PCR-BASED SCREENING OF *PLASMODIUM* SPECIES IN MOSQUITO VECTORS OF FAISALABAD DISTRICT, PUNJAB, PAKISTAN

K. Hayat¹, M.S. Sajid¹,², Z. Iqbal¹, M. Saqib³, F.A. Raza⁴, W. Akram⁵, H. Abbas⁶

¹Department of Parasitology, University of Agriculture, Faisalabad, Pakistan
²Center for Advanced Studies in Agriculture and Food Security (CAS-AFS) University of Agriculture, Faisalabad, Pakistan
³Department of Clinical Medicine and Surgery, Faculty of Veterinary Science, University of Agriculture, Faisalabad, Pakistan
⁴Pakistan Health Research Council, Research Center, Fatima Jinnah Medical University, Lahore, Pakistan
⁵KBCMA College of Veterinary & Animal Sciences (CVAS), Narowal, Sub-campus of University of Veterinary & Animal Sciences, Lahore, Pakistan
⁶Department of Entomology, University of Agriculture, Faisalabad, Pakistan

Corresponding Author’s Email: drsohailuf@hotmail.com

ABSTRACT

*Plasmodium* (*P*), mosquito-borne unicellular parasite, is responsible for “malaria”. Pakistan remains at risk of malaria and almost 1.6 million cases of malaria are reported every year. The present study was planned to screen the mosquito vectors for *Plasmodium* sp. in Faisalabad district, Punjab, Pakistan using nested PCR. For this purpose, convenient sampling of adult mosquitoes was done from different places including: animal populated areas, lavatories, water storage tanks, livestock farms and road-side ditches in 70% ethanol. DNA extraction was done after stereomicroscopic identification of the specimens. Species identification of *P. falciparum*, *P. vivax*, *P. ovale* and *P. malariae* was done through universal forward and species-specific reverse primers in the nested PCR. Prevalence of *Culex* mosquitoes was higher as compared to *Anopheles*. *Plasmodium falciparum* and *P. vivax* were found higher as compared to other species of *Plasmodium*. The overall prevalence of *Plasmodium* sp. in mosquito vectors was 46% (14 out of 30 pools for *Plasmodium* sp.). Results were analyzed through chi-square analyses. Present study may explore the vectorial capacity of mosquitoes which can be an indicator of *Plasmodium* sp. distribution in an area for large scale metagenomics.

Key words: PCR, Mosquito, Plasmodium, Faisalabad, Molecular epidemiology.

INTRODUCTION

*Plasmodium* (Haemosporida: Plasmodiidae) is responsible for the occurrence of “malaria”. Various species of *Plasmodium*, which have been reported to cause malaria, include *P. falciparum*, *P. hylobati*, *P. cynomolgi*, *P. malariae*, *P. vivax*, *P. inui*, *P. jefferyic*, *P. knowlesi*, *P. fieldi*, *P. simiovale*, *P. silvaticum*, *P. youngi*, *P. eylesi*, *P. coatneyi*, and *P. pitheci* (White 2008; Beignon et al. 2014; Indra et al. 2014; Maeno et al. 2015). In most parts of the world (Asia, Africa and America), it is considered as an endemic disease. Every year, more than 200 million cases and a million of those ending as death have been reported resulting in economic losses in the form of macroeconomics (like depletion of foreign investments and human capital) and microeconomics (like direct cost invested in treatment and prevention and indirect cost due to sickness) leading to increased poverty level and interruption in the economic development (Kenneth et al. 2004; Anonymous, 2014, 2017). According to a survey, about 216 million cases and 0.445 million deaths due to malaria were reported in 2016, globally (Anonymous, 2017). Endemic reports of malaria have been reported from different countries of the Indian subcontinent like Pakistan, India, Bangladesh and Sri Lanka. According to World Health Organization (WHO), Pakistan contributes 31% of estimated malaria cases in 2016 and falls among the countries which showed increase in case incidence from 2010 to 2016 (Anonymous, 2017). The prevalence of different species of mosquitoes depends upon the environmental conditions of the area under study, for example from rural areas; *Anopheles* (*An*) *culicifacies* has been reported (Pervez and Shah 1989; Rasheed et al. 2013) while *An. stephensi* is mostly reported in urban areas (Regmi et al. 2016). Similarly, *An. fluviatilis* and *An. pulcherrimus* have been found in the mountainous areas of Punjab and Khyber Pakhtunkhwa (KPK) provinces of Pakistan (Suleman et al. 1993). There are different diagnostic techniques (conventional and molecular) available for the detection of malaria. The gold standard and the older one conventional method used for the diagnostic purpose is the blood smear. It is cost effective and applicable on large scale (Hanscheid 1999). The disadvantages of conventional diagnosis are (a) time consuming and (b)
unable to detect low levels of parasitemia (Wongsrichanalai et al. 2007). While nucleic acid and proteins are being used in molecular diagnosis of malaria which is less time consuming but, expensive as compared to conventional diagnostic techniques (Wilson 2012). Based on the above mentioned facts, there was a need to optimize a molecular study on the epidemiology of Plasmodium species prevalent in mosquitoes. The study was aimed to extract DNA of the collected specimens, their identification and vectorial capacity of Plasmodium species through nested PCR in the selected study district (Faisalabad, Punjab, Pakistan).

MATERIALS AND METHODS

Study area: Faisalabad district (73°74 E; 30°31.5 N) is about 604 feet above sea level with maximum and minimum temperature ranges in summer 39 °C and 27 °C, respectively. Whereas, in winter the temperature ranges from 21 °C (70 °F) and 6 °C (43 °F).

Sampling and taxonomy of mosquitoes: Convenient sampling was done twice a day for collection of mosquitoes from the Faisalabad district during September 2015 till May 2016. General collecting nets were used for mosquito capturing and insect killer for indoor collection. Different localities of the study district were searched including human and animal populated areas, lavatories, clogged sewage drains, temporary road side ditches, stagnant stream side pools, household water storage tanks, cemented open water storage tanks, cemented temporary pools as these are the suitable habitats and favorable mosquito breeding sites (Fig. 1). During sampling, collection bottles containing 70% ethanol were used to ensure the safety of organism’s morphological structures from the transportation damage. The samples for further processing were transported to the Molecular Parasitology Laboratory, Department of Parasitology, University of Agriculture Faisalabad, Pakistan. Mosquito identification was performed using standard taxonomic keys (Sousbly 1982; Schaffner et al. 2001).

Molecular detection of Plasmodium species in vectors: Processing of mosquitoes was done after the pooling of female Anopheles mosquitoes. Each Eppendorf tube contained 15 female mosquitoes to attain the weight of 25 mg after grinding. Extraction of DNA was done using commercially available ThermoFisher Scientific Gene JET Genomic DNA purification kit (cat. # K0722, ThermoScientific, USA) as per the manufacturer’s recommendations. The DNA yield was determined with Nanodrop spectrophotometer 2000 (ThermoFisher Scientific, USA). Samples were stored at -20 °C till further use.

Nested PCR: The 18S rRNA genes at species-specific nucleotide sequences were replicated for P. vivax, P. ovale, P. malariae and P. falciparum following the primers designed by Han et al. (2007). In first round of amplification, a 25 µL reaction volume consisting of 2 µL of template DNA, 12.5 µL of PCR master mix consisted of (25 mM MgCl2, 0.25 U AmpliTaq Gold DNA polymerase, 1 x PCR Gold Buffer II (50 mMTris-HCl, 15 mMTris-HCl, pH 8.0), and 200 µM each deoxynucleoside triphosphate), 0.5 µM each Plasmodium universal forward (P1) and universal reverse primers (P2) and 9.5 µL PCR grade water. PCR cyclic protocol for first round of amplification was; initial denaturation at 94 °C for 10 minutes and 92 °C for 30 s, annealing at 60 °C for 1.5 minutes, and extension at 72 °C for 1 minute (35 cycles) with a final extension at 72 °C for 5 minutes.

For second round of amplification, amplified DNA of first round was used as template DNA and diluted 20 folds in PCR grade water and reaction volume was the same as that for first round except 1 µL DNA, universal forward Plasmodium genus-specific primers (P1) and each species specific reverse primers (of four species) for single PCR reaction (Table I). Cyclic conditions were also the same as that for first round except number of cycles which were 20 (Schaffner et al. 2001). PCR products of each round were subjected to 2% agarose gel. The positive control was the DNA extracted from the blood of malaria positive patients (courtesy: Pakistan Health Research Council, Research Center, Fatima Jinnah Medical University, Lahore, Pakistan).

Statistical analysis: The variable species of mosquito with respect to sex (categorical variables) were explored using chi-square test. Data was analyzed by chi-square test of independenceusing SPSS 20.0 software. P values of less than 0.05 were considered statistically significant (Schork and Remington 2010).

RESULTS

Conventional taxonomy of mosquitoes revealed the higher (82.6%) prevalence of Culex mosquitoes as compared to Anopheles (17.30%). However, the number of females Culex was found less (12.99 %) as compared to female Anopheles (72.5%). The higher prevalence of female Anopheles indicates the prevalence of Plasmodium vector in the study area. The total number of Culex and Anopheles mosquitoes identified using stereoscope from study district has been shown in Figure 2.

The results of nested PCR have been shown in Figures 3 and 4. Of 30 pools, 14 were infected with Plasmodium. The positive samples for Plasmodium genus have been shown at 160 base pair (bp). Plasmodium species show positive bands at 110 base pairs and P. falciparum (09/14) and P. vivax (05/14) were identified (Figure 4).
Figure 1. Physical map of Faisalabad district showing areas of sampling of mosquitoes.

Figure (2). Overall Prevalence of mosquito species during September 2015 to May 2016 in Faisalabad district.
Figure (3). DNA fragments amplified by genus specific primers of Plasmodium; Lane 1 & 8 are 100 bp plus DNA marker, Lane 2 is positive control, Lane 3, 4 and 6 shows positive samples, Lane 7 is negative control.

Figure (4). DNA fragments amplified by species specific primers of Plasmodium; Lane 7 is 100 bp plus DNA marker. Lanes 1 and 6 are negative control, Lane 2 is *P. malariae*, Lane 3 is *P. falciparum*, Lane 4 is *P. ovale*, Lane 5 is *P. vivax* PCR products, respectively.

Table 1. List of Primers used for genus and species specific amplification of *Plasmodium* sp. from mosquitoes collected from district Faisalabad, Punjab, Pakistan (Han et al. 2007).

<table>
<thead>
<tr>
<th>Primers</th>
<th>Sequence</th>
<th>Tm (°C)</th>
<th>PCR product size (bp)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Universal forward primer</td>
<td>5'-ACGATCAGATACCGTCGTAATCTT-3'</td>
<td>55.4</td>
<td>160</td>
</tr>
<tr>
<td><em>Plasmodium</em> genus specific</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reverse Primer (P2)</td>
<td>5'-GAACCCAAAGACTTTGATTTCTCAT-3'</td>
<td>53.8</td>
<td>160</td>
</tr>
<tr>
<td>Species-specific reverse primers for <em>P. falciparum</em></td>
<td>5'-CAATCTAAAAGTCACCTCGAAAGATG-3'</td>
<td>54</td>
<td>110</td>
</tr>
<tr>
<td>Species-specific reverse primers for <em>P. vivax</em></td>
<td>5'-CAATCTAAAAGTCACCTCGAAAGATG-3'</td>
<td>53.3</td>
<td>110</td>
</tr>
<tr>
<td>Species-specific reverse primers for <em>P. malariae</em></td>
<td>5'-CAATCTAAAAGTCACCTCGAAAGATG-3'</td>
<td>53.2</td>
<td>110</td>
</tr>
<tr>
<td>Species-specific reverse primers for <em>P. ovale</em></td>
<td>5'-CAATCTAAAAGTCACCTCGAAAGATG-3'</td>
<td>53.2</td>
<td>110</td>
</tr>
</tbody>
</table>

**DISCUSSION**

Mosquitoes are distributed all around the world with around 3,537 described species and 112 genera reported so far (Harbach 2014). Mosquitoes are responsible for many vector-borne diseases/pathogens such as malaria, Dengue fever virus, West Nile virus *Francisella tularensis, Wuchereria bancrofti* etc. Almost 700 million people around the globe are being encountered by mosquitoes on yearly basis (Caraballo and King 2014). The pregnant women are at higher risk of malaria due to lack of awareness to the disease prevention (Okiring et al. 2019). The study was planned to find out the prevalence of mosquito species in district Faisalabad, Punjab, Pakistan. The major impact of malaria disease in Faisalabad was reported by Anonymous (2012). In this investigation, mosquitoes were collected through convenient sampling from different subdivisions of study area. The prevalence of *Culex* mosquitoes was higher as compared to *Anopheles* mosquitoes which could be due to non-probability (convenient) sampling. It may have many positive and negative impacts on research as it provides convenient method of sampling and samples can be collected from different regions easily but it can provide false positive results as abundance of *Culex* or *Anopheles* mosquitoes can be different at different regions (Teddlie and Yu 2007).

The general collecting net was used for collection of samples but other methods for collection have also been used elsewhere which contains dry ice traps. The collected samples were then preserved in 70% ethanol as the preservation rate of tissue in ethanol is higher as compared to 10% formalin (Bressan et al. 2014). The samples were processed for DNA extraction
through DNA purification Thermofisher Scientific kit as it has more purification rate and reliable than conventional method (Ruizet al. 2015). DNA was extracted from the guts of mosquitoes as Plasmodium is present in midgut of mosquitoes (Aliyet al. 2009).

In past investigations, comparison has been done between two techniques which included nested PCR and LAMP (loop mediated isothermal amplification of DNA) for identification of Plasmodium species (Han et al. 2007). The efficiency of both techniques was almost equal in results. The method requires only two steps before running the samples on an agarose gel and is also having a practical value for large scale field based studies where reliable species identification is important. The study has been conducted in which very low parasitemia level of Plasmodium infection was detected as 0.1 Plasmodium per 50 μL of blood with the real time quantitative nucleic acid sequence based amplification (real-time QT-NASBA) assays to identify human malaria parasite. The sensitivity and specificity of this test makes it a diagnostic tool and more suitable for drug studies as compared to nested PCR (Mens et al. 2006).

Another study has been conducted which indicated that the examination of thick and thin blood smears by microscopy was insufficient for the diagnosis of malaria in Turkey. As the number of parasites in blood goes down from 100 parasites per mL, microscopic methods present decreased sensitivity as well as false negative results (Payne 1988; Snounou et al. 1993; Kain et al. 1993; Anonymous, 1999; Safeukui et al. 2008; Fuehrer et al. 2011; Joanny et al. 2014; Li et al. 2014). Nested PCR has more sensitivity and specificity than conventional microscopic methods as 100 % sensitivity, 73.3 % positive predictive values and 97.2 % specificity of nested PCR were reported elsewhere (Snounou et al. 1993; Fuehrer et al. 2011). In another study, out of the positive Plasmodium samples, 93.33 % were P. vivax (Doni et al. 2016).

The results were based on many factors as mentioned above which can also include seasonal modification. In Autumn and Winter, the prevalence of mosquitoes was higher as compared to Spring and early Summer, due to optimum temperature required for the growth and propagation of the mosquitoes. Mosquitoes are being found in peri-domestic and domestic environments. Use of land cultivation, open sewerage drainage etc. by human is playing a vital role in changing the composition of mosquito population and their pattern of transmission of different diseases. Mosquitoes are greatly influenced by different factors including environmental, socioeconomic and climate change. A variety of factors e.g. rapid changes in land use, trade globalization and social upheaval have been documented to affect the vectoral role of mosquitoes in transmission of diseases (Chaves et al. 2012). Environmental factors are firmly associated with the interactions between host and vector. These vectors are playing an imperious role in spread of vector-borne diseases to humans (Rochlin et al. 2016).

Based on the hypothesis and objectives of this investigation, following conclusions have been made: (a) the diversity of Plasmodium sp. in mosquitoes viz; P. falciparum and P. vivax were identified through nested PCR from mosquito vectors which confirmed that mosquito is a potential vector for Plasmodium infectivity in the study district (b) the prevalence of Culex mosquitoes was higher as compared to that of Anopheles (vector of malaria) in Faisalabad district and (c) infectivity burden of mosquito vectors was 46% in Faisalabad; 14 of 30 pools for Plasmodium species. In the present study, higher prevalence of mosquitoes in Sadar and Chak Jhumra tehsils might be attributable to increased population of humans in this area. Two species of Plasmodium were identified: P. falciparum and P. vivax while infectivity burden of Plasmodium was 46% in district Faisalabad. In literature, 2320 cases of malaria were reported in the Nation News (Anonymous, 2012) in 20 districts including Faisalabad. However, the infectivity rate of malaria was lower in Faisalabad as compared to other districts. The reason behind this could be the prevention and control strategies for disease which were used in past. Recently, Abbas et al. (2019) published on segmentation of Plasmodium on region growing and dynamic convolution based filtering algorithm from thin blood smear points and classified four species viz; P. falciparum, P. ovale, P. vivax and P. malariae. They found 96.75% of sensitivity for malaria parasitemia and 94.59% of specificity. Two species viz; P.vivax and P. falciparum have been reported in a baseline survey of the three districts (Bannu, Dera Ismail Khan and Lakki Marwat) of KPK (Qureshi et al. 2019). Another recent study compared the blood smear, specie-specific PCR and rapid diagnostic test for detection of malaria in human blood samples from district Bannu, KPK and found P. vivax as the dominating species followed by P. falciparum and mixed infections. Various social/ environmental determinants were also found statistically associated with the cases of malaria in this study (Jahan et al. 2019). Among the malaria free regions, Europe and Italy were also included since 1970s but in 2017, malaria due to P. falciparum was reported in the Italy which indicates the recurrence of this fatal disease (Tagliapietra et al. 2019). Most prevalent type of malaria in Nigeria is falciparum while malaria due to P. malariae and P. ovale are present but infrequently (Oboh et al. 2018).
management policy in various areas of the province/country. Determination of vectorial capacity of mosquitoes can be an indicator of distribution of *Plasmodium* in an area for large scale metagenomics. Alternative control of vector can be planned accordingly by knowing the species composition status in specified area.

**Acknowledgements:** We would like to acknowledge the financial assistance of U.S. Pakistan Center for Advanced Studies in Agriculture and Food Security (USPCAS-AFS) University of Agriculture, Faisalabad, Pakistan through the project titled “Metagenomics of mosquito vectors and abundance of mosquito-borne pathogens in different agro-geoclimatic areas of Punjab, Pakistan”.

**REFERENCES**


Li, P., Z. Zhao, Y. Wang, H. Xing, D.M. Parker, and Z Yang (2014). Nested PCR detection of malaria
directly using blood filter paper samples from epidemiological surveys. Malar. J. 13: 175.


