RESEARCH ARTICLE

Ethnobotanical perspective of antimalarial plants: traditional knowledge based study

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Abstract

Background: Considering the demand of antimalarial plants it has become essential to find and locate them for their optimal extraction. The work aims to find plants with antimalarial activities which were used by the local people; to raise the value of traditional knowledge system (TKS) prevalent in the study region; to compile characteristics of local plants used in malaria treatment (referred as antimalarial plants) and to have its spatial distribution analysis to establish a concept of geographical health.

Methods: Antimalarial plants are listed based on literature survey and field data collected during rainy season, from 85 respondents comprised of different ethnic groups. Ethno-medicinal utilities of plants was extracted; botanical name, family, local name, part used, folklore, geographical location and image of plants were recorded after cross validating with existing literatures. The interview was trifurcated in field, Vaidya/Hakims and house to house. Graphical analysis was done for major plants families, plant part used, response of people and patients and folklore. Mathematical analysis was done for interviewee’s response, methods of plant identification and people’s preferences of TKS through three plant indices.

Results: Fifty-one plants belonging to 27 families were reported with its geographical attributes. It is found plant root (31.75 %) is used mostly for malaria treatment and administration mode is decoction (41.2 %) mainly. The study area has dominance of plants of family Fabaceae (7), Asteraceae (4), Acanthaceae (4) and Amaranthaceae (4). Most popular plants found are Adhatoda vasica, Cassia fistula and Swertia chirata while % usage of TKS is 82.0 % for malaria cure.

Conclusion: The research findings can be used by both scientific community and common rural people for bio-discovery of these natural resources sustainably. The former can extract the tables to obtain a suitable plant towards finding a suitable lead molecule in a drug discovery project; while the latter can meet their local demands of malaria, scientifically.

Keywords: Antimalarial plants, Ethnobotany, Ethnoecology, Geographical health, Medicinal plants, Plant indices, Traditional knowledge system

Background

Traditional medicine plays a pivotal role in the economy and sustainable growth of developing nations especially for poor countries like India. The preventive health measures have still not been able to penetrate the economically downtrodden societies including typical rural and schedule tribe areas. Their life is purely dependent on traditional knowledge system (TKS) of herbal plants for medicinal cure purposes. The native people are exploiting a variety of herbals for effective curing of various ailments and most widely malaria. Such herbal plants possess potential remedy even for some incurable diseases as well. The plant parts used, preparation method of medicine from it, and its administration as drug varies geographically [1]. However, the knowledge of herbal
medicines is gradually perishing, although some of the traditional herbal men like Vaidyas and Hakims are still practicing the art of herbal healing effectively in such regions. Ethno-medical and ethno-botanical studies have offered immense scope and opportunities for the development and synthesis of new drugs. Modern drugs have been deducted from folklore and traditional medicines [2].

Malaria is a culprit that has victimized almost half of the modern civilization and it is endemic across more than 100 countries [3]. Malaria is a major public health problem in India. 40 million people are suffering from this single celled Plasmodium, a protozoan parasite and more than 1.5 million confirmed cases are reported annually by the National Vector Borne Disease Control Programme (NVBDCP), New Delhi of which 40–50% is due to Plasmodium falciparum (Pf). However, in the study area malaria is only due to Plasmodium vivax as Pf count was found to be zero [4]. Malaria can be considered as poor man’s disease and hence it requires focussed planning both at the level of government and at the community level.

In the Tarai regions of Eastern Uttar Pradesh (UP) the spreading of vector borne diseases becomes uncontrolled especially during rainy seasons [4]. In recent studies, chloroquine-resistant P. falciparum malaria has been observed with increasing incidence in the whole country, while it was effective for treating nearly all cases of malaria in the past. P. falciparum has become drug resistant now. The continued treatment of such cases with chloroquine is probably one of the factors responsible for the increased proportion of P. falciparum cases relative to P. vivax [5]. The current malaria therapies include methods such as passive surveillance of malaria, use of artesiminin combination therapy (ACT) and introduction of intervention like rapid diagnostic tests (RDT) for malaria cure [6]. The commercial industry on antimalarial drug is facing huge a challenge primarily due to development of drug resistance of malarial parasites. And, hence biodiscovery of antimalarial plants has become inevitable towards discovering a novel plant in order to find a lead compound towards malaria medication efforts. It is very likely that in times to come sustainable harvesting of this natural wealth needs to be done to meet the public health demands.

In this circumstance, ethnobotanical and ethnoecological study of antimalarial plants in three districts of Eastern UP was carried out. The native communities have been using their unique traditional knowledge (TK) system, culture, indigenous skills and expertise since the ancient times towards the disease control. TK refers to the ancient and non-conventional practices towards disease control mechanism. Local knowledge of a community is spread across various diseases and masses from developing countries utterly rely on the herbal treatment methods. India has witnessed its legacy from the times of Charaka and Susruta for traditional knowledge for antimalarial activities of various medicinal plants [7]. Considering the high time demand of antimalarial plant it has become inevitable to find and locate them for its optimal extraction for antimalarial actions.

A series of similar work has been done by many people in the country including Verma et al. [2] that has found 72 plant species in campus of Banares Hindu University, Varanasi, UP and has compiled the traditional uses by the local inhabitants. Ethnobotanical work has also been done for the Gorakhpur regions [8, 9] while Kumar and Akhtar [10] have worked on ethnomedicinal solanaceous plants of eastern UP and have found 14 species of medicinal angiosperms. Qayum et al. [1] has done geographic information system based study for antimalarial plants in three districts of UP to highlight geographical attributes of these plants. Tomar [11] has worked on folk medicinal uses of plant roots of Meerut city and has found 39 medicinal plant species belonging to 39 genera and 28 families which are used by rural and common people for various diseases. Srivastava [12] has done ethnomedicinal exploration with respect to food values of 27 underutilized edible fruits consumed by ethnic people of north-eastern terai region of UP and have established database of these fruits which is useful in bio-discovery projects for achieving food security and environmental sustainability. Shankar et al. [13] have listed all the antimalarial plants of north east India and has emphasized the need for an alternative drug for malaria for developing new antimalarial plants from the indigenous plants. Pandya et al. [14] have documented phyto-therapeutical practices in Mayurbhanj district of Orissa, eastern India and has described 112 plants from 62 families which are therapeutically used against different ailments including malaria. Bahekar and Kale [15] on “Herbal Plants Used for the Treatment of Malaria” have highlighted many plants which are used since ancient times for the treatment of malaria and have established pharmacotherapy is the most common treatment strategy for the disease. Sampath et al. [16] have described Swertia chirata as a traditional herb and has found it is used as a preventative measure for malaria during epidemics. Kamaraj et al. [17] has done an ethno-pharmacological investigation on antimalarial activities of medicinal plants traditionally used in the villages of Dharmapuri regions of south India and has identified 24 such plants.

The research objectives are to find all possible plants in the study area with antimalarial activities which were used by the local people and the tribes. This was intended to know and appreciate the TK system based medication
prevalent in the region. Therefore, it is aimed to compile and list characteristics of antimalarial plants prevalent in three districts of Kushinagar, Maharajganj and Gorakhpur of eastern UP and to show the distribution of antimalarial in various geographical regions. Further, the scope of present work has been extended to find out geographical health (GH) of antimalarial plants. GH refers to the state of plant presence in the study area. It is found that many plants are at the verge of either extinction, critically endangered or vulnerable [18]. Hence, immediate attention is highly expected from policy makers to safeguard the interest of people at large and some immediate action is needed from the government bodies to safeguard the current bio-diversity and medicinal plant richness of the region.

The current work is a fine mixture of literature survey and supplemented with collected information through interviews and field visits after cross validating the study area findings from Vaidyas/Hakims, and native rural people. The TK skills and practices thus developed are freely exchanged, cared for and nourished as a common property of the communities [19]. The current work has also highlighted the geographical location of antimalarial plants along with listing them with its family name, folklore, and image of plant in its natural habitat and geographical health has also been explored. It is anticipated that with these observations; traditional method of malaria cure can be accelerated especially for the low socio-economic regions where modern health measures are nearly absent.

Methods

Study area

The study area lies in the north-eastern corner of the most populous state of UP, India. It comprises a large stretch lying to the north of the river Rapti tributary to the Gandak river and also surrounded by Rohini river at northern side which is the major source of water in the region. The area comprised of three district of UP viz. Gorakhpur, Kushinagar and Maharajganj (Fig. 1). It has total area of 9,291 Km² (3.82 % of the state). This much of land area is home to people of countries like, Greece, Portugal, Sweden, etc. It also shares international borders with Nepal. The study area is one among highly dense region of the country (average density around 1210 people per Km²) and is home to more than 10.67 million Indian population [20]. The region is one among several vector borne diseases sensitive zones especially for Japanese encephalitis and malaria.

The study region is home to Tharu, Buksa, Raji and Jaunsari tribes (114,876 people) which are 1.075 % of total population. Two religious communities Hindus (82 %) and Muslims (15 %) find dominance while Buddhists and others constitute 3 % population of the study area. The economics is primarily based on agriculture (97.48 %) with 87,400 main industry working and to some extent on tourism because of presence of Kushinagar Baudh temple (one of the main attraction for the Buddhists). As per the recent census (2011) of UP, India [20] total Population of study area is 10,690,142 (Table 1) with 48.60 % female population and 1,680,587 as total house hold of which 87.98 % is rural house hold. The rural people migrate to big cities for work very often. Entire study area happens to be least developed part of one of the poorest State in India. It makes low socio-economic profile for the region with 3,462,855 total work participation (female: 28.3 %) and 1,708,932 main work participation (female: 19.1 %) and 1,753,923 marginal worker (female: 37.3 %) (Fig. 1).

Methodology

The work has been carried out as per the schematic flowchart (Fig. 2) and its various dimensions are

Pre-ethnobotanical surveys

Before conducting actual ethnobotanical survey pre-ethnobotanical survey was conducted to set the standard goal targets. It began with extraction of ethno-medicinal utilities of plants extracted from the relevant literature available in journals and books and cross examined with accessing traditional knowledge (TK) available with local community including tribal. Numerous related publications of different journals, accepted literature from books like Flora of upper Gangetic Plains [21], Flora Gorakhpurensis [22], Herbal Medicines [23] were searched and cross examined with databases like PubMed Central (PMC) and finally this collected information was compared with the field data collected.

Ethnobotanical survey setup

Survey was conducted in the study area based on the interviews of respondents chosen on criteria discussed below. The interview was trifurcated with respect to field, Vaidya/Hakims and house to house (Table 2). Total of 51 plants (Table 3) were recorded and tabulated. Interview was conducted to find out number of positive cases (n) towards malaria treatment for a particular plant of the region.

Sampling method

The survey was conducted during rainy (July–October 2013) months (Malaria epidemic season). Local population based survey sampling relying on TK system was
followed. Survey locality chosen based on the study of API (Annual parasitic index) of Malaria obtained from District Malaria Office. All those areas with relatively high API were selected for the survey while respondents were chosen based on their interface with TK System and this information was obtained from a local survey while herbalists (Vaidya/Hakim) of the locality were given precedence. In total 85 independent respondents were chosen from Gorakhpur (22), Kushinagar (38) and Maharajganj (35) districts (Table 4).

**Identification of plants**

Ethnobotanical data collected was observed by expert taxonomist and botanist Dr. H.B. Naithani (Senior Scientist, FRI University Dehradun, India) and taxonomic details were ascertained (Table 3). Botanical names of

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**Table 1: Socio-economic profile of the study area**

| District name   | Population type | Total house hold | Total population | Total male | Total female |
|-----------------|-----------------|------------------|------------------|------------|--------------|
| Gorakhpur       | Rural           | 554,999          | 3,604,766        | 1,838,726  | 1,766,040    |
|                 | Urban           | 137,961          | 836,129          | 439,051    | 397,078      |
|                 | Total           | 692,960          | 4,440,895        | 2,277,777  | 2,163,118    |
| Kushinagar      | Rural           | 533,834          | 3,396,437        | 1,730,377  | 1,666,060    |
|                 | Urban           | 27,228           | 168,107          | 87,678     | 80,429       |
|                 | Total           | 561,062          | 3,564,544        | 1,818,055  | 1,746,489    |
| Maharajganj     | Rural           | 175,359          | 1,101,460        | 564,281    | 537,179      |
|                 | Urban           | 7,497            | 45,201           | 23,349     | 21,852       |
|                 | Total           | 182,856          | 1,146,661        | 587,630    | 559,031      |

Source: census of India, 2011
plants and authority were established and cross. The data obtained from ecological sampling was used to determine geographical health of any plant in terms of vulnerable, nearly extinct or under threat. This was specified in terms of PK (percentage known) = 0 or PI (plant impression) as ‘unknown’.

Ethics statement and consent
This is to declare that the work has no completing interest. All respondents actively participated and the survey was purely participative and voluntarily in nature. Participants provided verbal informed consent to participate in this study. They were free to withdraw their information at any point of time. Participant consent was recorded on the designed sheet. The authors adhered with ISE 2006 and 2008 guidelines and all the principles laid down were followed. The entire voucher numbers of specimen collected were deposited in Forest Research Institute, Dehradun herbarium (Voucher Number 10787–10837). The work did not involve any protected area (National Park, Wildlife Sanctuary or Private Plantation). It was done on the land which can be easily accessed by the public and hence no such permission was required. The field studies did not involve any endangered or protected species.

GPS co-ordinates for the study region are: Gorakhpur (Lat. 26°13′N to 27°29′N and Long. 83°05′E to 83°56′E), Kushinagar (Lat. 26°39′N to 27°15′N and Long. 83°38′E to 84°15′E) and Maharajganj (Lat. 26°59′N to 27°19′N and Long. 83°09′E to 83°45′E).

Interview details and criteria
Eighty-five respondents from all ethnic groups comprising Tharu tribes, Hindus, Muslims were interviewed against designed format of set of questions like collection date, local name, plant image, plant location/region, plant description, method of usage of plant in malarial cases. There were 63 male and 22 female respondents from all three major localities (Table 4). No pre-test was conducted as the obtained information was cross validated with the existing TK system in literature databases (PMC etc.). Elderly (as they are TK rich) people above 50 years (mean age 52.0 years) and mainly males (74.12 %) were interviewed because of their easy availability. Samples were collected throughout the study area making each geographical representation possible (such as people residing in the area of forest, near water bodies, urban areas and rural areas). Participants were chosen based on their experience and as well as age. Plant
| Plant species                        | Families     | Method of interview | Positive response (n) | PK (%) | PR | PI* |
|-------------------------------------|--------------|---------------------|-----------------------|--------|----|-----|
| Abrus precatorius Linn.             | Fabaceae     | Field (√)           | 26                    | 30.6   | 3  | Fair|
| Acacia farnesiana (L.) Willd.       | Fabaceae     | Vaidya/hakim (*)    | #                     |        |    |     |
| Achyranthes aspera Linn.            | Amaranthaceae| *                   | 30                    | 35.1   | 1  | Fair|
| Adhatoda vasicca Nees               | Acanthaceae  | #                   | 49                    | 57.3   | 1  | Good|
| Aerva lanata (L.) Juss. ex Schultz. | Amaranthaceae| *                   | 6                     | 7.1    | 2  | Poor|
| Alstonia scholaris (L.) R.Br.       | Apocynaceae  | #                   | 29                    | 34.1   | 1  | Fair|
| Althenanthera sessilis (L.) R.Br. exDC. | Amaranthaceae| #                   | 6                     | 7.1    | 2  | Poor|
| Amaranthus spinosus Linn.           | Amaranthaceae| *                   | 4                     | 4.7    | 3  | Poor|
| Ammania baccifera Linn.             | Lythraceae   | #                   | 0                     | 0      | 3  | Unknown|
| Andrographis paniculata Wall. ex Nees | Acanthaceae  | *                   | 46                    | 53.8   | 1  | Good|
| Asteraacantha longifolia (L.) Nees  | Acanthaceae  | #                   | 8                     | 9.4    | 3  | Poor|
| Azardirachta indica A.Juss          | Meliaceae    | #                   | 27                    | 31.8   | 1  | Fair|
| Barleria prionitis Linn.            | Acanthaceae  | #                   | 12                    | 14.1   | 2  | Poor|
| Bauhinia variegata Linn.            | Fabaceae     | *                   | 43                    | 50.3   | 1  | Good|
| Boerhaavia diffusa L.nom.cons.      | Nyctaginaceae| #                   | 26                    | 30.6   | 1  | Fair|
| Caesalpinia crista (Linn.)          | Fabaceae     | *                   | 28                    | 32.9   | 2  | Fair|
| Canica papaya Linn.                 | Caricaceae   | #                   | 45                    | 52.7   | 1  | Good|
| Cassia fistula Linn.                | Fabaceae     | *                   | 51                    | 59.7   | 1  | Good|
| Cissampelos pareira Linn.           | Menispermaceae| #                   | 0                     | 0      | 3  | Unknown|
| Citrus medica Linn.                 | Rutaceae     | #                   | 11                    | 12.9   | 2  | Poor|
| Clerodendron infortunatum Linn.     | Verbenaceae  | #                   | 9                     | 10.6   | 2  | Poor|
| Cosmos sulphureus Cav.               | Asteraceae   | *                   | 0                     | 0      | 3  | Unknown|
| Cucula reflexa Roxb.                | Convolvulaceae| *                  | 32                    | 37.6   | 1  | Fair|
| Cyperus scariosus Br.               | Cyperaceae   | *                   | 28                    | 32.9   | 2  | Fair|
| Datura metel Linn.                  | Solanaceae   | #                   | 11                    | 12.9   | 2  | Poor|
| Eclipta prostrata (Linn.)Linn       | Asteraceae   | #                   | 17                    | 20.0   | 1  | Poor|
| Erythrina variegata Linn.           | Fabaceae     | #                   | 0                     | 0      | 3  | Unknown|
| Jatropha gossypifolia Linn.         | Euphorbiaceae| #                   | 0                     | 0      | 3  | Unknown|
| Lantana camara Linn.                | Verbenaceae  | #                   | 13                    | 15.3   | 1  | Poor|
| Leucas aspera (Willd.) Link.        | Lamiaceae    | #                   | 26                    | 30.6   | 2  | Fair|
| Ludwigia octovalvis (Jacq.) P.H. Raven | Onagraceae  | #                   | 7                     | 8.2    | 3  | Poor|
| Magnolia grandiflora Linn.          | Magnoliaceae | √                   | 0                     | 0      | 3  | Unknown|
| Momordica charantia Linn.           | Cucurbitaceae| *                  | 3                     | 3.5    | 3  | Poor|
| Murraya koenigii (L) Sprengel       | Rutaceae     | #                   | 8                     | 9.4    | 2  | Poor|
| Nyctanthes arbor-tristis Linn.      | Oleaceae     | *                   | 10                    | 11.8   | 1  | Poor|
| Ocimum sanctum Linn.                | Lamiaceae    | #                   | 28                    | 32.9   | 1  | Fair|
| Oenanthje javanica (BL.) DC.        | Apiaceae     | #                   | 13                    | 15.3   | 2  | Poor|
| Piper longum Linn.                  | Piperaceae   | #                   | 30                    | 35.1   | 1  | Fair|
| Pongamia pinnata (L) Pierre         | Fabaceae     | *                   | 45                    | 52.7   | 1  | Good|
| Putranjiva roxburghii (Wall)        | Euphorbiaceae| #                   | 27                    | 31.8   | 2  | Fair|
| Rauvofia serpentine (Linn.) Benth.  | Apocynaceae  | #                   | 4                     | 4.7    | 3  | Poor|
| Scoparia dulcis Linn.               | Scrophulariaceae| *             | 0                     | 0      | 2  | Unknown|
| Sida rhombifolia Linn.              | Malvaceae    | #                   | 5                     | 5.9    | 2  | Poor|
| Solanum indicum Linn.               | Solanaceae   | *                   | 12                    | 14.1   | 1  | Poor|
images have been taken from the plant’s natural habitat to build a digital database to facilitate the easy recognition of plant by the local people and later it is integrated with the known traditional applications of these plants as antimalarial plants. The interview was done in three modes of field, Vaidya/Hakims and house to house to strengthen the data collection process and at the finally it was cross checked.

Data collection
Data on ethno-medicinal applications of plants are collected in the sequences of: Serial number, botanical name, family, vernacular/local name, part used, methodology used, plant location, and plant image. Later, collected data was referenced using surveyed literature and databases. Demographic and socio-economic survey was also done to find correlation with malaria epidemic with these factors. Additional information (Additional file 1) like age of respondents, education background, monthly income and occupation was also recorded (Table 4). It was also queried for how frequent people use TK system for malaria cure.

Data analysis
Data obtained through ethnobotanical survey was analysed through following parameters:

1. Percentage known (PK): This is % of people who have knowledge of usage of plant species for malaria treatment and calculated as: $PK = \frac{n}{m} \times 100$; n = total number of positive responses and m = total number of respondents.

2. Preference ranking (PR): It is similar to the rank system used by Asase et al. [24]. Here, plants were ranked as per their effectiveness towards treatment. Rank 1, 2 and 3 were assigned where rank 1 means highly effective in treatment while rank 3 means least effective.

3. Plant impression (PI): It is the index indicating how a plant is perceived in the locality. PI is comprised of four categories as good, fair, poor and unknown. PI is ‘Good’ if $PK \geq 50$ %, ‘Fair’ if $30 \leq PK < 50$ %, ‘Poor’ if $0 < PK < 30$ %, and ‘Unknown’ if $PK = 0$ %

Results
Traditional knowledge system of antimalarial plants: Compilation of all antimalarial plants prevalent in the region (Table 3).

Graphical analysis (Fig. 3): Four pie charts are drawn and results are:

- Roots are mainly (31.8 %) used towards malaria cure (Graph 1).
- As many as 12 plant families have more than one plant in the region (Graph 2) and Fabaceae family makes highest influence of 7 plants in the list (Table 3).
- Response of people and patients was analysed. It was found that 41.2 % responses are ‘poor’ while 19.6 % people are unknown for any TK Based system in the region (Graph 3).
- In 41.2 % cases plant part used as decoction followed by plant usage as juices or in some form of beverage (27.5 %) and plants are also used as mosquito repellent (2 %) (Graph 4).
| S.no | Botanical name (Voucher no) | Family       | Vernacular/local name | Part used | Method used for cure | Plant location                                                                 | Reference          | Plant image |
|------|-----------------------------|--------------|------------------------|-----------|----------------------|--------------------------------------------------------------------------------|---------------------|-------------|
| 1.   | Abrus precatorius Linn. 10787| Fabaceae     | Ratti, Ghumchi         | Whole plant | Two spoonful decoction of plant is taken orally twice a day for 3 days | Fruit orchard and climbing over trees | [14], [22]: p. 89 |            |
| 2.   | Acacia farnesiana (L.) Wild. 10788 | Fabaceae | Tarua kadam (Ass)     | Bark       | Decoction of bark is used                                      | Found wild in wastelands, cultivated in gardens | [13], [22]: p. 125, [25] |            |
| 3.   | Achyranthes aspera Linn. 10789 | Amaranthaceae | Chirchita/Apamarga/Chictita | Roots     | With kali mirch used for intermittent fever and malaria       | Roadside, hills up to 900 m, Railway lines, wastelands | [22]: p. 271, [26]: p. 39, [27]: p. 2066 |            |
| 4.   | Adhatoda vasica Nees 10790  | Acanthaceae  | Arusa/ Vasaka          | Roots      | Powdered roots are used by native doctors for malaria           | Cultivated lands, Waste places and Railway tracks | [22]: p. 240, [27]: p. 1899 |            |
| 5.   | Aerva lanata (L.) Juss. ex Schult. 10791 | Amaranthaceae | Gorakhganga/Bhadra    | Whole plant | Plant is grinded and mixed with water and given to patient     | Weed of crop fields, in fruit orchards | [2], [22]: p. 271, [26]: p. 67 |            |
| 6.   | Alstonia scholaris (L.) R.Br. 10792 | Apocynaceae | Saptaparna/Saptachada/chatiyan | Leaves, Bark and Flower | Decoction is prepared and 2 teaspoon is given twice a day with honey | Planted as roadside tree and also found wild | [2], [22]: p. 192, [26]: p. 111 |            |
| 7.   | Alternanthera sessilis (L.) R.Br. ex DC. 10793 | Amaranthaceae | Gudrisag/Matsyaksi    | Leaves and Stems | Decoction of leaf is given                                      | Weed of cultivated field and in moist waste places | [1], [22]: p. 273, [26]: p. 118 |            |
| S.no | Botanical name (Voucher no) | Family | Vernacular/local name | Part used | Method used for cure | Plant location | Reference | Plant image |
|------|-----------------------------|--------|-----------------------|-----------|----------------------|----------------|-----------|-------------|
| 8.   | *Amaranthus spinosus* Linn. 10794 | Amaranthaceae | Chaulai Bhaji, Cholai | Roots | Juice obtained from squeezed roots is mixed with powdered rice and taken with water till cure | Along roads, canals, railway tracks and a weed of cultivated fields | [22]: p. 274, [28] | ![Plant Image] |
| 9.   | *Ammannia baccifera* Linn. 10795 | Lythraceae | Dadamari | Leaves | Leaves are used in fever | Marshy lands, Paddy fields, moist places | [22]: p. 136, [26]: p. 125, [35] | ![Plant Image] |
| 10.  | *Andrographis paniculata* Wall. ex Nees 10796 | Acanthaceae | Kalmegh | Leaves | Decoction of leaves is taken orally for twice a day with half glass of milk | Shady waste grounds | [14], [22]: p. 241 | ![Plant Image] |
| 11.  | *Asteracantha longifolia* (L.) Nees 10797 | Acanthaceae | Talmakhana | Whole plant | Juice of whole plant is given to patients | Shallow ditches along roads | [4], [22]: p. 244 | ![Plant Image] |
| 12.  | *Azadirachta indica* A.Juss 10798 | Meliaceae | Neem | Leaves and Fruits | Decoction of leaves and fruits is given | Planted in gardens and near temples | [2], [22]: p. 70, [26]: p. 227 | ![Plant Image] |
| 13.  | *Bauhinia variegata* Linn. 10799 | Fabaceae | Kachnar | Bark, Root and Leaves | Decoction of bark, root and/or leaves is used | Planted in gardens and as roadside tree | [2], [22]: p. 115, [26]: p. 256 | ![Plant Image] |
| S.no | Botanical name (Voucher no) | Family             | Vernacular/local name | Part used | Method used for cure                          | Plant location                                                                 | Reference                  | Plant image |
|------|-----------------------------|--------------------|-----------------------|-----------|-----------------------------------------------|--------------------------------------------------------------------------------|---------------------------|-------------|
| 15.  | Boerhaavia diffusa          | Nyctaginaceae      | Gadapurna / Punarnava  | Roots     | Drink this herb root paste for malaria treatment | Elevated lands, road sides, railway tracks, waste places, crevices of walls and fruit orchards | [22]: p. 269, [26]: p. 281, [29] | ![Plant Image](image1.jpg) |
| 16.  | Caesalpinia crista          | Fabaceae           | Kat-karanj, Karanju    | Roots and Seeds | Prepared in form of dry powder in dose of ½ gm with honey | Open waste-lands and along Nallas                                                 | [2], [22]: p. 115, [26]: p. 320 | ![Plant Image](image2.jpg) |
| 17.  | Carica papaya Linn.         | Caricaceae         | Papita                | Leaves    | Decoction of leaves is used                   | Cultivated around bungalows and gardens                                          | [22]: p. 143, [25]         | ![Plant Image](image3.jpg) |
| 18.  | Cassia fistula Linn.         | Fabaceae           | Amaltas               | Fruits and Buds | Decoction of fruits and buds are used        | Deciduous tree Planted roadside and in gardens                                   | [22]: p. 118, [30]: p. 856 | ![Plant Image](image4.jpg) |
| 19.  | Cissampelos pareira          | Menisperma-ceae    | Harjuri, Bharat buti  | Root      | Juice of the root is administered             | Fruit orchard, and as hedges of parks and gardens                               | [22]: p. 34,              | ![Plant Image](image5.jpg) |
| 20.  | Citrus medica Linn.          | Rutaceae           | Jameri-nimbu          | Fruit     | Juice is of fruit is used                     | Planted in Gardens, Lahl-adpur area                                              | [22]: p. 67, [25]         | ![Plant Image](image6.jpg) |
| 21.  | Clerodendron infortunatum    | Verbenaceae        | Bhat                  | Roots and Leaves | One tea spoonful leaf juice is taken 3 times daily for a week | Under shades of trees, fruit orchards                                             | [22]: p. 254, [28]: [31]   | ![Plant Image](image7.jpg) |
| S.no | Botanical name (Voucher no) | Family | Vernacular/local name | Part used | Method used for cure | Plant location | Reference | Plant image |
|------|-----------------------------|--------|-----------------------|-----------|----------------------|----------------|-----------|-------------|
| 22.  | *Cosmos sulphureus* Cav. 10808 | Asteraceae | Cosmos          | Leaves    | Leaves and aerial are part used in intermittent fever | Throughout study area | [9]           | ![Plant Image](cosmos_sulphureus.jpg) |
| 23.  | *Cuscuta reflexa* Roxb. 10809 | Convolvulaceae | Amarbel       | Stem      | Paste of about 10 gm stem and 7 black pepper seeds is taken with water | Twining upon *Adhatoda vasica*, near Suraajkund, Tiwaripur region | [14], [22]: p. 216 | ![Plant Image](cuscuta_reflexa.jpg) |
| 24.  | *Cyperus scariosus* Br. 10810 | Cyperaceae | Nagarmotha/Chakranksha | Roots | Decoction of root is used | Shallow water bodies of study area | [22], [32]: p. 2637 | ![Plant Image](cyperus_scariosus.jpg) |
| 25.  | *Datura metel* Linn. 10811 | Solanaceae | Dhatura        | Seed, Leaves, and Roots | Administered as decoction of plant parts | Frequently in waste places | [22]: p. 219, [33] | ![Plant Image](datura_metel.jpg) |
| 26.  | *Eclipta prostrata* (Linn.) Linn 10812 | Asteraceae | Bhangraiya, Bhringaraj | Whole plant, Root and Leaves | Plant and its parts are grinded and mixed with water and given to patient | Open pastures, wet regions, along water canals | [2], [22]: p. 175 | ![Plant Image](eclipta_prostrata.jpg) |
| 27.  | *Erythrina variegata* Linn. 10813 | Fabaceae | Pangara       | Bark      | Bark paste is made into pills and are taken till cure | Moderate sized deciduous tree planted in gardens, Near Ramgarh tal | [22]: p. 99, [28] | ![Plant Image](erythrina_variegata.jpg) |
| 28.  | *Jatropha gossypifolia* Linn. 10814 | Euphorbiaceae | Bhakrend      | Seeds    | Seeds are taken with water | Roadside weed and found at other waste ground | [22]: p. 296, [28] | ![Plant Image](jatropha_gossypifolia.jpg) |
| 29.  | *Lantana camara* Linn 10815 | Verbenaceae | Ghaneri       | Whole plant | Plant decoction is given | Roadside, Wild, Wastelands and Railway colony | [22]: p. 256, [34] | ![Plant Image](lantana_camara.jpg) |
| S.no | Botanical name (Voucher no) | Family | Vernacular/local name | Part used | Method used for cure | Plant location | Reference | Plant image |
|------|-----------------------------|--------|-----------------------|-----------|----------------------|---------------|-----------|-------------|
| 30.  | *Leucas aspera* (Willd.) Link 10816 | Lamiaceae | Gopha, Drona pushpi | Leaves | Leaves used as mosquito repellent by the rural people | Weed of crop field, waste places, dry open sandy soil, Bhathat region | [14], [22]: p. 263, [41] |
| 31.  | *Ludwigia octovalvis* (Jacq.) P. H. Raven 10817 | Onagraceae | Panijalokia | Leaves | Leaf juice is used in intermittent fever | Wet places, sides of tanks | [22]: p. 141, [35] |
| 32.  | *Magnolia grandiflora* Linn. 10818 | Magnoliaceae | Andachampa | Bark | Bark is boiled in water and remaining water is given to patient | Planted in gardens, Gorakhnath temple area | [22]: p. 31 |
| 33.  | *Momordica charantia* Linn. 10819 | Cucurbitaceae | Kathnim, Karavelak | Roots and Fruits | Decoction of roots and fruits is used | Cultivated, found wild, climbing on hedges | [2], [22]: p. 149 |
| 34.  | *Murraya koenigii* (L.) Sprengel 10820 | Rutaceae | Bursunga/ Gandhla | Roots | Juice of roots is given in malaria | Deciduous shrub on waste grounds along water bodies, planted in gardens | [2], [22]: p. 69, [36]: p. 472 |
| 35.  | *Nyctanthes arbor-tristis* Linn. 10821 | Oleaceae | Harsingar | Leaves | 250 gm leaf is boiled in ½ lit water and mix with leaf juice of *Ocimum tenuiflorum*. Mix with honey, 50 ml of this for 3 days | Gardens, Bungalow, Temple and Railway colonies | [14], [22]: p. 191, [40] |
| 36.  | *Ocimum sanctum* Linn. 10822 | Lamiaceae | Tulsi | Roots | Decoction of roots given as diaphoretic in malarial fever | Found as an escape from cultivation in moist places | [9], [22]: p. 267 |
### Table 3 continued

| S.no | Botanical name (Voucher no) | Family | Vernacular/local name | Part used | Method used for cure | Plant location | Reference | Plant image |
|------|-----------------------------|--------|-----------------------|-----------|----------------------|----------------|-----------|-------------|
| 37.  | Oenanthe javanica (Bl.) DC. 10823 | Apiaceae | Pan tarori | Whole Plant | Plant extract is used in mild fever | Weed in moist waste places, fruit orchards, along water channels | [32]: p. 156, [35] |
| 38.  | Piper longum Linn. 10824 | Piperaceae | Peeper, Peepramool | Fruits and Roots | Plant part is ground, mixed with water and administered orally | Forest Zone of whole study area and hotter regions | [27]: p. 2128 |
| 39.  | Pongamia pinnata (L) Pierre 10825 | Fabaceae | Karanja | Fruit | Fruit is boiled in water and administered as decoction | Roadside, near Canals, Wasteland, Moist regions, Pharenda and Ramgarh forest | [22]: p. 108 |
| 40.  | Putranjiva roxburghii (Wall.) 10826 | Euphorbiaceae | Putjev, Jiaputa, Putrajiva | Leaves | Leaves and stones given in decoction for cold fever | Wild, tropical and cultivated, hedge plants in gardens | [9], [27]: p. 2237, [22]: p. 299 |
| 41.  | Rauvolfia serpentine (Linn.) Benth. 10827 | Apocynaceae | Dhamarharua | Roots | A paste of root and black pepper is administered | Damp places, wild in forests | [14], [22]: p. 196, [28] |
| 42.  | Scoparia dulcis Linn. 10828 | Scrophulariaceae | Mithi patti | Leaves | Two teaspoonful of leaf juice is taken twice a day | Waste places and a weed of crop fields | [22]: p. 231, [28] |
| 43.  | Sida rhombifolia Linn. 10829 | Malvaceae | Barbara | Roots | Boiled extract is given | Shady waste places near tals (water bodies), hedges | [22]: p. 55, [37] |
| 44.  | Solanum indicum Linn. 10830 | Solanaceae | Lapta Brihatti, Banbhanta | Fruits | Burnt fruits are consumed | Found as wild in whole study area | [22]: p. 222, [25] |
Beverage is also plant extract based drink which usually have low concentration than decoction

| S.no | Botanical name (Voucher no) | Family       | Vernacular/local name       | Part used | Method used for cure                     | Plant location                                      | Reference   | Plant image  |
|------|-----------------------------|--------------|-----------------------------|-----------|------------------------------------------|-----------------------------------------------------|-------------|--------------|
| 45.  | Stephania japonica (Thunb.) Miers 10831 | Menispermaceae | Rajpatha                   | Roots     | Sun-dried roots powder is given orally with boiled water twice a day | Hedges on moist ground | [2]: p. 36      | ![image](image) |
| 46.  | Streblus asper Lour. 10832 | Moraceae     | Singhor                    | Bark      | Juice obtained from squeezed bark is taken till cure | Small evergreen tree found throughout the study area | [22]: p. 308, [28] | ![image](image) |
| 47.  | Swertia chirata Buch Ham 10833 | Gentianaceae | Chiraita, Charayatah Kirata tikta | Whole plant | Plant part is boiled in water till 75 % is evaporated and it is drink like tea | Temperate Himalayas, 4000-10000 ft, Paniara region | [27]: p. 1664 | ![image](image) |
| 48.  | Tinospora cordifolia (Thunb.) Miers 10834 | Menisperma-ceae | Gurch, Giloe | Stems and Roots | Decoction of roots is given for malaria | On hedges and trees, tropical regions of study area | [2], [22]: p. 35, [36]: p. 77 | ![image](image) |
| 49.  | Vandella sessiliflora Benth. 10835 | Scrophularia-ceae | Lindernia sp. Indian | Whole plant | Decoction of whole plant is used | Damp and shady places, grows with grasses | [22]: p. 229, [38] | ![image](image) |
| 50.  | Vernonia cinerea (Linn.) Less. 10836 | Asteraceae   | Sahdevi                    | Whole plant | Decoction is prepared and 2 tea spoonful is given twice a day | Weed of crop field and waste grounds | [2], [22]: p. 181 | ![image](image) |
| 51.  | Xanthium strumarium Linn. 10837 | Asteraceae   | Lapetua                    | Roots     | Decoction is prepared of roots of Lapetua | Waste places, long railway tracks and road sides | [2], [22]: p. 183 | ![image](image) |

a Decoction is an extraction method by boiling of dissolved chemicals of medicinal plant or plant parts
Plant identification and people's preferences:

- Considering people's perception there are 11 plants reported to be 'unknown' to the community people against malaria treatment while 8 plants are 'Good', 12 plants are 'Fair' and 21 plants are 'Poor' in their efficacy.
- Only 7 plants were reported during all three modes of interview conducted.
- *Cassia fistula* has got highest number of positive response (n = 51) among community people, followed by *Adhatoda vasica* (n = 49) and *Swertia chirata* (n = 48). All these plants are most popular antimalarial plants.

Socio-economic and ethnographic results:

- 97.48% population is agrarian, mean age of respondents is 52.0 years, total literacy is 68.5%, monthly income is 4298.3 INR (~70.3 USD), and Gender (M/F) respondents were (78/22)%.
- TK system usage is among 82% of population but they also rely on modern...
method of allopathic treatment when TKS becomes ineffective.

Discussion
In the study area two species namely Nagarmotha (*Cyperus scariosus*) and Goma or Drona pushpi (*Leucas aspera*) are at the verge of extinction mainly due to the change in water reservoir structure i.e. because of loss of water bodies like ponds and other reservoirs for the former and because of change in land-use pattern for the latter. The ethnecology of the study region does not produce the scintillating picture. Further, due to ruthless exploitation, many important medicinal plants species are becoming rare and some of them are critically endangered as per the IUCN (International Union for Conservation of Nature and Natural resource), Switzerland red list criteria. It is estimated that 10 % of all plant species are currently endangered in India [39].
It is found that 51 plant species out of various plants studied in the region belong to 27 families are used by native people malaria treatment (Table 3) and out of these families studied certain family of plants like, Fabaceae (7), Acanthaceae (4), Amaranthaceae (4), Asteraceae (4), and Menispermaceae (3) are prevalent in the region. A commendable work has been done by Duthie for the flora of Flora of Upper Gangetic Plains [21] and by Srivastava for the Flora Gorakhpurensis [22]. Some plants like *Cosmos sulphurosus*, *Piper longum* and *Swertia chirata* were found in the study area which missed its place in the Srivastava’s work and also these are not listed in Duthie’s work. These plants might have grown up in the area during the recent decades or may have come through migrations.

Spatial distribution of antimalarial plants found in the study area including types of habitat is supplied in Table 3. Plant diaspora usually found in the tree/forest, open pastures, river and water body regions; while some are found in some specific locations like Lahladpur, Surajkund, Tiwaripur, Ramgarh Tal, Gorakhnath Temple, Pharenda (forest), Ramgarh (forest), Paniara, Bhatat areas whereas and some are found vaguely throughout the region. Further, there are few plants which are found in fruit orchards, waste/open areas and along railway tracks. Some are distributed in moist waste places, crop fields and along roadside and some are in marshy lands, moist places, garden and temples (in settlements) and near nallas/canals.

The region falls in low socio economic zones with monthly income ~70.3 USD while population is agrarian (97.48 %) and hence their obvious dependency for malaria cure is TKS. It is also found that malaria incidences are relatively higher in the socio-economic inferior regions. There are sizeable amount of *Vaidya/Hakims* (Experts in TKS based applications) who derive their raw material from nearby forests, railway tracks, fruit orchards or from target plantations. The region has 1,436,878 as total households in which 87.98 % is rural while merely 12.02 % is urban and demographic divide lies with 51.25 % males while 48.75 % females in the entire study area [20].

In drawing Pie Chart for plant parts used; rationale used is total number of plants with a particular plant part used is divided by total plants in the study area and multiplied by 100 to compute its %. It is found that among collected plants mostly (31.75 %) roots are used for malaria treatment followed by leaf (25.40 %) and the least used part of plant is stem (3.17 %) preceded by seeds (4.76 %) (Graph 1). Details of most widely plant parts used is necessary to ascertain the significance of that particular part and to establish the coherence of the work with other similar works e.g. for the medicinal plants of BHU region of Varanasi UP [2]. It has been established that for that given region 30 % of preparations are derived from roots which is maximum in plant parts used. In another similar work of Shankar et al. [13] on antimalarial plants of northeast India, frequently used plant parts were roots (31 %), after leaves (33 %). It can be established that in most of the cases root is most frequently used towards medicinal purposes and in some cases leaves are also widely used. Thus, there is a need of expertise for extraction of artemisinin or quinine alkaloid compounds preferably from the roots and leaves.

There are 12 plant families including Acanthaceae, Amaranthacea, Apocyanaceae, Asteraceae, Euphorbiaceae, Fabaceae, Lamiaeceae, Menispermaceae, Rutaceae, Scrophulariaceae, Solanacea and Verbenaceae that have more than one plant in the region (Graph 2) while Fabaceae makes highest contribution of 7 plants namely *Abrus precatorius*, *Acacia farnesiana*, *Bauhinia variegata*, *Caesalpinia crista*, *Cassia fistula*, *Erythrina variegated* and *Pongamia pinnata* (Table 3). Response of these plants among people and patients was upright and it had been acting as good alternative to modern means

| S. no | Plant species          | IUCN status         | S. no | Plant species          | IUCN status         |
|-------|------------------------|---------------------|-------|------------------------|---------------------|
| 1     | *Abrus precatorius*    | Not threatened      | 11    | *Cassia fistula*       | Not yet been assessed |
| 2     | *Achyranthes aspera*   | Not yet assessed    | 12    | *Cuscuta reflexa*      | Not yet been assessed |
| 3     | *Adhatoda vasica*      | Not yet assessed    | 13    | *Cyperus scanus*       | Not yet been assessed |
| 4     | *Alstonia scholaris*   | Least concerned     | 14    | *Leucas aspera*        | Not yet been assessed |
| 5     | *Andrographis paniculata* | Not yet assessed  | 15    | *Ocimum sanctum*       | Not yet been assessed |
| 6     | *Azadirachta indica*   | Not yet assessed    | 16    | *Piper longum*         | Not yet been assessed |
| 7     | *Bauhinia variegata*   | Not yet assessed    | 17    | *Pongamia pinnata*     | Least concerned      |
| 8     | *Boerhaavia diffusa*   | Not yet assessed    | 18    | *Putranjiva roxburghii* | Not yet been assessed |
| 9     | *Caesalpinia crista*   | Not Threatened      | 19    | *Swertia chirata*      | Not yet been assessed |
| 10    | *Canica papaya*        | Not yet assessed    | 20    | *Tinospora cordifolia*  | Not yet been assessed |

Based on IUCN red list criteria
of medication and had been catering to the need of millions from the ancient times. Folklore (mode of administration) of plant parts is decoction (41.2 %) where plant parts are boiled in water and water is evaporated to extend that plant part makes thick syrupy liquid. It is an excellent way to prepare herb with an awful taste. Decocations of roots and barks are very often prepared while decoctions of leaves, flowers, or seeds are rarely prepared.

The interview was trifurcated in three categories of field, Vaidya/Hakims and house to house to understand the method of plant identification and people perception (Table 2). It was found that as many as seven plants were obtained through all three interview modes. Three indices, PK, PR and PI are used to understand perception of plants among community people. Total number of positive responses (n) were collected and combined for all 51 reported plants. PK signifies popularity of a plant as antimalarial. If PK > 55 % such plants are considered as most popular plants. For 11 plants, PK = 0 was reported that signifies plant is unknown in the locality among people, during field survey they were found and such plants also found space in literature and journals. Plants with PK = 0 are highly important and further work has to be done to enhance its PI which will lead to increased plant’s medicinal utility. These are the plants which have least importance among communities and these are ecologically available for future potential application. These plants are not known due to over-dependence on plants with PK > 55, in the study area.

PR has been assigned to each plant either as 1, 2 or 3 depending on people perception as well as research findings. 1 signifies for highly effective in treatment while 3 for least effective in treatment. There are 19 plants with PR as 1 i.e. They are rated as effective in malaria treatment. It is observed that indices like PK and PI are in resonance for most of the plants; higher is PR (PR = 1) higher is PI (Good) and vice versa and runs parallel. 21 plants have ‘Poor’ PI (41.2 %). It is because of its inefficacy towards fever, intermittent fever or malaria cure and hence these plants are least preferred by the local communities. IUCN status of plants with ‘fair’ and ‘good’ impression (PK > 30 %) towards malaria cure is tabulated to understand geographical health of the plant as per the red list criteria (Table 5).

Having life in close vicinity of the nature, traditional societies have acquired unique knowledge about the use of flora and fauna in wild, most of which are still unknown to the common masses. The research findings can be used by both scientific community and common rural/tribal people for bio-prospecting of these natural resources sustainably. The former can extract the tables obtained in the research work to obtain a suitable plant for finding a lead molecule towards a drug discovery project; while the latter can use Table 3 information to meet the local demand for malaria cure. Plant image, methodology and plant location can be seen together to bring malaria cure measures in friendly manner for local communities at their door step. This will be much useful for the developing countries like India where the modern medical facilities have still not penetrated down deeper. It provides sustainable alternate to the existing system of malaria medication. Findings of such works should be made open and unrestricted for its elaborated application to benefit the public at large. The work has also included many plants that are not widely used and are not popular in the study area. This widens the scope of extraction of other non-traditional plants in cases of poor ethnobotany especially during extinction or vulnerability of the traditional plants because of over harvesting and over exploitation of these medicinal plants.

**Conclusion**

The study region has monsoonal rainfall with numerous rivers emanating from Himalayas and low gradient leads to stagnation of water that makes it favourable for vector borne diseases. TK coupled with information technology makes the study highly useful for basic amenity stressed population. The lack of ecology-related knowledge and awareness which is evident from low socio-economic profile of the study region gives signs of over harvesting of plants. This is reinforced by the observed poor geographical health of plants as some plants are found vulnerable; some has become rare, while some are nearly extinct. It further widens the horizon of socio-economic based utility of this kind of research work. The research work fully addresses the issue of making public the availability of information of antimalarial plants for its cheapest and sustainable harvesting for malaria cure locally and it opens gates for numerous opportunities of public health at large.

The work carried out revealed the plants recorded are highly valuable for antimalarial application and in future, bio-prospecting projects can be further initiated for sustainable harvesting towards developing antimalarial drug for curing malaria at large. It would help researchers to find out suitable lead molecules with antimalarial activity towards drug discovery. The study provides ample ground to believe that the traditional medicinal system practice using native medicinal plants is alive and well functioning in the selected area. Many communities use antimalarial plant parts and whole plant for their primary healthcare. It is primarily due to lack of modern medicines, medications, self-reliance on herbs, poor economic condition and more importantly faiths in TK System. The treatment of malaria with plants and plant parts
causes little or no side effects and also it is very cheap and affordable. Some plants are nearly extinct in the region, the reason being change in land use pattern and shrinking of water bodies along with over harvesting of herbs. The bio-depletion of these antimalarial plants is due to the burgeoning population and unscientific management of the natural resources.

The work has highlighted the fact that some species with medicinal applications are not ethnoecologically rich. People residing in the study area are not aware that some of the medicinal plants are becoming extinct gradually. The current work of listing these antimalarial plants would assist people in identifying ecologically sensitive species and hence adoption of regeneration technique for that particular plant species, thus it supports health and economy of the community. There exists alarming need to conserve and protect these important species for sustainable harvesting. A serious endeavour has to be taken to save these natural resources for the generations to come. Study area in the work happens to be least developed part of one of the poorest State in India. Thus, working for low socio-economic profile region will certainly be useful at larger scale and will bear extended benefits when the work will be thoroughly evaluated.

Future work
Exhaustive research should be done on comparative analysis of different antimalarial plants to comprehend if the local evaluation of the effectiveness of the different species can be scientifically authenticated. Listed medicinal plants can be potentially used for extracting antimalarial plants content for further chemical extraction and its analysis as a potential constituent of malaria drug can be established. The plants can be further studied across its family to establish antimalarial activity relationship of various families and correlation based study can also be done to generate coefficient of correlation for a particular plant family as an antimalarial. The present findings can be extended to chalk out a complete roadmap of geographical health of antimalarial plants in terms of IUCN criteria of red list and for detailed ethnoecology work.

Additional file

Additional file 1. Survey format.

Authors’ contributions
AQ proposed the idea, made analysis, drafted the manuscript and implemented the idea. AML channelized the work, made critical evaluation and provided continuous feedbacks. RA was responsible for socio-economic evaluation and ethnoecology and was responsible for carrying theoretical work related to the manuscript preparation. All authors read and approved the manuscript and designed the overall architecture of the work. All authors read and approved the final manuscript.
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