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Geospatial mapping of antimalarial plants used by the ethnic groups of Anuppur district (Madhya Pradesh, India)

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The present ethnobotanical study was conducted to document indigenous knowledge and practices for treatment of malaria in Annupur district, Madhya Pradesh, India. This paper also reports on geographical distribution of prevalent antimalarial plants. Information was collected from 29 traditional healers and 240 other informants about their socio-economy and knowledge of plants by means of semi-structured questionnaires-SSQ and interview-SSI. Global Positioning System (GPS) coordinates were recorded for marked locations and integrated in ArcGIS to develop geospatial map. A total of 19 plants belonging to 15 families were identified against malaria. Majority of these were growing wild in forest area (57.89%). *Andrographis paniculata* was the most cited plant (19.23%) followed by *Vitex negundo* (10.57%). Highest AMI was recorded for *A. paniculata* (0.338), whereas, lowest (0.029) for *Schefflera vinosa* and *Datura metel. S*ynergic antimalarial recipes prepared from two or more plants were preferred over single plant recipe. Roots (63.15%) were the most frequently used plant part followed by leaves (42.10%) and seeds (21.05%). This is the first ethnopharmacological documentation of antimalarial plants in Central India. It highlights potential sources for the development of novel antimalarial remedies from indiginous traditional knowledge. The spatial maps facilitate the access of local tribal population to these plants.

Keywords: Antimalarial plants, Anuppur, Ethnobotany, GIS mapping, Traditional knowledge, Tribal

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Medicinal plants play a significant role in human life to prevent disease, maintain health and/or cure ailments. Since prehistoric times, mankind is using plants for basic preventive and curative health care. This form of knowledge, termed as 'traditional systems of medicines' contain a vast reservoir of plants. According to the World Health Organization (WHO), a majority of the population in developing countries, including nearly 65% of the Indian population, relies mainly upon traditional systems of medicine for their primary health care needs[1]. In India, there are more than 1.5 million traditional medical practitioners using medicinal plants for preventive, promotional, and curative purposes[2]. Plant-based medicines are at the root of modern health care system. One in every four allopathic prescriptions in country like United States is either synthesized or derived from plants[3]. Increasing population, high prices and incidence of side effects of allopathic medicines do not support to provide modern medicines to a vast section of population living in rural and remote areas of the country (i.e., affordability)[4]. These have further accelerated the popularity of alternative medicines especially amongst the rural and remote populations.

According to the 2011 census, tribal population in India is around 8.2% of the total population (www.censusindia.gov.in). Different tribal groups are one of the important stakeholders of traditional medicinal knowledge[5-6]. Due to lack of education and rampant poverty, tribal population has seldom been a part of national decision making system. Tribal medicine (also known as 'folk' or 'indigenous' medicine) is a form of traditional medicines that play

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an important role in health care of Indian society, mainly in rural/indigenous/ethnic communities. However, this knowledge is usually passed verbally from generation to generation without any written script. This makes documentation and record keeping almost impossible. Tribal and ethnic communities in India as part of their health care systems use more than 8,000 species of plants resulting in nearly 25,000 effective plant-based formulations[2].

Nearly 36% of global population (across 95 countries) is at risk of malaria. The WHO estimates 200 to 300 million new cases of malaria worldwide, every year, mostly in Asia, South America, Africa and South Pacific Islands, which causes at least 1 million deaths annually[7]. However, the number of cases as well as death has declined substantially since year 2000. For instance, the number of malaria cases was 262 million globally in 2000 that declined to 214 million in 2015, a decline of 18%. Similarly, the number of malaria deaths globally fell from an estimated 839000 in 2000, to 438000 in 2015, a decline of 48%. Majority of deaths occurred in the African Region, followed by the South-East Asia. Annually, around 2.5 million malaria cases are reported from South-East Asia, of which 76% are from India[8]. The vast number of antimalarial drugs is available; however, malaria treatment has been carried by the drug associations with quinine and artemisinine derivatives. After many years of empirical phytotherapy by traditional practitioners using infusion, decoction and other formulations of *Cinchona officinalis* and *Artemisia annua*, the respective molecules of quinine and artemisinine were isolated and recognized as potential antimalarial substances till date[9]. Appearance of drug-resistant strains of *Plasmodium* is a serious problem to control malaria. *Plasmodium vivax* and *P. falciparum* parasites are vastly resistant to synthetic antimalarials viz. chloroquine, pyrimethamine and sulfadoxine[10]. In addition, the *Anopheles* mosquitoes have developed resistance to many insecticides[11]. The unpublished data of the Pushparajgarh division of district Anuppur (MP, India) show that cerebral malaria caused by the protozoan parasite, *P. falciparum* is highly prevalent in the area; whereas, incidences relating to *P. vivax* and other forms are rare. Hence, there is an urgent need to find new drugs to combat the disease. A careful analysis of traditional medicinal knowledge and associated medicinal plants often used to cure malaria could be of great assistance to the global drug discovery programs[12-16]. However, due to lack of and improper documentation, traditional medicinal knowledge of the country is under great threat. It has long been advocated that for taxonomy, conservation, management and sustainable use of plant wealth, floristic study of previously unexplored areas is needed[17].

Geographic Information System (GIS) has emerged as an important tool for managing natural and other resources across the scale (i.e., local to global). During the last couple of decades, use of GIS along with remote sensing data to characterize and validate spatial distribution of plants has increased considerably[18-20].

In the present study, we have gathered and presented the information on the anti-malarial plants commonly used by the tribes of the district Anuppur, Madhya Pradesh, which is highly prone to different form of malaria (unpublished data). We integrated this data with GIS to locate spatial distribution of these plants. Besides strengthening the livelihood base of the area, the study aims to facilitate sustainable use and conservation of these plants.

Methodology

Study area

Anuppur is one of the tribal dominated districts of India, with 47.9% of scheduled tribe (ST) population (www.censusmp.nic.in). The district is located in the eastern corner of Madhya Pradesh state of India (Fig. 1) having 3724 sq. km area lying between 22º7' and 23º25'N latitude and 81º10' and 82º 10'E longitude. Historically, the area has been a part of erstwhile Gondwana Kingdom (i.e., land of Gond tribe) thickly populated by many other tribes, with Gond as major community. The district has been divided into four administrative divisions (i.e., tehsil) namely-Pushparajgarh, Anuppur, Jaithari and Kotma. Pushparajgarh is the largest division of the district with predominantly rural (96%) area comprising of 269 villages and 119 panchayats. Owing to lack of advance medical facilities in remote areas of the division, and partly because of deep cultural roots, this area harbors many traditional/folk healers. A substantial part of the division is hilly, covered with Sal (*Shorea* spp.) dominated moist-deciduous forests, having black and red soils. The area receives annual rainfall of 120 cm; summer temperature ranges from 28 - 46ºC, while average winter temperature remains around 15ºC. Nearly, 77% of the total population is made up of scheduled tribes (www.censusmp.nic.in).

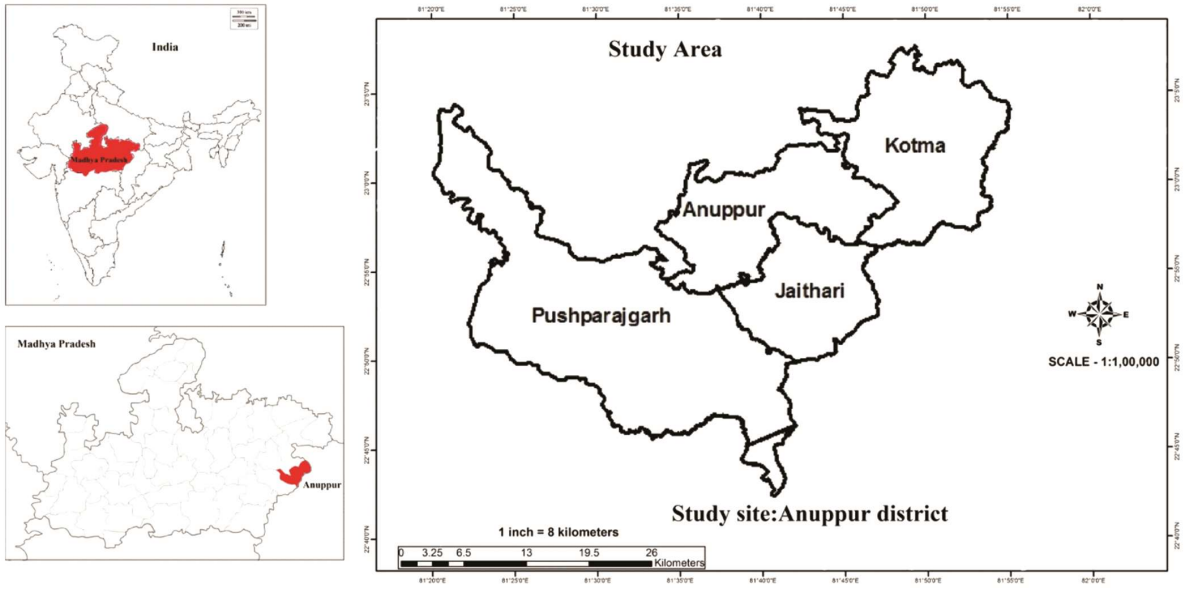

Fig. 1 — Representative map of study site

The study area is highly remote and isolated, full of natural resources and indigenous life style. The inhabitants of the study area have diverse livelihood and cultural activities.

Ethical considerations for the study

Ethical approval for the ethnobotanical survey was obtained from the Natural Resources Data Management System (NRDMS) unit of Ministry of Science & Technology (MST), Government of India and Research & Development Cell, Indira Gandhi National Tribal University (IGNTU), Amarkantak. The research began upon receiving the authorizations and residents of the communities studied gave their consent. The community leaders and village elders were consulted and subsequently approved the study to be conducted within the villages. The participants in this study were provided with information on the nature of study, benefits and risks involved.

Ethnobotanical survey, identification and documentation

Appropriately designed ethnobotanical studies are key to the documentation of traditional knowledge of any area. The researchers took several trips to all the four divisions of the district and lived in the villages of the study area with different ethnic groups. After authorization by NRDMS, the fieldwork was conducted between July 2016 and the end of October 2017. We have adopted 'Snowball method' for the search of key informants[9]. The survey team comprised of all the authors who visited the local villages and interacted with tribal and local healers. Interviews were conducted with people of 18 years or older that had encountered malaria or treated someone who suffered from it. Ethnobotanical data was collected by means of semi-structured questionnaires-SSQ[21-22]. Since, majority of respondents were illiterate with a few having primary level schooling, therefore, the team conducted face-to-face interviews in local languages (Hindi, Gondi, Chattisgarhi) and recorded their conversation (semi-structured interview, SSI). The collected information included socio-economic data (sex, age, professional, level of schooling, monthly family income, number of residents) and plant data (site of collection, local name, part(s) of plants used, ailments treated, therapeutic indications, doses, methods of preparation, route of administration and counter-indications). Plant vouchers were collected, mostly in collaboration with the informants. A total of 269 people were interviewed. The age of informants varied from 18 to 80 years which included students, peasants, housewives, gold smiths, shepherds, shop keepers, Sarpanch/Pradhan (headmen of villages) and forest dwellers. We have also recorded the response of non-tribal healers practicing in that area. The study was concluded when no more new information was realized. Suggested anti-malarial plants were collected, tagged and entered in field data book with important botanical information for herbarium preparation as described by Maden, et al. (2004)[23]. Voucher specimens were deposited at the Herbarium

of Department of Botany, IGNTU. The plant specimens were identified in consultation with experts following suitable literature/flora[24-25].

Anti-malarial index (AMI) demonstrates relative importance of each plant species. It is calculated using the formula as explained before by Umair et al., 2017 with slight modification[26]. AMI=U/N, where 'AMI' refers the anti-malarial index which is equivalent to the use value of each species; 'U' refers the number of uses recorded for that species and 'N' refers the total number of informants. The maximum AMI value i.e. close to 1 indicates that well known species are used by a large proportion of indigenous communities. However, low AMI close to 0 specifies that the informants use this species infrequently to treat malaria.

GIS Mapping

Global Positioning System (GPS) coordinates were recorded for marked locations (e.g., forest area, rivers side, road sides) using hand held GPS (Montana 680; Garmin^{TM}). The ground survey data, GPS coordinates were integrated in ArcGIS 10.3 environment. To develop distributional maps, we procured topo-sheet of the survey area (operation land imager (OLI) satellite imagery) from regional office of the Survey of India at Jabalpur (MP).

Results and discussion

Socio-demographic data of respondents

Table 1 reflects that the survey team interacted with 29 traditional healers including 26 men and 03 women, spread over four divisions of Anuppur district. However, informants other than traditional healers comprised 205 (85.4%) male and 35 (14.6%) female. All 29 traditional healers and other indigenous informants belong to four major tribal communities i.e. Gond (37.5%), Panika (22.7%), Baiga (21.2%) and Bheel (14.9%). Only 10 out of 269 informants

Table 1 — Demographic profile of respondents

Variable	Categories	Frequency
Informant category	Traditional healers	29
	Indigenous people	240
Experience of healers	5-20 years	09
	21-40 years	16
	Above 40 years	04
Gender of respondents	Female	
	Traditional healers	3
	Indigenous people	35
	Male	
	Traditional healer	26
	Indigenous people	205
Age of respondents	Up to 40 years	80
	41-60 years	103
	61-70 years	62
	71-80 years	24
Occupation	Traditional health practitioners	17
	Peasants	146
	Blacksmiths	11
	Shepherds	09
	Shop keepers	15
	House wives	22
	Students	49
Literacy level	Illiterates	69
	Primary education	112
	Secondary education	64
	Graduate	24
Tribal/Sub tribal communities	Gond	101
	Baiga	57
	Panika	61
	Bheel	40
	Others	10

were non-tribals. Majority of the traditional healers (55%) have 21-40 years of experience for treating malaria using plants. Most of the informants spoke Gondi and Hindi languages during their interview and used only vernacular name of the recommended plants. They used other local languages like Chattisgarhi and Bagheli less frequently. Seventeen of the 29 healers were renowned herbalist in their region and found to be self-employed with their traditional skills of curing diseases and setting dislocated bones. Other healers have opted farming, shop keeping and iron molding for livelihood. Most of the informants (67.2%) were either illiterate or had only primary level of education.

A high proportion of male healers (89.6%) reflect patrilineal culture of kinship in the study area, where traditional knowledge of disease identification and treatment is transfer through male lineage. Despite, 3 women healers were identified in the region acting as midwives. Old aged tribal people (50-70 years) have more knowledge on medicinal plants and their uses due to direct contact with plant resources. Whereas, younger people have little interest in traditional medicine as they are exposed to modern education and hence not interested in learning and practicing ethnomedicinal wisdom that would perpetuate indigenous knowledge[27]. Some previous reports also showed similar findings where indigenous knowledge on use of medicinal plants is strong with elderly people[28-29]. Very old aged (75-85 years) traditional healers were unable to practice and not replaced by skilled descendants. It also became evident during the personal interviews with the traditional healers that they were not willing to disclose the name of the plants. It is not a good sign, as it can diminish the possibility of exploring the traditional knowledge system. Conduction of workshop by gathering the local ethno-practitioners from different places, share of the benefits and their proper acknowledgement can improve the situation[30]. The traditional knowledge available with the ethnic people like Gonds and Baigas plays an important role in quick and proper identification of natural resources. Baiga are considered as vulnerable tribes in India which depend upon forest produce for sustenance. They never believe in farming and used to live a semi-nomadic life, and practice shifting cultivation in the forest areas. Gonds and Baigas have been reported to treat diabetes, jaundice, mouth ulcers, anemia, bronchitis, snake bite, gastric disorders including diarrhea and dysentery etc.[31-34].

Diversity of antimalarial plants and floristic analysis

In our investigation, we reported 19 plants commonly used by tribal healers of the area to treat malaria. The mentioned species belong to 13 different families and 19 genera. All species belong to the dicotyledonous group of angiosperms. Table 2 indicates the identified plant species in alphabetical order together with their local names, family, habit, useful plant parts, methods of preparation, source of the plant (wild or cultivated), collection time and antimalarial index. Among the 13 families, the most represented are Acanthaceae, Asteraceae, Caesalpiniaceae, Lamiaceae, Menispermaceae and Solanaceae, each of which contributed 2 species (10.52% each). Other families are separately represented by only one plant species.

Plants of family Asteraceae, Lamiaceae, Solanaceae and Menispermaceae have also been reported for the treatment of malaria and other diseases in South west Nigeria[35]. Amzad et al. (2015) also found the antimalarial uses of Acanthaceae, Asteraceae and Lamiaceae plants in Jammu-Kashmir[36]. The ethnopharmacological uses of some anti-malarial plant species of Lamiaceae, Asteraceae, Acanthaceae and Solanaceae were identified by Alebie et al. (2017) in different regions of Ethiopia[37]. These finding suggest that abovementioned families harbors some active principles which is responsible for antiplasmodial activity of the plant extract. Bioactive compounds like alkaloids, terpenoids, flavonoids, quinones and xanthones are found in Solanaceae and Lamiaceae that play significant roles in anti-plasmodial activity[38-39].

The growth forms of the antimalarial plants in the study area were found with the predominance of annual/perennial herbs (36.84%) followed by shrubs (26.31%). Climbers and twinners like *Cissampelos pareira*, *Citrullus colocynthis, Rubia cordifolia, Schefflera vinosa* and *Tinospora cordifolia* are also used (26.31%) for treatment. Trees are poorly represented antimalarial plants by only 2 species (10.52%). The herbs and climbers are more diverse in the study area and show their better adaptation and acclimatization to the topographic and climatic conditions. The herbs easily grow on the roadside, in home gardens, on farmland and in wild habitats. The high use of herbs is also reported in some other ethnopharmacological studies because of their potency and fast regeneration[40-42].

Table 2 — List of plants used for treatment of malaria by traditional healers in Anuppur district

Botanical name of plants (Voucher number)	Vernacular (local) name	Family	Part(s) used	Preparation	Habit	Occurrence	Anti-malarial index	Collection time
Andrographis paniculata (Burm.f.) Nees (AM/DOB/001)	Chiraeta/ Kalmegh	Acanthaceae	All parts	Hot infusion	Herb	Forest area	0.338	Rainy and Winter season
Azadirachta indica A.Juss. (AM/DOB/011)	Neem	Meliaceae	Root, Leaves	Hot infusion, decoction	Tree	Forest/cultivated area	0.107	Throughout year
Caesalpinia bonduc (L.) Roxb. (AM/DOB/007)	Gattaran	Caesalpiniaceae	All parts	Maceration	Shrub	Road side	0.059	Rainy and winter season
Cassia tora L. (AM/DOB/014)	Chakoda	Caesalpiniaceae	Root, seed	Hot infusion	Herb	Waste land	0.059	Rainy and winter season
Cissampelos pareira L. (AM/DOB/010)	Padhin	Menispermaceae	Root, leaves	Hot infusion	Climber	Forest area	0.118	Throughout year
Citrullus colocynthis (L.) Schrad. (AM/DOB/013)	Indrawan	Cucurbitaceae	Root	Hot infusion	Climber	Forest area	0.048	Summer and rainy season
Datura metel L. (AM/DOB/009)	Dhatura	Solanaceae	Seed	Hot infusion, decoction	Shrub	Road side	0.029	Rainy and winter season
Holarrhena antidysenterica (Roth) Wall. ex A.DC. (AM/DOB/006)	Kurraiya/ Karayan	Apocyanaceae	Bark	Hot infusion	Tree	Forest area	0.118	Winter season
Justicia adhatoda L. (AM/DOB/012)	Bhuleem	Acanthaceae	Root, leaves	Hot infusion	Herb	Forest area	0.078	Throughout year
Ocimum tenuiflorum L. (AM/DOB/002)	Tulsi	Lamiaceae	Leaves	Hot infusion, decoction	Herb	Forest/cultivated area	0.100	Throughout year
Parthenium hysterophorus L. (AM/DOB/016)	Gajar ghas	Asteraceae	Root, flowers	Hot infusion	Herb	Waste land	0.048	Throughout year
Rubia cordifolia L. (AM/DOB/017)	Manjistha	Rubiaceae	Root	Hot infusion	Climber	Forest area	0.104	Rainy and winter season
Schefflera vinosa (Cham. & Schltdl.) Frodin & Fiaschi (AM/DOB/018)	Dev-semal	Araliaceae	Stem	Hot infusion	Climber	Forest area	0.029	Winter season
Solanum virginianum L. (AM/DOB/015)	Kanteli	Solanaceae	Root, seed	Cold infusion	Shrub	Road side	0.040	Throughout year
Thalictrum foliolosum DC. (AM/DOB/003)	Mamira	Ranunculaceae	Root	Cold infusion	Herb	Forest area	0.092	Winter season
Thespesia lampas (Cav.) Dalzell (AM/DOB/008)	Charmuhi	Malvaceae	Root	Cold infusion	Shrub	Forest area	0.070	Rainy and winter season
Tinospora cordifolia (Willd.) Miers (AM/DOB/005)	Giloy	Menispermaceae	Leaves	Hot infusion	Climber	Forest area	0.078	Throughout year
Vernonia anthelmintica (L.) Willd. (AM/DOB/019)	Banjit	Asteraceae	Root	Hot infusion	Herb	Forest area	0.048	Winter season
Vitex negundo L. (AM/DOB/004)	Nirgundi	Lamiaceae	Leaves	Hot infusion	Shrub	Forest/cultivated area	0.185	Throughout year

Majority of these plants were growing wild on terrestrial habitats such as forest area (57.89%), roadside (15.78%), and wasteland (10.52%). It reflects the social importance of the local phyto-resources. Nearly, 15.78% of plants like *Azadirachta indica*, *Ocimum tenuiflorum* and *Vitex negundo* were found under cultivation in home gardens as well as wild in study area. These findings are in agreement with a recent report which showed that the majority (83.3%) of the medicinal plants used to treat malaria by the ethnic groups of Ethiopia were obtained from the wild[43]. Similarily, plants growing in wild are also most commonly used for antimalarial purposes in other regions of India and in Pakistan[30, 44-46].

The most frequently cited plant species were *Andrographis paniculata* (19.23%), *V. negundo* (10.57%), *C. pareira* (6.76%), *Holarrhena antidysenterica* (6.76%), *A. indica* (6.13%) *R. cordifolia* (5.28%),

O. tenuiflorum (5.70%) and *Thalictrum foliolosum* (5.28%). The antimalarial index of surveyed plants is presented in Table 2. The highest range of AMI was recorded 0.338 for *A. paniculata*, which indicates that 91 out of 269 informants have suggested/used the plant alone or in synergy with other plants for the treatment of malaria. The lowest AMI was 0.029 for *S. vinosa* and *Datura metel* where only 8 respondents have acknowledged these plants, separately. The present study reports on potential use of *A. paniculata* in traditional therapy of malaria, either alone or in combination with other plants. Besides ethnopharmacological reports, *in vivo* and *in vitro* antiplasmodial activities of *A. paniculata* extracts have been examined[47-48]. Similarly, *in vitro* anti-plasmodial activity of bark extracts of *H. antidysenterica*, leaves of *T. foliolosum* and *O. tenuiflorum* and roots of *R. cordifolia* have been studied[49-53].

It is worth mentioning that investigated antimalarial plants were also prescribed for treatment of other human ailments by the traditional practitioners. As the present study deals with the antimalarial aspects of the collected plants, this issue was not highlighted in the present report.

Mode of preparation and administration

Our data showed that the roots are primary choice for their use in treatment of malaria. Traditional healers used roots more frequently in 63.15% preparations as compared to other plant parts like leaves (42.10%), seeds (21.05%) and stems (15.78%). The flowers of *Parthenium hysterophorus* and bark of *H. antidysenterica* are also used separately (5.26%) in the treatments.

The common use of roots is novel finding, compared to the majority of ethnobotanical studies where leaves are preferred over other parts of the plant[21, 54-55]. The use of leaves is more sustainable as compared to roots and ensures biodiversity conservation; however, roots and underground parts are easily traded in the herbal market due to their size. Hence, preference is given to roots in various ethnic communities. There may be a wide variety of active phytochemical compounds stored in roots which might play an important role in the treatment of various diseases[56].

Most of the healers suggested the used of synergic antimalarial recipes for better results, which is prepared from two or more plants and their products. The recipe of *A. paniculata* was used singly, as well as in combination with other plants like *C. pareira* in ratio of 1:1*, R. cordifolia* (2:1), *T. foliolosum* (2:1) and *A. indica* (3:1). Other recommended combinations were *V. negundo* with *O. tenuiflorum* (3:1) and *H. antidysenterica* with *T. cordifolia* (3:1). This report is consistent with the earlier ethnopharmacological reports in which the combined plants may enhance the action and activities of other herbs[57-59]. Some possible mechanisms for enhanced activity include an increase in permeability of the *Plasmodium* membrane to the active constituents, their absorption and metabolism, and inhibition of pump mechanisms for eliminating the drugs[60-61]. The most desirable interactions are those which can result in additional therapeutic benefit. However, the effects can be unpredictable and complicated in herb-herb combination therapy as various interactions can occur among multiple components in the herbal products[62]. The combined effects of ethnoformulations, either complementary or antagonistic were well perceived by traditional healers after long experience of practical application. There are reports of combination therapy between different plant extracts which are traditionally combined, but the exact mechanisms of the synergy have not been elucidated[63]. *A. paniculata* and *Hedyotis corymbosa* extracts with curcumin displayed a clear synergistic effect *in vitro* and also *in vivo* in rodent malaria models[64]. Synergistic *in vitro* anti-plasmodial activity has been demonstrated by Azas et al. (2015) between extracts of *Mitragyna inermis*, *Nauclea latifolia*, *Guiera senegalensis* and *Feretia apodanthera*, traditionally used in Mali to treat malaria[65]. Enhanced bioactivity could possibly be attributed to synergistic effects of a range of pharmacologically active compounds in combined plants, potentially augmenting the chance of the drug interacting with numerous different biological targets. Such traditional practices could provide the opportunity to understand drug interaction and mechanisms of actions, and suggest the way to discover lead structures for the development of novel anti-malarial drugs[37].

Most of the traditional remedies are prepared directly in water. Hot infusion was the main mode of preparation of herbal medicines accounting for 43.75%. Water is easily available solvent that can dissolve a high number of metabolites, and high temperature would permit a rapid extraction of active ingredients. Decoction accounts for 18.75%, 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. Powder preparations are used by15.62% healers, followed by cold infusion (9.37%) and maceration (3.12%). Some of the drugs (9.37%) can also be eaten directly without any preparation as *A. paniculata*, *T. foliolosum* and *V. negundo*. Various other additives like jaggery, honey, tea, milk or even local alcoholic drink was suggested by folk healers to consume with herbal remedies for better results and to minimize the bitter taste of phytoproducts. Additives were mostly used to moderate the power and/or improve the taste and enhance the efficacy and healing conditions of the remedy[66-67]. Oral administration of plant recipes is the preferred mode of treatment and usually drunk as teas. However, steam or smoke inhalations through nasal route were also adopted. Topical application of some infusions is used to reduce the body temperature after plasmodial infection.

Spatial distribution of antimalarial plants

The geospatial map is drawn on the basis of GPS coordinates collected during field visits. All 19 antimalarial plants of the study area are grouped in a GIS map to demonstrate their prevalent geographical location (Fig. 2). However, they are also found on other locations of the study area. There are many hilly terrains in the study site which were unreachable for GPS data collection, though indicated by the healers for the presence of plants. None of the antimalarial plant was confined to single geographical region and most of them are distributed throughout Anuppur District. Maximum occurrence of antimalarial plants are shown in Amarkantak region of Pushparajgarh division with due fact that the area holds the forest region and maximum number of traditional healers. Due to less anthropogenic access and poor population in the area, a large number of medicinal plants are growing in the wild. Bhundakona, Harratola, Barati, Ponki, Kabir chabutara, Babaghat, Jaleshwar, Kapildhara, Mohandi, Khati etc. are some specific villages where antimalarial plants are nicely distributed along roadside, deep in the forest and in moist wastelands. GIS based mapping of medicinal plants is a novel approach which gives precise

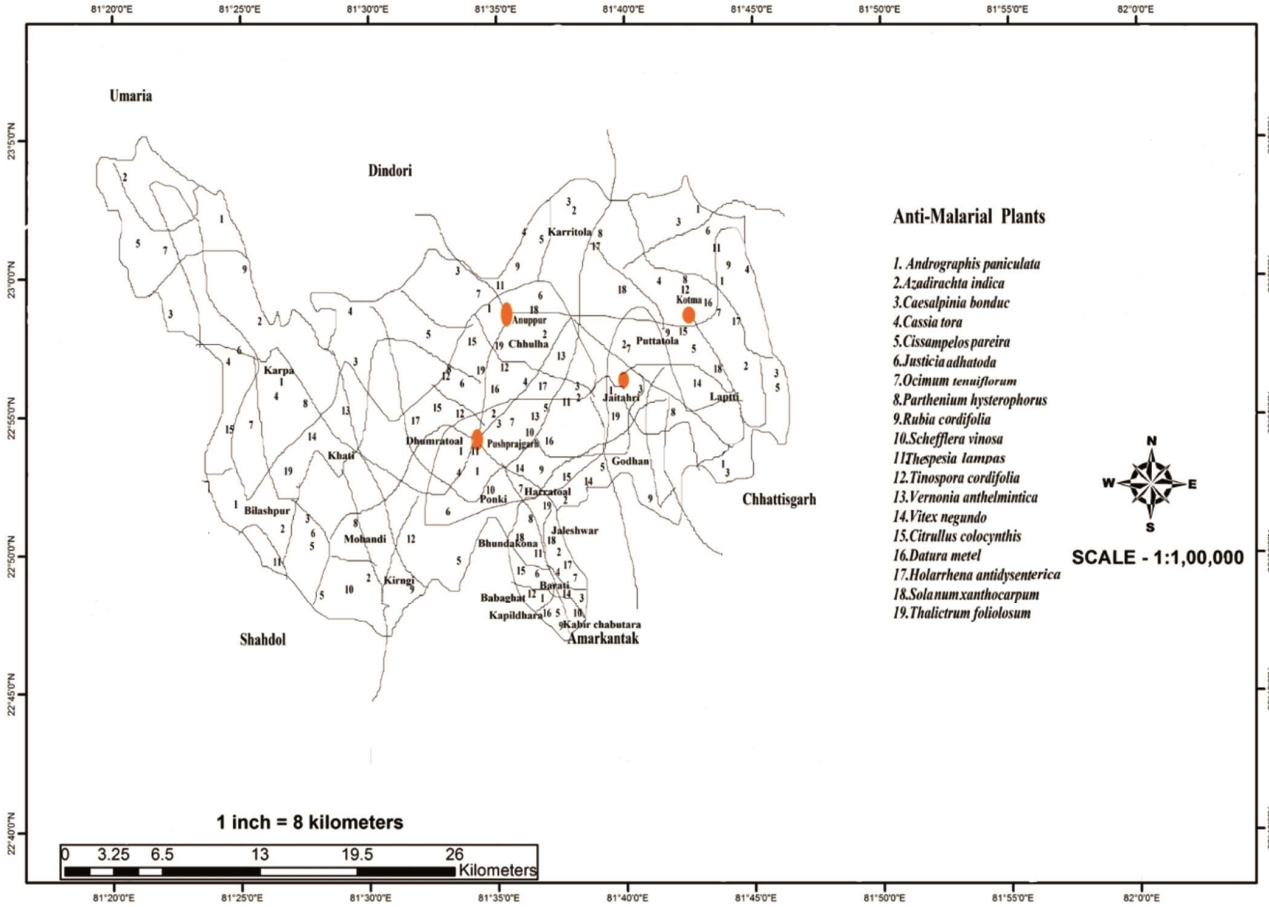

Fig. 2 — GIS map of antimalarial plants distributed in Anuppur district

location of interested plant[68]. The presented paper is the first hand report on documentation and geospatial mapping of antimalarial plants in Anuppur district.

Use of traditional phytomedicine is often questionable due to lack of scientific validation and its action mechanisms. In traditional medicinal systems, some of important clinical parameters such as quantity, duration and time interval of doses are subjective, depending upon the healers's past experience. Similarly, factors such as age, physical fitness, stage of illness, pregnancy, past illness records were also taken into account without scientific reasoning. The respect of traditional medicines is costing adversely due to increasing access to allopathic medicines, lack of precision and standardization, poor maintenance of clinical data, and uneducated background of tribal healers, which often lead to concurrent therapies viz. allopathic, homeopathic medicines alongside traditional medicines. There is a need to ensure quality, safety and efficacy by expanding knowledge base to make traditional medicines accessible and respectable.

Conclusion

Pushparajgarh division of Anuppur district is a natural reservoir of antimalarial and other medicinal plants. The area is highly populated by tribal communities, having indigenous life style and relies on natural resources. They have remarkable traditional knowledge for treatment of malaria and various other diseases using phytoresources. Frequent incidence of malaria in the area and the remoteness of the villages is probable cause of their expertise in phytomedicine. However, this traditional knowledge is vulnerable due to lack of interest in younger generation. The findings of the present ethnobotanical study provide a foundation for exploration of novel antimalarial compounds for drug development. Combination therapy, using mixed herbal formulations may also provide better therapeutic benefits. *in vitro* and *in vivo* antimalarial activities of the identified plants should be evaluated with chloroquine and artemisinin resistant malaria parasite. It can further validate the ethnoknowledge of traditional healers. The GIS based technique is a promising tool to understand ethnography, and can be used to locate the geographically distributed plants of interest. Local communities need to give attention on sustainable utilization of such phytoresources. None of the plants reported in the study are endemic to this area. All are part of already known Indian traditional medicine. Nevertheless, their use in malaria treatment is new. Furthermore, to have a better use of the field-data as a guide for laboratory studies, it is important to know the frequency of citation (or use-reports) per species, application and therapeutical use of local flora.

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