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**Research Article****Invasion and distribution range expansion of fall armyworm (*Spodoptera frugiperda*) in Azad Jammu & Kashmir, Pakistan**Iraj Yaseen<sup>1</sup>, Muhammad Imran<sup>1</sup>, Muhammad Awais Aslam<sup>2</sup>, Sohaib Ali Bashrat<sup>3</sup>, Mujtaba Ahmed Salik<sup>1</sup>, Ali Hassan<sup>1</sup>, Muhammad Saqlain Shad<sup>1</sup>, Rimsha Salim<sup>1</sup>, Naila Nazir<sup>1</sup><sup>1</sup>Department of Entomology, Faculty of Agriculture, University of Poonch Rawalakot Azad Jammu & Kashmir, Pakistan.<sup>2</sup>Department of Agriculture Azad Jammu & Kashmir.<sup>3</sup>Department of Information Systems, Holmes Institute, Melbourne, Australia.**ABSTRACT**

The Fall Armyworm (FAW) (*Spodoptera frugiperda*), a polyphagous pest, is rapidly expanding its distribution range and has invaded all areas of northern Pakistan. The current study was carried out to confirm the presence of FAW in the state of Azad Jammu & Kashmir (AJ&K). For this survey, three maize fields were selected from each district of administratively three divisions of AJ&K. This selection was based on surveying the FAW distribution and infestation and farmer reports on alarming maize yield losses due to large scale attack of FAW. Data on FAW infestation and invasion were collected from the extension wing, Department of Agriculture, AJ&K, and by fortnightly visits of selected localities. The overall results show the uniform distribution of FAW throughout the study area with very rapid dissemination to other areas and expansion of host range was also observed. This is the first study in Kashmir to report the occurrence of FAW in Kashmir. This study will be helpful for pest forecasting of FAW and planning management strategies to protect this important crop from the yield losses.

**Keywords:** Azad Jammu & Kashmir; fall armyworm; higher altitudes; maize; yield loss.

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**INTRODUCTION**

The Fall Armyworm (FAW), *Spodoptera frugiperda* (Lepidoptera: Noctuidae), is a significant and wide spread pest of maize, sorghum, rice, and other economically important crops (Nagoshi et al., 2007). It attained the status of significant global threat to agricultural productivity and food security. *S. frugiperda* is a notorious migratory pest native to the tropical and subtropical regions of the Americas (Suby et al., 2020) also native to parts of the New World, widespread across both North and South America (Carvalho et al., 2018). In 2016, the FAW was detected in sub-Saharan Africa, West African countries including Nigeria, Sao Tome and Principe, Togo, and Benin (Goergen et al., 2016; Sisay et al., 2018). It subsequently expanded to 44 African countries including Ethiopia, Tanzania, Uganda, Rwanda, Kenya etc due to its high migratory ability (Otim et al., 2018; Sisay et al., 2019; Elibariki et al., 2020; Matova et al., 2020). FAW spread rapidly across India, southeastern Asia and Australia (Goergen et al., 2016; Ganiger et al., 2018). Normally prevalent in North and South America, *Spodoptera frugiperda* invaded Africa in 2016 and spread to regions outside of its natural range (Goergenn et al., 2016). By 2018, it had spread to 16 different Asian countries (Kalleswaraswamy et al., 2018; Sharanabasappa et al., 2018; Shylesha et al., 2018; Suby et al., 2020; Deshmukh et al., 2021; Sun et al., 2021). In the Asian subcontinent, it was first reported in 2018 from India (Ganiger et

al., 2018) with later incidences in Sri Lanka, Nepal, Bangladesh, China, and Pakistan (Naeem-Ullah et al., 2019). The Near East and Asian/Southeast Asian nations, such as India, China (Taiwan), Japan, Myanmar, Indonesia, Papua New Guinea, and the Philippines, have also reported cases of FAW (Ganiger et al., 2018). In Asia, Karnataka was the first state to report fall armyworm infestation (Sharanabasappa et al., 2018). FAW continued to expand its range to the east and north, passing through several Indian states. The pest spread quickly throughout the Asia-Pacific region between 2018 and 2021 (Prasanna et al., 2021). After first record of FAW from China in 2018 (Cheng et al., 2020), it moved swiftly through 27 provinces, covering an area of around 1.2 million hectares. The FAW was reported in Yunnan in January 2019, and by the end of the year, reports of it had come from 1524 counties in 26 provinces and municipalities, totaling 1125.33 thousand hectares of damage. Yunnan is the most severely damaged region in China as of September 2019; between January and September 2019, Yunnan accounted for 59.31 percent of all affected regions in China (Jiang et al., 2019).

In Pakistan, the pest was collected from maize fields of Sindh in 2019 (Naeem-Ullah et al., 2019). its presence has already been reported in the maize growing districts of upper Sindh (Naeem-Ullah et al., 2019; Gilal et al., 2020). Recently, a report has also been published confirming the presence of *S. furgiperda* on maize from Faisalabad (Khan et al., 2020). Yousef et al. (2022) also documented the presence of this pest from various parts of Punjab, Khyber Pakhtankhwa, and Sindh during 2019 with maximum damage in various districts of Sindh. Another study confirmed its presence in Punjab. Maximum damage to maize field was reported from Kasur and Lahore district (Khan et al., 2020). FAW invasion was reported during 2017 and early 2018 (Sidana et al., 2018) whereas its first case documented from region of Indian occupied Kashmir during 2020 (Anonymous, 2020) but there is no published study on occurrence of FAW was found until now.

## MATERIALS AND METHODS

### Distribution of FAW in three divisions of AJ&K

#### Study area

During the current study three maize fields were selected from each district of administratively three divisions of Azad Jammu & Kashmir for surveying the fall armyworm distribution and infestation (Table. 1, Figure1, 2). The geographical co-ordinates including altitude, latitude, longitude of the respective localities are given in table (1) were recorded by using Global Positioning System (GPS). Data of FAW infestation and invasion was also collected from Extension Wing of Department of Agriculture AJ&K and by fortnightly visits of selected localities.

Table1. Selected localities of study site along with their coordinates.

S. No	Localities	Longitude(E)	Latitude (N)	Altitude (ft)
1	Rawalakot	73.7654	33.8584	5,374
2	Hajira	73.8948	33.767	3,196
3	Devigali	73.8507	33.7747	5,479
4	Pallandri	73.6861	33.7145	4,501
5	Trarkhel	73.7882	33.7615	6,502
6	Azad Pattan	73.6124	33.7399	2,408
7	Bagh	73.7772	33.9794	3,405
8	Dhirkot	73.5771	34.0391	5,498
9	Dhuli	73.9073	33.9283	5,075
10	Forward Kahuta	74.1034	33.8844	4,596
11	Aliabad	74.9712	34.7198	7,237
12	Khurshidabad	74.1724	33.9221	1,948
13	Kotli	73.9007	33.5008	2,772
14	Nakyal	74.1049	33.4882	5,000
15	Sehnsa	73.7566	33.5116	2,239
16	Mirpur	73.7537	33.148	1,509
17	Dadyal	73.6831	33.3462	1,457
18	Chakswari	73.7851	33.2643	1,332
19	Bhimber	74.0858	32.9753	1,066
20	Samahni	74.1372	33.0903	5,023

21	Bernala	74.2443	32.8695	1,027
22	Sharda	74.7931	34.7931	6,306
23	Attmuqam	73.911	34.5883	4,547
24	Kel	74.3588	34.8272	6,879
25	Muzaffarabad	73.4769	34.3551	2,418
26	Garidopata	73.6154	34.2256	2,680
27	Danna	73.7681	33.7492	2,652
28	HattianBala	73.7441	34.1707	5,429
29	Chikar	73.6757	34.1486	5,272
30	Leepa Valley	73.4769	34.3551	6,730

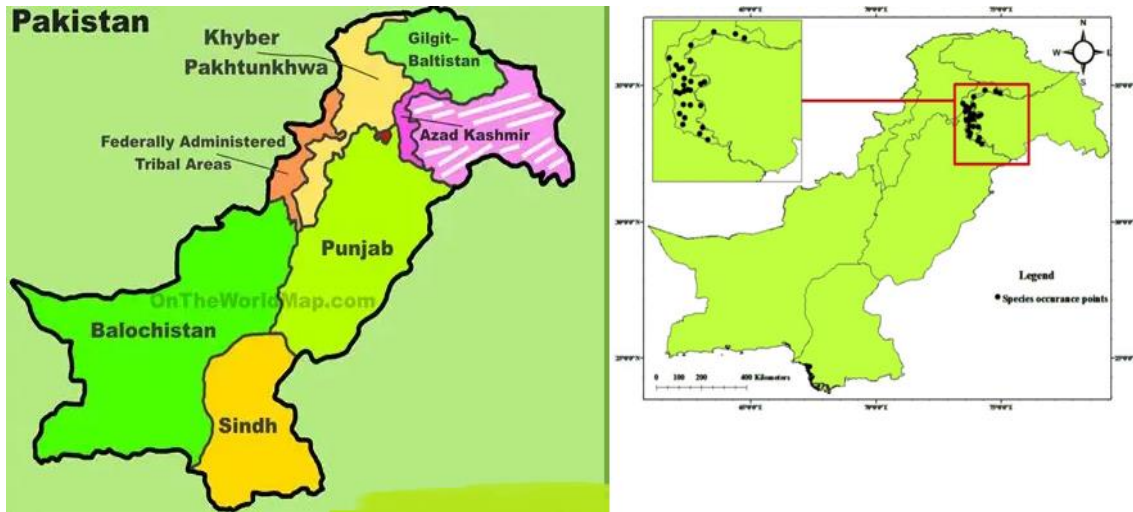


Figure 1. Selected localities of FAW infestation and occurrence in northern areas (Azad Jammu and Kashmir) of Pakistan.



Figure 2. Field infestation during surveys from study site.

**Field surveys**

During maize growing season of 2022 and 2023, farmer interviews, surveys and random sampling was carried out from each field of selected localities. Larvae found feeding within the whorls of maize leaves were collected and transferred to the laboratory of department of Entomology, University of Poonch Rawalakot. These larvae were reared until adult emergence for the confirmation of FAW by taxonomic identification (CABI, 2017) with the help of available literature. Additionally, monitoring of the pest emergence was also carried out at different temperature and altitudinal ranges.

## RESULTS AND DISCUSSION

### Distribution of fall army worm in study area

Fall armyworm larvae were collected from all selected localities during different time periods at different altitudinal ranges. Active period of FAW at Rawalakot was recorded during July-Oct at average temperature 27°C (Table 1-2: Figure 3). Active period of FAW at Hajira was recorded during June-Sep at average temperature 33°C (Table 1-2: Figure 3). Active period of FAW at Devigali was recorded during July-Sep at average temperature of 32°C (Table, 1, 2: Figure 3). Active period of FAW at Pallandri was recorded during June-Oct at average temperature of 28°C (Table 1-2: Figure 3). Active period of FAW at Trarkhel was recorded during Aug-Oct at average temperature of 27°C (Table 1-2: Figure 3). Active period of FAW at Azad Pattan was recorded during June-Sep at average temperature of 37°C (Table, 1, 2: Figure 3). Active period of FAW at Bagh was recorded during May-Oct at average temperature of 32°C (Table, 1, 2: Figure 3). Active period of FAW at Dhirkot was recorded during July-Sep at average temperature of 33°C (Table, 1,2: Figure 3). Active period of FAW at Dhuli was recorded during June-Sep at average temperature of 29°C (Table, 1, 2: Figure 3). Active period of FAW at Forward Kahuta was recorded during June-Sep at average temperature of 29°C (Table, 1, 2: Figure 3). Active period of FAW at Aliabad was recorded during Aug-Sep at average temperature of 25°C (Table, 1, 2: Figure 3). Active period of FAW at Khurshidabad was recorded during July-Sep at average temperature of 2°C (Table, 1, 2: Figure 3). Active period of FAW at Kotli was recorded during June-Sep at average temperature 37°C (Table, 1, 2: Figure 4). Active period of FAW at Nakyal was recorded during July-Sep at average temperature of 26°C (Table, 1, 2: Figure 4). Active period of FAW at Sehnsa was recorded during June- Sep at average temperature of 40°C (Table, 1, 2: Figure 4). Active period of FAW at Mirpur was recorded during June-Sep at average temperature of 41°C (Table, 1, 2: Figure 4). Active period of FAW at Dadyal was recorded during June-Sep at average temperature of 35°C (Table,1, 2: Figure 4). Active period of FAW at Chakswari was recorded during June-Sep at average temperature of 39°C (Table, 1, 2: Figure 4). Active period of FAW at Bhimber was recorded during June-Sep at average temperature of 37°C (Table, 1, 2: Figure 4). Active period of FAW at Samahni was recorded during June-Sep at average temperature of 37°C (Table, 1, 2: Figure 4). Active period of FAW at Bernala was recorded during June-Sep at average temperature of 36°C (Table, 1, 2: Figure 4). Active period of FAW at Sharda was recorded during June-Sep at average temperature 31°C (Table, 1,2: Figure 5). Active period at Attmuqam of FAW at was recorded during June-Sep at average temperature of 24°C (Table, 1, 2: Figure 5). Active period of FAW at Kel was recorded during July- Sep at average temperature of 29°C (Table, 1, 2: Figure 5). Active period of FAW at Muzaffarabad was recorded during June-Sep at average temperature of 41°C (Table, 1, 2: Figure 5). Active period of FAW at Garidopata was recorded during June-Sep at average temperature of 36°C (Table, 1, 2: Figure 5). Active period of FAW at Danna was recorded during June-Sep at average temperature of 39°C (Table, 1, 2: Figure 5). Active period of FAW at HattianBala was recorded during July-Sep at average temperature of 40°C (Table, 1, 2: Figure 5). Active period of FAW at Chikar was recorded during July-Sep at average temperature of 36°C (Table, 1, 2: Figure 5). Active period of FAW at Leepa Valley was recorded during July-Sep at average temperature of 40°C (Table, 1, 2: Figure 5).

### Fall army worm distribution from other provinces of Pakistan

Punjab (Multan, Faisalabad Sargodha, Lahore, Bhawalpur, Kasur, Islamabad), (Gilal et al., 2020; Ibrahim et al., 2021; Ramzan et al., 2021; Yousaf et al., 2022, Altaf et al., 2022; Ajmal et al., 2024).

Sindh (Ghotki, Hyderabad, Jacobabad, Jamshooro, Khairpur, Larkana, Matiari, Mirpur Khas, Naushaharo Feroze, Sukkur, Shaheed Benazirabad, Shikarpur, TandoAllahyar, Thatta,Umerkot) (Wyckhuys et al., 2024, Gilal et al., 2024).

Khyber Pakhtunkhwa (KPK) (Still not reported from KPK)

Baluchistan (Still not reported)

Gilgit Baltistan (Still not reported)

Overall results shown the uniform distribution of FAW throughout the study area with very rapid dissemination this pest to other areas and expansion of host range was also observed. It was the first study in Kashmir to report the occurrence.

Table 2. Active period of FAW on selected localities at different temperature ranges during 2022.

S. No	Localities	Active period (2022)	Temperature °C	Active period (2023)	Temperature °C
1	Rawalakot	July-Oct	27	July-Oct	27
2	Hajira	Jun-Sep	35	Jun-Sep	33
3	Devigali	July-Sep	33	July-Sep	32
4	Pallandri	June-Oct	27	June-Oct	28
5	Trarkhel	Aug-Oct	27	Aug-Oct	27
6	AzadPattan	Jun-Sep	37	Jun-Sep	37
7	Bagh	May-Oct	33	May-Oct	32
8	Dhirkot	July-Sep	32	July-Sep	33
9	Dhuli	June- Sep	30	June- Sep	29
10	ForwardKahuta	June-Sep	28	June-Sep	29
11	Aliabad	Aug-Sep	27	Aug-Sep	25
12	Khurshidabad	July-Sep	26	July-Sep	26
13	Kotli	June-sep	37	June-sep	37
14	Nakyal	July-sep	26	July-sep	29
15	Sehnsa	June-sep	40	June-sep	40
16	Mirpur	June-sep	41	June-sep	41
17	Dadyal	June-sep	35	June-sep	35
18	Chakswari	June-sep	39	June-sep	39
19	Bhimber	June-sep	37	June-sep	36
20	Samahni	June-sep	35	June-sep	35
21	Bernala	June-sep	36	June-sep	36
22	Sharda	June-sep	31	June-sep	30
23	Attmuqam	June-sep	24	June-sep	23
24	Kel	July-sep	29	July-sep	30
25	Muzaffarabad	June-sep	41	June-sep	41
26	Garidopata	June-sep	36	June-sep	36
27	Danna	June-sep	39	June-sep	39
28	HattianBala	July-sep	40	July-sep	41
29	Chikar	July-sep	36	July-sep	37
30	LeepaVelley	July-sep	40	July-sep	40

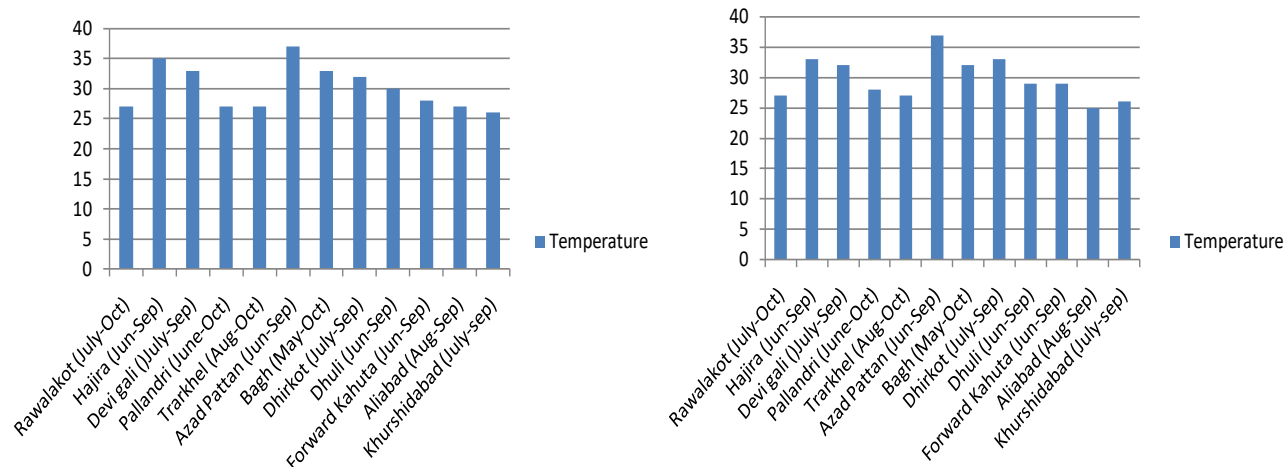


Figure 3. Active period of FAW on selected localities of division Poonch at different temperature ranges during 2022 and 2023.

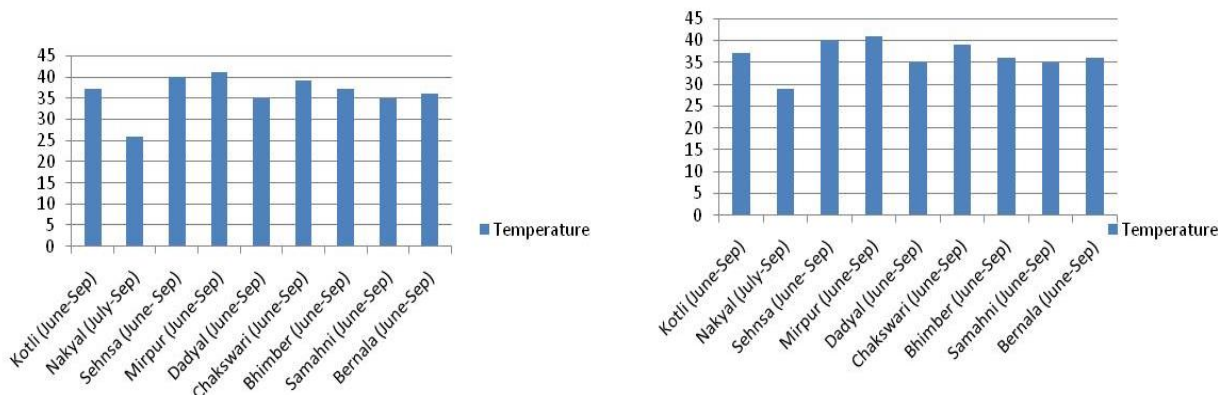


Figure 4. Active period of FAW on selected localities of Mirpur division at different temperature ranges during 2022 and 2023.

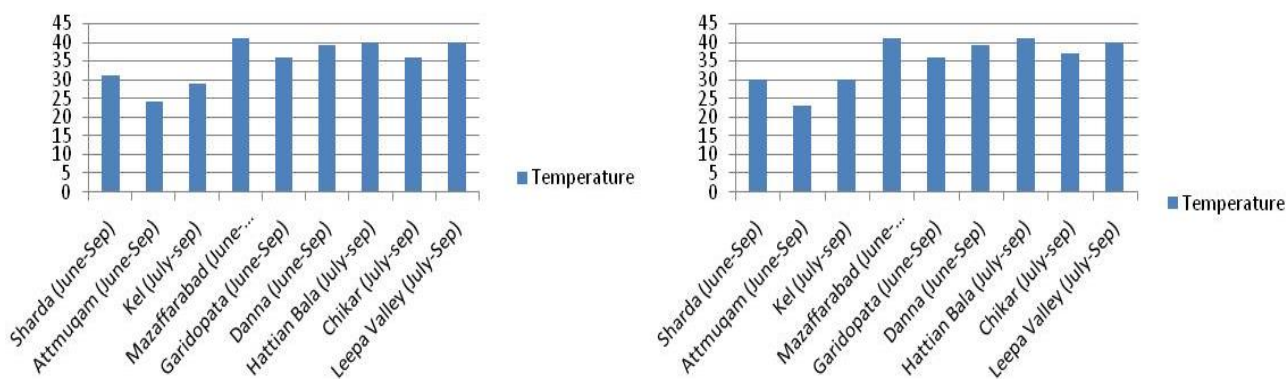


Figure 5. Active period of FAW on selected localities of Muzaffarabad division at different temperature ranges during 2022 and 2023

of FAW in this area. Naeem-Ullah et al. (2019) reported the invasion of *Spodoptera frugiperda* after attack of damaging pest of the same genus *Spodoptera litura* and *Spodoptera exigua*. It was also reported from Sindh on maize crop in 2019, and also found to expand its host range other than maize such as sorghum, millet and attack to various parts of the country (Gilal et al., 2020; Ramzan et al., 2021). Yousaf et al. (2022) also documented the presence of this pest from various parts of Punjab, Khaver Pakhtankhwa, and Sindh during 2019 with maximum damage in various districts of Sindh. Another study confirmed its presence in Punjab. Maximum damage to maize field was reported from Kasur and Lahore district (Khan et al., 2020). In India FAW invasion was reported during 2017 and early 2018 (Sidana et al., 2018) whereas its first case documented from region of Indian occupied Kashmir during 2020 (Anonymous, 2020) but there is no published study on occurrence of FAW was found until now. Due to strong migration ability *Spodoptera frugiperda* has invaded 47 African countries, 18 Asian countries, and Australian region till 2021 (Jing et al., 2021). China was also invaded by FAW during 2018 with its attack reported from twenty-six provinces at the same year (Huang et al., 2020), also reported from Philippine during 2019 (Navasero et al., 2019). Geographical range, survival, mortality and various life parameters of FAW are strongly affected by climatic conditions (Ramirez et al., 2020), long distance migrations ability along with suitable environmental conditions are key contributing factors to rapid expansion of this pest to different areas of the world (Westbrook et al., 2007). Low temperature and high altitudinal ranges causes FAW to descend down which is in line to our results as we observed that FAW activity was found at optimum temperature during summer month at appropriate elevation ranges of study site. Favorable conditions for the FAW are warm and humid climate with heavy rainfall (Forster et al., 2011; Early et al., 2018) due to high temperature accelerated growth and development also prevents FAW from vulnerable stages of predation and rapid adult emergence enhance their flight activity (Sharma et al., 2014; Fand et al., 2015).

## CONCLUSION

The study concludes by confirming that fall armyworm (FAW) is a widespread and vigorous seasonal occurrence in all investigated localities, with peak activity often occurring between May and October in warm weather. The pest was able to adapt to a variety of altitudinal ranges, and its activity was strongly correlated with favorable climatic conditions

including increased humidity and temperatures. The results demonstrate the fast expansion, robust migratory ability, and growing host range of FAW, which is the first recorded occurrence in the Kashmir region. Overall, its distribution and population dynamics are greatly influenced by environmental factors, especially temperature, which makes it easier for it to establish itself and keep growing in the research region.

### AUTHOR'S CONTRIBUTION

IY and NN designed and conducted the experiment, collected and analyzed the data, and wrote manuscript; MI and MAA helped in apprehending the idea of this research, designing the layout of experiment and improving the write-up, format and language of this manuscript; MAS and SAB reviewed the manuscript, added and improved declaration section, edited the format of the tables according to the format of the journal; RS, AH and MSS contributed in data setting for analysis, reviewed the final manuscript and made the format of this manuscript according to the format of the journal; This final manuscript was ultimately perused, scrutinized and approved for final submission by all the authors.

### FUNDING

No funding was received for the present study.

### AVAILABILITY OF DATA AND MATERIAL

The datasets supporting this study are included in the article. Extended methodological details and raw data can be accessed by contacting the corresponding author, subject to ethical and institutional guidelines

### ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This study did not involve human subjects or animal models. In accordance with institutional guidelines, ethical approval and informed consent requirements were formally waived for this research.

### CONSENT FOR PUBLICATION

All the authors are agreed on the publication.

### CONFLICT OF INTERESTS

The authors declare no conflict of interest.

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