



# Population Fluctuation of Various Insect Pests of Summer Sorghum in North Gujarat, India

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**Abstract:** The present study was conducted during the summer of 2024 at the Agronomy Instructional Farm, Sardarkrushinagar Dantiwada Agricultural University (SDAU), Sardarkrushinagar, Gujarat, to investigate the population dynamics of major insect pests and natural enemies of sorghum, and their relationships with abiotic factors. Observations on pest incidence were recorded weekly from crop emergence to harvest using six quadrats, with five plants examined in each quadrat. The results revealed that shoot fly (*Atherigona soccata*) damage reached a maximum of 40% dead hearts during the 15<sup>th</sup> standard meteorological week (SMW), while stem borer (*Chilo partellus*) infestation peaked at 40.00% during the 19<sup>th</sup> SMW. The shoot fly complex, including *Ectecephala* spp. and *Oscinella* spp., showed peak activity during the 17<sup>th</sup> SMW. Among foliage feeders, ash weevil population reached a maximum of 0.73 weevils' plant<sup>-1</sup> during the 18<sup>th</sup> SMW, while leafhopper population peaked at 0.56 hoppers plant<sup>-1</sup> during the 21<sup>st</sup> SMW. The natural enemy, like spiders, attained a maximum population of 0.23 spiders' plant<sup>-1</sup> during the 18<sup>th</sup> SMW. Correlation analysis indicated a significant negative relationship between wind speed and shoot fly incidence, whereas bright sunshine hours showed a significant positive correlation with stem borer and leafhopper populations. Maximum relative humidity was positively associated with spider abundance.

**Keywords:** Sorghum, Insect pests, Seasonal incidence, Abiotic factors, Correlation, Shoot fly complex, Stem borer.

## 1. INTRODUCTION

Sorghum [*Sorghum bicolor* (L.) Moench] (2n=20) belongs to the grass family (Poaceae) and is an important cereal crop in India. It is popularly known as jowar, great millet, Indian millet, milo, durra and shallu. Sorghum is a climate-smart C<sub>4</sub> crop that can produce grain and fodder in harsh environments under low-input conditions, delivering high net returns. In India, the major sorghum-producing states are Maharashtra, Karnataka, Madhya Pradesh, Andhra Pradesh, Telangana, Tamil Nadu, Gujarat, Uttar Pradesh, Rajasthan and Haryana. In Gujarat, sorghum is cultivated across all three seasons: *kharif* (summer monsoon season), *rabi* (winter season), and *zaid* (short season between *rabi* and *kharif*), covering an area of about 42,660 ha, with a production of 66,130 tonnes and an average productivity of 1,550 kg ha<sup>-1</sup> (Anonymous, 2025). Sorghum fodder is highly nutritious, containing more than 50% digestible nutrients, along with approximately 8% protein, 2.5% fat, and 45% nitrogen-free extract. However, the sorghum crop is constrained by various insect species under both field and

stored conditions. Damage from these causes results in serious losses (Daware et al., 2011). In India, shoot fly and stem borer significantly reduce yield, at times as high as 100% in grain and crop stand (Padmaja et al., 2010). In the northern dry zone of Gujarat, the insect pests, namely, shoot fly: *Atherigona soccata* Rondani (Diptera: Muscidae), Sorghum stem borer: *Chilo partellus* Swinhoe (Crambidae: Lepidoptera), Ear headworm: *Helicoverpa armigera* (Noctuidae: Lepidoptera) and aphids: *Melanaphis sacchari* (Zehntner) are the important regular pests. The losses due to shoot fly alone were to the tune of 22.11 to 83.94% (Jotwani & Sukhani, 1971; Mote et al., 1981 and 1982). Sorghum stem borer, *C. partellus* (Crambidae; Lepidoptera) is one of the most important pests in Asian and African countries (Arabjafari & Jalali, 2007). Among sucking pests, the aphid *M. sacchari* (Zehntner) (commonly known as the sugarcane aphid) is becoming a constraint in rabi sorghum-growing areas. The aphid affects not only grain and fodder yields but also fodder quality. Sorghum aphid caused 23-70% grain loss and 20% fodder yield loss, and led to deterioration of

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fodder quality (Balikai & Lingappa, 2002). The earlier authors also found that biotic and abiotic factor plays crucial role in the population build-up of insect pests and predators.

**2. MATERIAL AND METHODS**

**2.1. Experimental Site and Season**

Agronomy Instructional Farm, SDAU, Sardarkrushinagar, during the summer season of 2024. The experimental site is loamy-sandy and supports the plant stand with sprinkler irrigation. Overall, the study highlights that abiotic factors significantly influence pest and natural enemy dynamics in sorghum. Understanding these relationships can help predict pest outbreaks and develop effective, timely pest management strategies for sustainable sorghum production.

**2.2. Experiment Details**

Sorghum variety, Swarna, was raised as per the SDAU package of practices, and Fixed Plot Observational Design was used for this study. The crop was sown in the 1<sup>st</sup> week of March and kept free of insecticide sprays. The crop was sown in a plot measuring 9 m × 7.5 m with a spacing of 45 cm row to row and 15 cm plant to plant.

**2.3. Observation Procedure**

Observations were recorded from the initial occurrence of insect pests up to the crop harvesting stage at different weekly intervals during morning hours between 6:00 am and 8:00 am from different quadrates. A total of six quadrats

were selected, with five plants per quadrat examined for pest incidence. The population of shoot fly and stem borer were recorded by their damage symptoms (dead heart) per cent, shoot fly complex recorded as (maggots/quadrates), ash weevil, leaf hoppers recorded as (number plant<sup>-1</sup>) and spiders were recorded as (number plant<sup>-1</sup>).

**2.4. Meteorological Observations**

Meteorological data from March to June 2024, viz., temperature (maximum and minimum), relative humidity, bright sunshine hours and wind speed, were obtained from the Department of Agricultural Meteorology, SDAU, Sardarkrushinagar, and are provided in Table 4.

**2.5. Statistical Analysis**

All the data collected during the study period were managed using Microsoft Excel version 2019 and analysed by the Statistical Program for Social Sciences (SPSS) version 32. The independent variables were the weather parameters like temperature (maximum and minimum), relative humidity, bright sunshine hours and wind speed at the study site. The dependent variables were pests' prevalence and infestation level. The association between the occurrence of insect pests on the crop at the study site was analysed using simple linear regression (Pearson, 1895).

**3. RESULTS AND DISCUSSION**

The incidence of various insect pests and natural enemies of sorghum is mentioned in Table 1, Figure 1, and their

**Table 1.** Seasonal incidence of sorghum insect pests and shoot fly species in relation to weather parameters during *summer 2024*

Month	WAS	SMW	Shoot fly	Stem borer	<i>Etecephala</i> spp	<i>Oscinella</i> spp	Ash weevil	Leaf hopper	Spider
			Dead heart (%)	Maggots / plant	Number plant <sup>-1</sup>	Number plant <sup>-1</sup>			
March 2024	1	12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	2	13	10.00	0.00	0.00	0.00	0.00	0.00	0.00
April 2024	3	14	16.67	0.00	0.00	0.63	0.16	0.00	0.03
	4	15	40.00	0.00	0.23	0.96	0.23	0.00	0.03
	5	16	36.67	6.66	0.86	1.73	0.60	0.10	0.10
	6	17	30.00	16.67	2.93	4.63	0.67	0.16	0.03
May 2024	7	18	23.33	26.67	0.63	3.50	0.73	0.23	0.23
	8	19	13.33	40.00	0.00	2.20	0.56	0.36	0.10
	9	20	6.67	33.33	0.00	0.73	0.50	0.50	0.03
	10	21	0.00	26.67	0.00	0.00	0.36	0.56	0.00
	11	22	0.00	20.00	0.00	0.00	0.26	0.36	0.00
June 2024	12	23	0.00	3.33	0.00	0.00	0.13	0.16	0.00
	13	24	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<b>Mean</b>			<b>13.59</b>	<b>13.33</b>	<b>0.35</b>	<b>1.10</b>	<b>0.32</b>	<b>0.18</b>	<b>0.04</b>

WAS: Weeks after sowing; SMW: Standard meteorological weeks

correlation with weather parameters is described in Table 2.

### 3.1. Shoot Fly and Its Complex Species

The shoot fly dead heart percentage gradually increased, peaking at 40.00 %dead hearts during the 15<sup>th</sup> SMW. A declining trend was observed from the 18<sup>th</sup> SMW, with the dead heart % reducing to 23.33%. This highlights that the early vegetative phase of sorghum is particularly vulnerable. A significant negative correlation ( $r = -0.625$ ) was observed between shoot fly dead heart incidence and wind speed. A positive but non-significant association was recorded between dead hearts and maximum relative humidity, while the remaining weather parameters had no significant influence on shoot fly dead heart formation. Monitoring of

the shoot fly complex population revealed that *Etecephala* spp maggots were first observed during the 15<sup>th</sup> SMW and attained their peak during the 17<sup>th</sup> SMW (4.63 maggots/quadrate) and completely declined during the 18<sup>th</sup> SMW to 0.63 maggots/quadrate. Correlation with weather parameters revealed that among all the weather parameters, bright sunshine hours ( $r = 0.067$ ) and maximum relative humidity ( $r = 0.081$ ) showed a positive and non-significant relation with *Etecephala* spp maggots. *Oscinella* spp were first observed during 14<sup>th</sup> SMW and attained their peak during 17<sup>th</sup> SMW with (4.63 maggots/quadrate), and a declining trend was observed during 19<sup>th</sup> SMW to 2.20 maggots/quadrate. Weather parameters correlation with

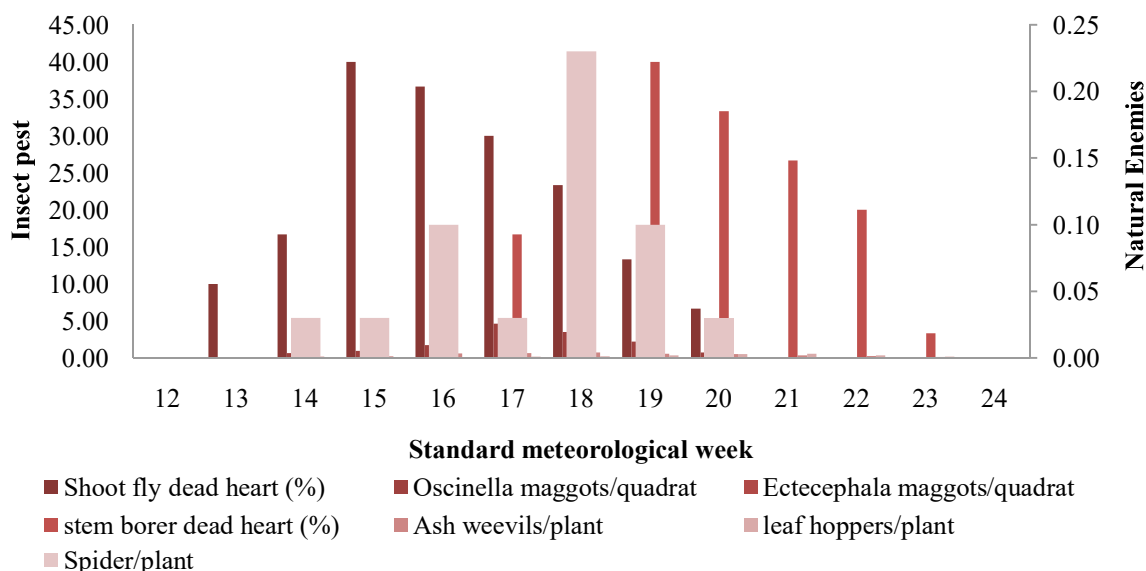


Figure 1. Graphical illustration of insect pests infesting summer sorghum 2024

Table 2. Correlation of weather parameters with insect pests infesting summer sorghum 2024

Insect pest/Natural enemy			Abiotic factors					
			Bright sunshine hours	Wind speed (Km h <sup>-1</sup> )	Temperature °C		Relative humidity (%)	
					Maximum	Minimum	Maximum	Minimum
Borers	Dead heart (%)	Shoot fly	-0.113 <sup>NS</sup>	-0.625*	-0.361 <sup>NS</sup>	-0.375 <sup>NS</sup>	0.103 <sup>NS</sup>	-0.097 <sup>NS</sup>
		Stem borer	0.611*	0.150 <sup>NS</sup>	0.400 <sup>NS</sup>	0.275 <sup>NS</sup>	-0.034 <sup>NS</sup>	-0.423 <sup>NS</sup>
Shoot fly species	Maggots / quadrat	<i>Etecephala</i>	0.067 <sup>NS</sup>	-0.382 <sup>NS</sup>	-0.343 <sup>NS</sup>	-0.180 <sup>NS</sup>	0.081 <sup>NS</sup>	-0.178 <sup>NS</sup>
		<i>Oscinella</i> spp	0.133 <sup>NS</sup>	-0.429 <sup>NS</sup>	-0.411 <sup>NS</sup>	-0.279 <sup>NS</sup>	0.234 <sup>NS</sup>	-0.215 <sup>NS</sup>
Foliage feeders	Number plant <sup>-1</sup>	Ash weevil	0.411 <sup>NS</sup>	-0.166 <sup>NS</sup>	-0.009 <sup>NS</sup>	0.073 <sup>NS</sup>	0.265 <sup>NS</sup>	-0.270 <sup>NS</sup>
		Leaf hopper	0.717**	0.355 <sup>NS</sup>	0.677*	0.573*	-0.052 <sup>NS</sup>	-0.300 <sup>NS</sup>
Natural Enemy	Number plant <sup>-1</sup>	Spiders	0.105 <sup>NS</sup>	-0.191 <sup>NS</sup>	-0.333 <sup>NS</sup>	-0.183 <sup>NS</sup>	0.571*	-0.045 <sup>NS</sup>

\* Significance at 5 % level of significance ( $r' = 0.553$ ); \*\* Significance at 1% level of significance ( $r' = 0.684$ )

*Oscinella* spp resulted in bright sunshine hours ( $r = 0.133$ ) and maximum relative humidity ( $r = 0.234$ ) showing a positive and non-significant relationship. The regression equation for shoot fly (*Atherigona soccata*), indicated that maximum temperature ( $X_1$ ), minimum temperature ( $X_2$ ), relative humidity ( $X_3$ ) and wind speed ( $X_6$ ) had negative effects on shoot fly incidence, whereas bright sunshine hours ( $X_4$ ) and rainfall ( $X_5$ ) showed a positive influence. The model explained about 60 % ( $R^2 = 0.60$ ) of the variation in shoot fly incidence, indicating a moderate influence of weather parameters. In the case of shoot fly complex species such as *Oscinella* spp. and *Ectecephala* spp., the regression models explained 61% ( $R^2 = 0.61$ ) and 76% ( $R^2 = 0.76$ ) of the variability in their populations, respectively. Among these, *Ectecephala* spp. showed the highest  $R^2$  value, suggesting that weather parameters had a relatively stronger influence on its population dynamics compared to other pests (Table 3).

### 3.2. Stem Borer

The stem borer dead heart percentage gradually increased, peaking at 40.00 % dead hearts during the 19<sup>th</sup> SMW. The dead heart percentage started to decline from the 21<sup>th</sup> SMW to 26.67 % dead hearts. The late vegetative phase and early reproductive stage of sorghum are particularly vulnerable to the stem borer. Correlation analysis indicated that bright sunshine hours showed a significant positive relationship ( $r = 0.611^*$ ) with stem borer dead heart % formation. Wind speed, maximum temperature and minimum temperature also exhibited positive but non-significant correlations ( $r = 0.150$ ,  $r = 0.400$  and  $r = 0.275$ , respectively) with stem borer dead heart incidence. For the stem borer (*Chilo partellus*), the regression model indicated that most of the weather variables had a positive influence on pest incidence except wind speed. However, the coefficient of determination was relatively low ( $R^2 = 0.47$ ), suggesting that other factors, such as crop stage or natural enemies, may also influence stem borer populations (Table 3).

### 3.4. Ash Weevil

Ash weevil population first observed during 14<sup>th</sup> SMW and lasted up to a week before harvest, with a population peak (0.73 weevils plant<sup>-1</sup>) during 18<sup>th</sup> SMW and a decline of population to 0.36 weevils plant<sup>-1</sup> during 21<sup>st</sup> SMW. A positive but non-significant relationship is established between bright sunshine hours ( $r = 0.411$ ), minimum temperature ( $r = 0.073$ ) and maximum relative humidity ( $r = 0.265$ ) with the ash weevil population. Similarly, the ash weevil population showed a weak association with weather parameters, as reflected by a lower coefficient of determination ( $R^2 = 0.47$ ). This indicates that abiotic factors had a limited influence on its population build-up during the study period (Table 3).

### 3.5. Leaf Hoppers

Leafhopper incidence was first recorded during the mid-vegetative stage (16<sup>th</sup> SMW) and persisted until harvest. The population peaked during the 21<sup>st</sup> SMW (0.56 hoppers plant<sup>-1</sup>) and declined in the 22<sup>nd</sup> SMW (0.36 hoppers plant<sup>-1</sup>). Correlation analysis revealed a highly significant positive association with bright sunshine hours ( $r = 0.717^{**}$ ), as well as significant positive correlations with maximum temperature ( $r = 0.677^*$ ) and minimum temperature ( $r = 0.573^*$ ). Wind speed showed a positive but non-significant relationship ( $r = 0.355$ ) with leafhopper population. Leaf hopper population exhibited the highest coefficient of determination ( $R^2=0.79$ ), suggesting that weather parameters strongly influenced leaf hopper population dynamics. Most of the weather variables showed a positive relationship with leaf hopper incidence, indicating favourable conditions for their multiplication (Table 3).

### 3.6. Spider

The natural enemy (spiders) was spotted during 14<sup>th</sup> SMW, where the peak population of spiders (0.23 spider plant<sup>-1</sup>) was attained during 18<sup>th</sup> SMW, and a decline of population was observed during 19<sup>th</sup> SMW, with (0.10 spider

**Table 3.** Multiple regression equation of insect pests of sorghum with various environmental factors infesting summer sorghum

Insect	Multiple regression equation	Coefficient of determination $R^2$
Shoot fly	$Y = 31.49 - 3.21X_1 - 11.30X_2 - 1.26X_3 + 2.42X_4 + 0.87X_5 - 0.67X_6$	0.60
<i>Oscinella</i> spp	$Y = 24.14 - 0.15X_1 - 0.95X_2 - 0.70X_3 + 0.66X_4 + 0.01X_5 - 0.16X_6$	0.61
<i>Ectecephala</i> spp	$Y = 24.35 - 0.13X_1 - 0.59X_2 - 0.64X_3 + 0.60X_4 + 0.06X_5 - 0.11X_6$	0.76
Stem borer	$Y = -69.70 + 4.59X_1 + 0.53X_2 + 1.13X_3 + 0.14X_4 + 0.17X_5 - 0.55X_6$	0.47
Ash weevil	$Y = 1.30 + 0.02X_1 - 0.13X_2 - 0.06X_3 + 0.08X_4 + 0.01X_5 - 0.02X_6$	0.47
Leaf hopper	$Y = -1.66 + 0.09X_1 + 0.01X_2 + 0.02X_3 + 0.09X_4 - 0.00X_5 - 0.00X_6$	0.79
Spider	$Y = -0.80 - 0.00X_1 - 0.01X_2 + 0.01X_3 - 0.00X_4 - 0.01X_5 - 0.00X_6$	0.61

**Table 4.** Details of weather parameters during *summer* 2024

Month	WAS	SMW	Bright sun shine hours	Wind speed	Maximum temperature	Minimum temperature	Maximum relative humidity	Minimum relative humidity
March 2024	1	12	9.8	1.6	35.0	14.5	69	35
	2	13	8.7	0.8	39.0	18.5	65	40
April 2024	3	14	9.3	1.9	36.5	20.0	73	48
	4	15	9.2	0.5	40.0	19.5	70	40
	5	16	8.5	2.4	39.0	22.5	76	43
	6	17	10.0	0.8	37.0	20.0	70	37
May 2024	7	18	10.5	1.9	36.5	21.0	89	42
	8	19	9.2	2.3	40.0	19.5	65	38
	9	20	11.0	2.3	43.5	25.0	66	34
	10	21	11.4	2.8	45.5	27.5	70	39
	11	22	11.5	5.1	42.0	27.0	78	39
June 2024	12	23	8.3	3.8	39.5	26.0	78	59
	13	24	6.9	4.0	42.0	26.0	74	44

WAS: Weeks after sowing; SMW: Standard meteorological weeks

plant<sup>-1</sup>). Maximum relative humidity showed a significant positive correlation ( $r = 0.571^*$ ) with spider population, and a positive but non-significant correlation ( $r = 0.105$ ) with bright sunshine hours. In the case of natural enemies, spiders showed a moderate relationship with weather parameters ( $R^2 = 0.61$ ). Although the regression coefficients were small, the model indicated that weather conditions had some influence on spider population dynamics in the sorghum ecosystem.

Overall, the regression analysis indicated that weather parameters had varying levels of influence on different insect pests and natural enemies in sorghum, with the strongest effect observed on leaf hopper populations. These findings highlight the importance of considering abiotic factors while predicting pest incidence and developing effective pest management strategies.

These findings are in line with Khan et al. (2024), as the shoot fly infestation peaked after the 4<sup>th</sup> week of sowing, and some of the weather parameters were not significant. The shoot fly infestation in terms of mean % of plants with dead heart formation had a significant negative correlation ( $r = -0.928$ ) with minimum temperature, the mean number of eggs per five plants had a significant negative correlation with minimum temperature ( $r = -0.834$ ) and average temperature ( $r = -0.909$ ). Further these results are in accordance with Meena and Bhamare (2024) in which the incidence of shoot fly complex like *A. soccata*, *Oscinella sp.* and *Ectecephala sp.* in case of time of incidence, number and their correlation revealed a significant negative relationship ( $-0.639^*$ ) between wind speed and the population of *A. soccata*

maggots and it was observed that no significant negative correlation between rainfall ( $r = -0.192$ ), maximum temperature ( $r = -0.473$ ), and minimum temperature ( $r = -0.371$ ) and the *A. soccata* maggot population. Nevertheless, there was no significant negative association between rainfall ( $r = -0.170$ ), maximum temperature ( $r = -0.391$ ), and lowest temperature ( $r = -0.200$ ) and the maggot population of *Oscinella spp.* on sorghum. Similar results were reported by Rakesh et al. (2022) in terms of time of pest occurrence, like shoot fly, leaf hoppers and their correlation with the abiotic factors and found that morning and evening relative humidity and rainfall showed a significant positive correlation ( $r = 0.642$ ,  $0.643$  and  $0.701$ , respectively) with the *A. biguttula biguttula* population. Further, minimum temperature showed a positive correlation ( $r = 0.280$ ) while the maximum temperature and evaporation showed, a negative correlation ( $r = -0.340$  and  $-0.451$ , respectively) with the *A. biguttula biguttula* population but statistically found to be non-significant. Integrating pest monitoring with abiotic factor analysis and crop development stages can improve pest management strategies for the sorghum crop.

#### 4. CONCLUSION

From the results, it is concluded that the shoot fly incidence was observed more in the vegetative stages of the crop period compared to later stages. The weather parameters, such as wind speed and maximum temperature, exerted varying degrees of influence on shoot fly dynamics across different growth stages of the crop's growing period. The significant negative correlations with wind speed

underscored its role in shaping population trends. Bright sunshine hours had played a vital role in the population dynamics of stem borer for their development and persistence at later stages of crop growth. None of the shoot fly complex (*Etecephala* spp and *Oscinella* spp) maggots were significantly influenced by weather parameters that prevailed during the early stages of crop growth. Ash weevil prevailed from the early stages of crop growth to the later stages and was not significantly influenced by any of the weather parameters. Bright sunshine hours showed a highly significant positive correlation with leaf hopper population, whose abundance was higher during the later stages of the cropping period. The maximum and minimum temperatures also affected pest survival and dispersal. Natural enemies like spiders also prevailed during the cropping period, from the initial to the later stages. Weather parameters like maximum humidity paved the way for spider survival.

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#### CRediT Authorship Contribution Statement

**Koosi Sai Thilak:** Conceptualization, Data collection, Methodology, Software, Writing original draft, Formal analysis, Tabulation, Data curation and Graphical Analysis.

**Bindu Panickar:** Supervision, Fund provision and visualization. **Chandaragi M K:** Supervision, Reviewing and editing. **Jyotika Purohit:** Reviewing and editing. **G**

**Balraj:** Reviewing and editing.

#### Conflict of interest

The authors have no conflicts of interest to declare.

#### Declaration of Generative AI and AI-assisted technologies in the writing process

The authors used Grammarly only for checking grammar and sentence structure during the preparation of this manuscript. No content was generated by AI tools. After using Grammarly, the authors carefully reviewed and edited

the entire manuscript themselves to ensure clarity and correctness. The authors take full responsibility for the content of the manuscript.

#### Data Availability Statement

The data supporting the findings of this study are available within the article (Tables 1-4 and Figure 1). Any additional datasets generated or analyzed during the current study are available from the corresponding author on reasonable request.

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