ORIGINAL RESEARCH PAPER

Volume - 14 | Issue - 04 | April - 2025 | PRINT ISSN No. 2277 - 8179 | DOI : 10.36106/ijsr

INTERNATIONAL JOURNAL OF SCIENTIFIC RESEARCH

MALARIAL PARASITE PREVALENCE AND THE IMPACT OF CLIMATIC FACTORS IN A SUBDIVISION OF MATHURA DISTRICT,INDIA.

Medical Microbiology

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ABSTRACT

Introduction: Malaria, caused by *Plasmodium falciparum*, remains a potentially life-threatening disease in humans, with *P. falciparum* contributing significantly to malaria-related deaths. Other species, such as *P. vivax, P. ovale,* and *P. malariae*, generally cause milder infections. Malaria incidence exhibits seasonal variation, peaking during the rainy season. The Government of India has initiated a national program to eliminate malaria by 2030. **Aims and Objectives:** This study aimed to analyze the seasonal trends of malaria and assess its impact based on factors such as age, sex, and *Plasmodium* species distribution in the study region.**Materials And Methods:** A prospective cross-sectional study was conducted over eight months (June 2024–January 2025) at a microbiology diagnostic laboratory in a tertiary care hospital in Mathura, Uttar Pradesh. Malaria diagnosis was confirmed through microscopic examination of thick and thin peripheral blood smears and rapid antigen detection tests. **Results:** Among 899 febrile patients (458 males, 441 females), only seven cases (0.78%) tested positive for malaria. Of these, four were female, and three were male. Seasonal analysis revealed that during the rainy season, two males (0.75%) out of 264 tested positive, whereas one male (0.52%) out of 194 was positive in winter. Among females, four cases (1.89%) were detected in the rainy season, while none were found in winter. *P. vivax* was responsible for all cases (100%), with one mixed infection involving *P. falciparum* recorded in October. Malaria prevalence was highest from June to September, with peak positivity in June (2.80%). The highest incidence (3.33%) was observed in the 16–30-year age group during the rainy season, while no cases were detected above 45 years of age. In children (0–15 years), positivity was 1.51%, and in the 31–45-year age group, it was 1.35%, both during the rainy season.**Conclusion:** This study highlights that *P. vivax* is the predominant cause of malaria in this region, with the majority of cases occurring in individuals aged 16–45 years. No cases were recorded above 45 years of age. Female febrile patients exhibited a higher positivity rate (1.89%) than males (0.75%) during the rainy season. Nearly all positive cases were detected during the monsoon months (June–September), emphasizing the strong seasonal influence on malaria transmission.

KEYWORDS

Malaria, Seasonal Trends, Malaria Elimination Program, Plasmodium vivax, WHO Malaria, Indigenous Malaria Transmission, National Framework for Malaria Elimination.

1-INTRODUCTION

Malaria remains a major public health concern, primarily caused by *Plasmodium* parasites (*P. vivax, P. falciparum, P. malariae,* and *P. ovale*), transmitted through female *Anopheles* mosquitoes. The disease burden varies across regions, with India making significant strides toward elimination.

1.1 Historical Background of Malaria in India

- 1897: Sir Ronald Ross discovered mosquito transmission of malaria.(Ref.1,2).
- 1935: India recorded 100 million cases and 1 million deaths *(Ref. 3)*.
- 1958: National Malaria Eradication Programme (NMEP) launched.
- 1965: Malaria cases dropped to 0.1 million with zero deaths *(Ref. 4,5)*.
- 1975: Resurgence due to DDT resistance – 6.5 million cases reported *(Ref. 6)*.
- 2015: The Prime Minister of India joined 17 Asia Pacific leaders in endorsing a plan and roadmap to eliminate malaria throughout the region by 2030(Ref.7). India further pledged to achieve this goal by 2027 - three years ahead of the regional and global target.

1.2 India's Commitment to Malaria Elimination

Over the past 15 years, India has made considerable progress in reducing malaria burden. The disease is on the decline although this has little or no change somewhat over the past few years. During 2017, a total of 842,095 cases and 104 deaths were reported by the National Vector-Borne Disease Control Programme (NVBDCP), the agency responsible for malaria programme in India(Ref.8). However, the World Health Organization (WHO) in its 2017 Global Report cited an estimated 13.1 million cases and 23,990 malarial deaths in India for the same year(Ref.9). The Report claimed that India's malaria surveillance mechanism detected a mere eight per cent of cases.

Nearly 70 per cent of malaria cases in India are contributed by five out of 36 States and Union Territories(Ref.10). These include Odisha (36%), Chhattisgarh (12%), Jharkhand (9%), Madhya Pradesh (9%) and Maharashtra (5%). Historically, the above mentioned States and northeastern States such as Meghalaya, Mizoram, Nagaland, which have a wide coverage of forest, hilly, tribal and conflict-affected areas accounted for the most of malaria burden in the country.(Ref.10)

The Government of India has developed a National Framework for Malaria Elimination (2016-2030)[10] and a National Strategic Plan (NSP, 2017-2022) with the aim to eliminate malaria (zero indigenous cases) in all Category 1 and 2 districts by 20221[Ref.11]. In Category 3 or the highest transmission districts, the target is to bring them under a pre-elimination and elimination programme by 2022.

Extracts from National Framework for Malaria Elimination, 2016-30

A. Categorisation of districts-

Category	Definition	Number of districts
Category 0	Districts/unitshistorically considered to be without local transmission and reporting no case for last 3 years. Vigilance will be maintained in these districts to prevent reintroduction of malaria in view of climate change	75
Category 1	Districts/units having API less than 1 per 1000 population	448
Category 2	Districts/units having API 1 and above, but less than 2 per 1000 population. These are targeted for elimination in the subsequent years	46
Category 3	Districts/units having API 2 and above per 1000 population. These are positioned for elimination targeting in the subsequent years	109

Categorisation of states and timeline for malaria elimination Based on the above categorisation, staggered targets have been given for elimination of malaria by the States as follows:

1. 15low transmission States and UTs (with State and all its districts reporting an API of less than 1 case per 1000 population at risk) have been identified for attainment of zero indigenous malaria transmission by 2020 and prevention of re-establishment of local transmission of malaria.
2. 11 moderate transmission States and UTs (with an API of less than 1 case per 1000 population at risk, but some of their districts are reporting an API of 1 case per 1000 population at risk or above) have been identified for attainment of zero indigenous malaria transmission by 2022 and prevention of re-establishment of local transmission of malaria.

3. 10 States/UTs (with an API of 1 case per 1000 population at risk or above) will reduce the incidence of malaria to less than 1 case per 1000 population by 2024 and attain zero indigenous malaria transmission by 2027 and prevent re-establishment of local transmission of malaria.
4. All States to achieve zero indigenous transmission by 2027 and the country to get WHO certified malaria free status at the national level by 2030 and maintain status quo thereafter.

1.3 Malaria Burden and Trends in India

In the WHO South-East Asia Region, three countries accounted for 98% of the total reported cases in the region, the main contributor being India (58%), followed by Indonesia (30%) and Myanmar (10%). According to the *WMR 2019*, India represents 3% of the global malaria burden. Despite being the highest malaria burden country of the SEA region, India showed a reduction in reported malaria cases of 49% and deaths of 50.5% compared with 2017.

India has made remarkable progress during the recent years in reducing the malaria incidence. The good news is that the World Malaria Report has also documented the remarkable decline in malaria incidence in India, the estimated malaria cases were reduced by 24% in 2017 compared to 2016 and 28% in 2018 compared to 2017.[Ref.12]

India's epidemiological progress is particularly evident in the movement of states to lower disease burden categories. From 2015 to 2023, numerous states have transitioned from the higher-burden category to the significantly lower or zero-burden category. In 2015, 10 States and Union Territories were classified as high burden (Category 3), of these, in 2023 only two states (Mizoram & Tripura) remain in Category 3, whereas 4 states such as Odisha, Chhattisgarh, Jharkhand, and Meghalaya, have reduced the case-load and moved to Category 2. Also, the other 4 States, namely, Andaman & Nicobar Islands, Madhya Pradesh, Arunachal Pradesh, and Dadra and Nagar Haveli have significantly reduced the caseload and moved to Category 1 in 2023. In 2015 only 15 states were in Category 1, whereas in 2023, 24 states and UTs (progressed from high/medium-burden categories to Category 1, reporting an API of less than 1 case per 1000 population). As of 2023 Ladakh, Lakshadweep and Puducherry are in Category 0 i.e. zero indigenous Malaria cases. These areas are now eligible for subnational verification of malaria elimination. Additionally, in 2023, 122 districts across various states reported zero malaria cases, which demonstrates the efficacy of targeted interventions.[Ref.13]

WHO has released world malaria report 2024 according to which , in south east asia region the parasites causing malaria are P. vivax (51%), P. falciparum and mixed (48%) and other (1%). Another noteworthy achievement in the region was India's official exit in 2024 from the HBHI group of countries, following substantial reductions in malaria incidence and mortality in its high endemic states.[Ref.14]

In 2018 and 2019, Uttar Pradesh, India's most populous state, had a fifth of all malaria cases in the country, followed by Chhattisgarh (18.3%). Detection is patchy, however, as evidenced by the erratic case load each year; in 2020, the state reported 28,668 cases. The number fell to 10,792 in 2021 and to 7,039 in 2022. In 2023, the caseload spiked to 13,603 cases, an increase of 93.25% from the previous year. Testing rates fluctuated—from 2.01% in 2017 to 2.32% in 2018 to 1.8% in 2021, before recovering to 4.5% in 2023.[Ref.15]

According to the report presented in Indian parliament ,(LOK SABHA UNSTARRED QUESTION NO.1288 TO BE ANSWERED ON 28TH JUNE, 2019) the data for malaria positive cases district wise was submitted for the year 2017, 2018 and 2019 . The relevant data is extracted from this report as given below- [Ref.16]

1- Total positive malaria cases in India reported in 2019 (up to April) -50532
2- Total positive malaria cases in Uttar pradesh reported in 2019 (up to April) – 3458
3- Total positive cases in Mathura district of UP reported in 2019 (upto April) – 06
4- Highest reported positive cases in Sonbhadra district of UP (upto April)- 593

The same report presented in parliament mentions about death number district wise due to malaria in the year 2017,2018 and 2019 is given as under –

Year	Total Death in whole country (No.)	Total Death in Uttar pradesh (No.)	Highest Death in Chhatisgarh state
2017	194	0	81
2018	96	0	39
2019 (upto May)	13	0	07

5. Future Projections (2023-2030)-The forecasting of the malaria cases for the next eight years (2023–2030) showed that the rapid decline from 2017–2022 was likely to continue, assuming the extraneous factors would be constant and there are no outbreaks. These observations imply that the target level of zero indigenous malaria cases would be achieved by 2027–2028 .(Ref 17)

The latest World Malaria Report 2024, released by the World Health Organization (WHO), celebrates India's significant progress. India's achievements include a significant reduction in malaria cases and malaria-related deaths between 2017 and 2023. This success is further highlighted by India's exit from the WHO's High Burden to High Impact (HBHI) group in 2024, signifying a turning point in its fight against malaria. These achievements reflect the nation's robust public health interventions and its vision to achieve malaria-free status by 2030.[Ref.14]

6. CONCLUSION

India has made substantial progress in reducing malaria burden. The country exited the WHO's High Burden to High Impact (HBHI) group in 2024, demonstrating major success.

However, continued surveillance, healthcare strengthening, and targeted interventions are essential to sustain progress and achieve malaria elimination goals by 2027-2030.

2-MATERIAL AND METHODS-

2.1. Study Area

The study was conducted in the Microbiology Laboratory of the tertiary care hospital and research center at K.D. Medical College, Mathura. The institution is located 24 km from Mathura city, along the Agra–Delhi National Highway, in the Chhata subdivision of Mathura district. The hospital is surrounded by a cluster of rural villages, making it a key healthcare provider for the local population.

According to the 2011 Census, Chhata subdivision of Mathura district, Uttar Pradesh, had a total population of 569,021, with 119,485 in urban areas and 449,536 in rural areas, resulting in a population density of 539 people per square kilometer.

2.1.Climate of the Study Area-

The region experiences a monsoon-influenced humid subtropical climate, characterized by significant variations in temperature and precipitation between summer and winter. The monsoon season typically starts in late June and extends until mid-September.

2.2. Sample Collection

This study analyzed all blood samples referred by different specialties for the detection of malarial parasites between June 2024 and January 2025.

Study period division:

- Rainy season: June, July, August, September
- Winter season: October, November, December, January

The prevalence of positive cases was analyzed in both segments, considering various parameters. Prior to sample collection, informed consent was obtained from each patient.

2.3. Inclusion and exclusion criteria –

Inclusion Criteria:

- Febrile patients for whom malarial testing was recommended in OPD and IPD across different specialties.

Exclusion Criteria: Repeat or duplicate samples were excluded from the study.

2.4. Sample size of the study - Total sample tested are 899. In rainy season season (four months) 476 samples were tested and 423 samples were tested in winter season.

2.5. Sample testing in Microbiology Lab- Malaria rapid diagnostic tests (RDTs) assist in the diagnosis of malaria by detecting evidence of malaria parasites (antigens) in human blood. These tests require a drop of peripheral blood, normally collected from a finger or heel prick. Visual read-outs are available typically within 20 mins or less.

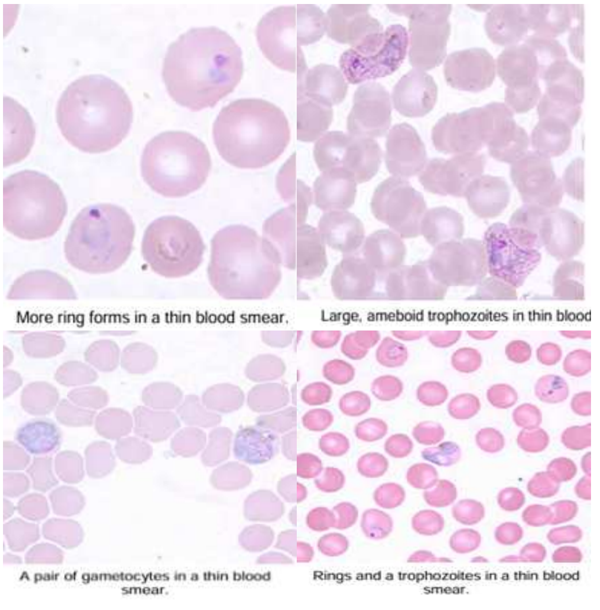
Basic guidelines

A. Capillary blood should be obtained by fingerstick, or venous blood should be obtained by venipuncture.

B. Blood smears, at least two thick and two thin, should be prepared as soon as possible after col lection. Delay in preparation of smears can result in changes in parasite morphology and staining characteristics.

C. Schüffner's dots can be demonstrated in Giemsa stain, which is preferred to Wright or Wright Giemsa stains.

Plasmodium vivax under Microscope-



2.6. Statistical Analysis-

A informed consent of all the participants was taken. A descriptive analysis was done to characterize the participant population by socio demographic data (eg, Age, Gender,Month & referring speciality). All Non-parametric variables were compared using Chi-square.

3-RESULTS –

3.1 Monthly Distribution of Tested Samples and Positive Cases

The distribution of malarial parasite-positive cases across different months is presented in Table 1.

Table 1- Monthly distribution of tested samples and positive cases

Month	Total sample tested (n)	Positive cases (n)	Positivity Rate (%)
June 2024	107	03	2.80%
July 2024	52	01	1.92%
Aug. 2024	83	02	2.40%
Sept. 2024	234	Nil	00.00%
Oct. 2024	299	01	0.33%
Nov. 2024	80	Nil	00.00%
Dec. 2024	25	Nil	00.00%
Jan 2025	19	Nil	00.00%
Total	899	07	00.78%

Observations:A total of 899 blood samples were tested for malaria during the study period, with only 7 samples (0.78%) testing positive.

- The highest positivity rate was observed in June (2.80%), followed by August (2.40%) and July (1.92%).
- No malaria cases were detected from September 2024 to January 2025, except for a single positive case in October (0.33%).
- The study area falls under Category 1, where the Annual Parasite Incidence (API) is <1 case per 1000 population.

To achieve Category 0 status by 2027, targeted malaria elimination strategies need to be implemented

3.2 Seasonal Distribution of Malaria Cases

The seasonal distribution of malaria cases is summarized in Table 2.

Table 2- Distribution of cases during Rainy (june, july,Aug,sept) season and winter season(oct, Nov,Dec, Jan) -

Season	Total sample tested (n)	Positive cases (n)	Positivity Rate (%)
Rainy Season	476	06	1.26%
Winter season	423	01	0.24%
Total	899	07	0.78%

Observations:

- The majority of malaria cases (1.26%) occurred during the rainy season, with 6 out of 476 samples testing positive.
- Only 1 positive case (0.24%) was reported in the winter season out of 423 tested samples.

3.3 Gender-wise Distribution of Malaria Positive Cases

Table 3- Distribution of positive cases based on Season and gender-

season	Total male sample tested (n)	Male positive (n)	Male positivity Rate (%)	Total Fe male sample tested (n)	Female positivity (n)	Female positivity Rate (%)
Rainy Season	264	02	0.75%	212	04	1.89%
Winter season	194	01	0.52%	229	00	00
Total	458	03	0.66%	441	04	0.91%

Observations:

- Female patients had a higher positivity rate (1.89%) compared to male patients (0.75%) during the rainy season.
- In winter, only one male (0.52%) tested positive, while no female cases were recorded.
- Overall, female patients (0.91%) showed a higher malaria positivity rate than males (0.66%).

3.4 Age-wise and Species Distribution of Malaria Cases

Table 4- Distribution of positive cases based on Age,Gender , Species and department

S.NO.	Malarial parasite detected	Gender	Patient age (yrs)	Name of department
1	P . Vivax	Female	34	Medicine
2-	P. vivax	Male	17	Medicine
3-	P. vivax	Male	30	Medicine
4-	P. vivax	Female	14	Pedia
5-	P. vivax	Female	26	Medicine
6-	P. vivax	Female	26	Medicine
7-	P. falciparum plus P. P.vivax	Male	25	Medicine

Observations:

- 6 out of 7 cases (85.71%) were due to *Plasmodium vivax*, indicating high endemicity of P. vivax in the region.
- One case (14.28%) was co-infected with *Plasmodium falciparum*.
- All cases except one were referred from the Medicine department, with only one pediatric case (14-year-old female).

3.5- Age wise positivity Rate of Patients-

Table 5- Distribution of samples based on season and age of patient

Age bracket (Yrs.)	Total sample tested (Rainy season) (n)	Total positive sample (Rainy season (n1)	Positivity Rate in Rainy season (%)	Total sample tested (Winter season) (n)	Total positive sample (Winter season) n1	Positivity Rate (%) in Winter season
0-15	66	01	1.51%	55	00	00
16- 30	120	04	3.33%	109	01	0.91%
31- 45	74	01	1.35%	62	00	00
46-60	65	00	00	51	00	00
➢ 60	151	00	00	146	00	00
Total	476	06	1.26%	423	01	0.24%

Observations

The highest positivity (3.33%) was recorded in patients in the age group of 16-30 years in rainy season and 0.91% in winter season . No case was found positive above age of 45 years. 1.51% positivity was recorded in 0-15 years and 1.35% in 31-45 years age group in rainy season.

4-DISCUSSION-

This study highlights the low prevalence (0.78%) of malaria in the study region, with P. vivax being the predominant species.

Key Findings:

1. **Seasonal Variations:**
- Malaria incidence was significantly higher during the rainy season (1.26%) compared to winter (0.24%), aligning with known seasonal malaria patterns. In one study carried out in 2019 confirms that Malaria cases peaked during the monsoon season, with a lag of about one month between the peak in rainfall and the peak in malaria cases. [Ref.33.]

2. **Gender Differences:**
- Females had a higher malaria positivity rate (1.89%) than males (0.75%) in the rainy season, indicating increased exposure or susceptibility.

3. **Age Distribution:**
- The highest malaria positivity (3.33%) was recorded in the 16–30 years age group during the rainy season.
- No malaria cases were reported above 45 years of age.

4. **Effect of Temperature and Climate:**
- Malaria transmission increases at temperatures between 20–30°C, with peak transmission at ~29°C.
- Rainfall and humidity play a crucial role, as higher humidity (66–81%) and wet conditions enhance mosquito survival.

Public Health Implications

- Given the low API (<1 per 1000 population), this region is close to malaria elimination goals.
- Targeted intervention strategies (vector control, early diagnosis, community awareness) are needed to achieve Category 0 status by 2027.

Effect of Temperature on Malaria-

Temperature can significantly affect malaria transmission dynamics. Higher temperatures favor malaria expansion by quickening mosquito larvae development and enhancing reproduction, increasing activity and frequency of blood feeds, and faster digestion [Ref18]. Warm temperatures can lead to high malaria transmission during wet years. An increase in daytime surface temperature to more than optimum temperature results in a decrease in the malaria incidence ratio (PR) [Ref.19]. According to studies, the extrinsic incubation period of *plasmodium* often shortens as the temperature rises, suggesting higher infection and transmission rates [Ref.20]. The ideal temperature range for the breeding and reproduction of malarial mosquitoes is 20–30 °C. Mosquitoes are active between 20 °C and 34 °C, with peak transmission occurring at temperatures up to 29 °C [Ref.21,22]. For each 1 °C increase in maximum temperature lagged by one month, the prevalence of *P. falciparum* and *P. vivax* increases by 0.6% and 1.5%, respectively[Ref.23]. Temperatures below 25 °C are associated with an extended malaria transmission season (LTS), while temperatures above 35 °C cause the LTS to decline [Ref.24]. Short rains, wet season temperatures, and clinical malaria cases are likely to increase [Ref.25].

Effect of Rainfall on Malaria-The climatic variable with the most substantial influence on malaria is rainfall. It is important for malaria epidemiology because it provides aquatic stages and raises air moisture, which makes mosquitoes live longer. Mosquito development requires a minimum seasonal average rainfall of 1.5 mm per day [Ref.26].

Effect of Relative Humidity on Malaria

Precipitation and hydrology are important environmental factors that affect malaria by affecting the breeding habitats and population dynamics of mosquitoes [Ref.31] Humidity with a time lag of 3 months had a significant positive effect on total malaria cases [Ref.27]. Humidity with temperature and rainfall has the most significant effect on malaria transmission [Ref.28]. Humidity (66% to 81%) with temperatures 20 °C to 33 °C maintained a warmer, wetter climate for mosquito growth, parasite development, and malaria transmission [Ref29]. Mosquitos are favored by high humidity [Ref.30]. For most Anopheles vector species of malaria, the optimal temperature range for their development lies within 20°C to 30°C. However, transmission of P. vivax requires a minimum average temperature of 15°C and transmission by P. falciparum, requires a minimum temperature of 19°C.(Ref. 32)

5- CONCLUSION-

This study demonstrates that:

- ✓ Plasmodium vivax is the dominant species in this region.
- ✓ Young adults (16–30 years) were most affected, with no cases reported above 45 years.
- ✓ Females had higher positivity rates than males during the rainy season.
- ✓ Rainfall and humidity significantly influence malaria transmission, necessitating seasonal malaria control strategies.

These findings underscore the importance of sustained malaria control efforts to meet the national malaria elimination targets by 2027.

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