Serville) and *Chrotogonus oxypterus* (Blanchard)

In *Kharif* 2023, Grasshopper populations began in the 36th SMW (first week of September) at 0.33 per metre row. The population peaked at 0.67 per metre row in the 37th SMW (second week of September) and declined to 0.11 in the 43rd SMW (fourth week of October). At harvest, the population stabilized at 0.22 grasshoppers per metre row. Whereas in 2024, Grasshopper populations started at 0.44 per metre row in the 28th SMW (first week of July). The population peaked in the 31st SMW (last week of July) and declined to 0.22 per metre row by the 36th SMW (first week of September). At

harvest, the population stabilized at 0.22 per metre row.

4. Aphid, *Hysteroneura setariae* (Thomas)

During kharif 2023, aphid populations were began with 0.22 per leaf in the 36th SMW (first week of September). The highest population of 0.56 aphids per leaf was recorded during the 37th SMW (second week of September). The population declined to 0.11 aphids per leaf by the 41st SMW (second week of October), with natural enemies such as coccinellids and spiders observed feeding on aphids. Whereas in kharif 2024, the aphid populations commenced at 0.22 per leaf in the 28th SMW (first week of July). The population peaked at 0.56 aphids per leaf during the 30th SMW (third week of July) and declined to 0.11 per leaf by the 33rd SMW (second week of August), with coccinellids and spiders feeding on them.

Natural enemies

Coccinellids, *Coccinella transversalis* (Fabricius) and *Coccinella septempunctata* (Linnaeus)

Spiders, (*Thomisus* sp.)

In Kharif 2023, Coccinellids were first observed in the 36th SMW (first week of September) at 0.22 per plant, peaking at 0.56 per plant during the 38th SMW (third week of September). Their activity persisted until the 43rd SMW (last week of October) at 0.11 per plant. Spiders first appeared at 0.11 per plant in the 36th SMW, reaching a peak of 0.89 per plant in the 39th SMW (fourth week of September). Whereas in Kharif 2024, Coccinellids were first observed in the 28th SMW (first week of July) at 0.11 per plant, peaking at 0.44 per plant in the 30th SMW (third week of July). Their activity persisted until the 35th SMW (last week of August) at 0.11 per plant. Spiders began at 0.11 per plant in the 28th SMW and peaked at 0.56 per plant in the 30th SMW (third week of July).

Correlation matrix between dead-heart and meteorological variables during Kharif 2023 and 2024

During kharif 2023, the per cent infestation due to shoot fly revealed a significant positive correlation with minimum temperature ($r = 0.778$), a non-significant positive correlation with afternoon relative humidity ($r = 0.574$) and total rainfall ($r = 0.509$) and a non-significant negative correlation with maximum temperature ($r = -0.491$), morning relative humidity ($r = -0.617$) and sunshine hours ($r = -0.269$). The present findings more or less showed similar to that Saxena *et al.* (2022) [13] revealed that dead-heart ($r = 0.68$) and adult flies ($r = 0.79$) showed positive significant correlation with minimum temperature. Karibasavaraja and Balikai (2006) [7], who reported positive association between egg load and dead-hearts with rainfall. Delobel and Lubega (1984) [2], Gahukar (1987) [4] and Kumar *et al.* (2015) [9], also reported similar results. However, Rai and Wakgari (2012) [12] revealed that rainfall had very poor non-significant positive correlation with infestation ($r = 0.15$). Whereas during kharif 2024, The per cent infestation due to shoot fly revealed a significant negative correlation with minimum temperature ($r = -0.690^*$), a non-significant positive correlation with morning relative humidity ($r = 0.537$) and total rainfall ($r = 0.203$) and a non-significant negative correlation with maximum temperature ($r = -0.396$), afternoon relative humidity ($r = -0.185$) and sunshine hours ($r = -0.255$). The present findings are similar with reports of Kumar *et al.* (2015) [9] which revealed that the minimum temperature during 14 days after emergence of the crop showed negatively significant. Whereas, Swathi *et al.* (2022) [15] showed significant negative correlation with minimum temperature, evening RH ($r = -0.513$, $r = -0.476$) and non-significant negative correlation with maximum temperature ($r = -0.307$) and non-significant positive influence with morning RH ($r = 0.298$) in little millet.

Table 1: Correlation matrix between dead-heart and meteorological variables during Kharif 2023

Parameters	X ₁	X ₂	X ₃	X ₄	X ₅	X ₆	R ²
Y -Dead-heart (%)	-0.491	0.778*	-0.617	0.574	-0.269	0.509	
X ₁ -Maximum temperature	1.000	-0.160	-0.025	-0.720*	0.672*	-0.218	
X ₂ -Minimum temperature		1.000	-0.496	0.580	-0.382	0.498	0.989
X ₃ -Morning relative humidity			1.000	0.101	-0.188	-0.316	
X ₄ -Afternoon relative humidity				1.000	-0.811**	0.459	
X ₅ -Sunshine hours					1.000	-0.579	
X ₆ -Rainfall						1.000	

* Correlation is significant at the 0.05 level (2-tailed); ** Correlation is significant at the 0.01 level (2-tailed); r^2 = Regression

Table 2: Population dynamics of insect pests of little millet and their natural enemies during Kharif 2023

Particulars		Insect Pests				Natural enemies	
Month	SMW	Per cent dead-heart	Grasshoppers/metre row	Weevils/plant	Aphids/leaf	Coccinellids/plant	Spiders/plant
September	36	21.11	0.33	0.00	0.22	0.22	0.11
	37	28.89	0.67	0.33	0.56	0.33	0.22
	38	31.11	0.56	0.33	0.33	0.56	0.67
	39	24.44	0.33	0.89	0.22	0.44	0.89
October	40	18.89	0.22	0.22	0.22	0.33	0.11
	41	17.78	0.33	0.11	0.11	0.33	0.22
	42	12.22	0.22	0.11	0.00	0.22	0.11
	43	11.11	0.11	0.00	0.00	0.11	0.00
November	44	0.00	0.22	0.00	0.00	0.00	0.00

SMW: Standard Meteorological Week

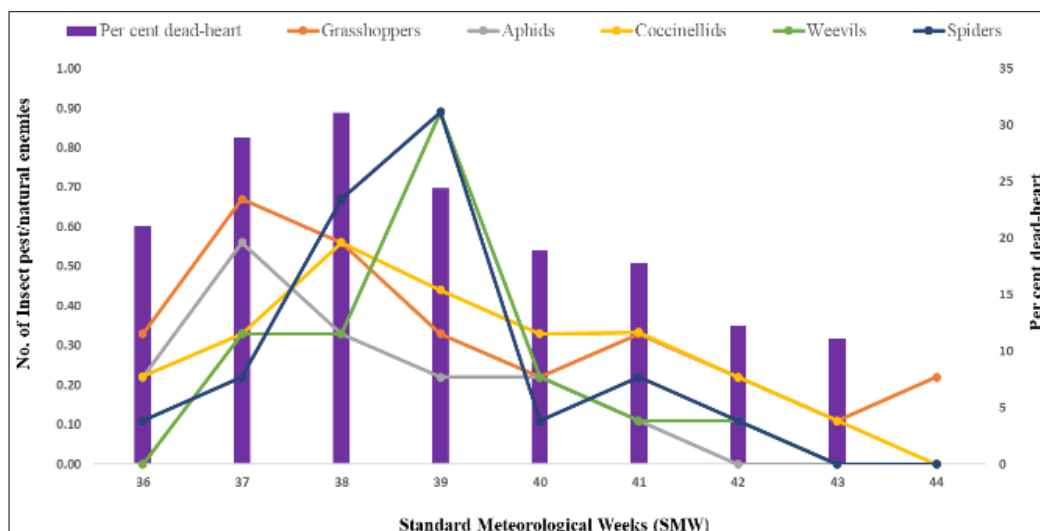


Fig 1: The population dynamics of insect pests and natural enemies in little millet during *Kharif 2023*

Table 3: Correlation matrix between dead-heart and meteorological variables during *Kharif 2024*

Parameters	X ₁	X ₂	X ₃	X ₄	X ₅	X ₆	R ²
Y -Dead-heart (%)	-0.396	-0.690*	0.537	-0.185	-0.255	0.203	0.937
X ₁ -Maximum temperature	1.000	0.524	-0.318	-0.443	0.942**	0.409	
X ₂ -Minimum temperature		1.000	-0.310	-0.185	0.419	0.123	
X ₃ -Morning relative humidity			1.000	-0.017	-0.281	-0.059	
X ₄ -Afternoon relative humidity				1.000	-0.593	0.077	
X ₅ -Sunshine hours					1.000	0.251	
X ₆ -Rainfall						1.000	

* Correlation is significant at the 0.05 level (2-tailed); ** Correlation is significant at the 0.01 level (2-tailed); r² = Regression.

Table 4: Population dynamics of insect pests of little millet and their natural enemies during *Kharif 2024*

Particulars		Insect Pests				Natural enemies	
Month	SMW	Per cent dead-heart	Grasshoppers/metre row	Weevils/plant	Aphids/leaf	Coccinellids/plant	Spiders/plant
July	28	27.78	0.44	0.11	0.22	0.11	0.11
	29	32.22	0.56	0.33	0.33	0.33	0.33
	30	38.89	0.44	0.56	0.56	0.44	0.56
	31	37.78	0.89	0.44	0.22	0.22	0.33
August	32	34.44	0.56	0.22	0.22	0.11	0.22
	33	21.11	0.33	0.11	0.11	0.22	0.11
	34	18.89	0.22	0.00	0.00	0.11	0.11
	35	17.78	0.22	0.00	0.00	0.11	0.00
September	36	0.00	0.22	0.00	0.00	0.00	0.00

SMW: Standard Meteorological Week

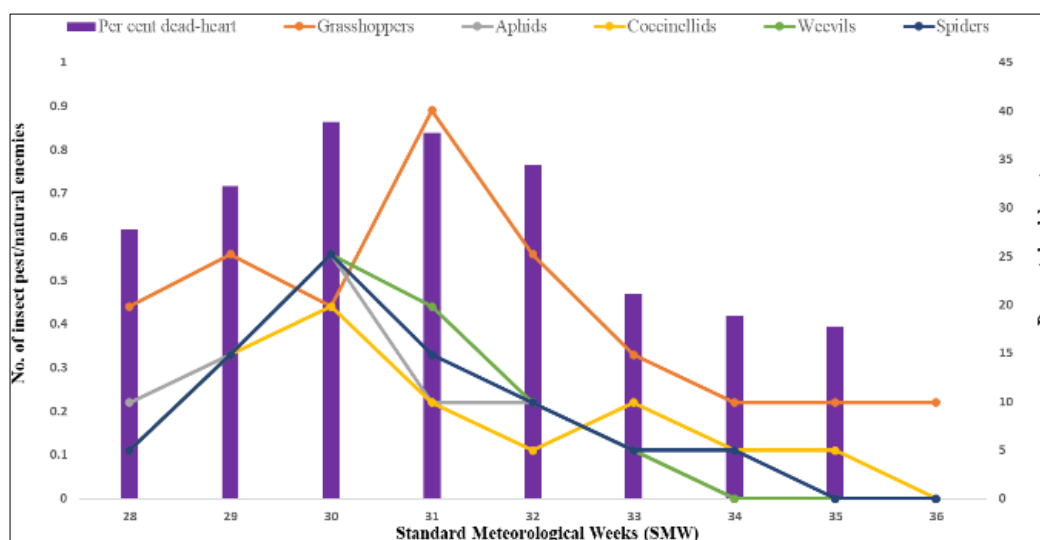


Fig 2: The population dynamics of insect pests and natural enemies in little millet during *Kharif 2024*

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