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The Influence of Climate Change on Medicinal Plant Availability on Malaria Treatment

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ABSTRACT

Climate change significantly alters the distribution and availability of medicinal plants, affecting global health, especially in regions reliant on these plants for treating malaria. Medicinal plants, recognized for their therapeutic properties and low side effects, have been integral to malaria treatment in traditional and modern medicine systems worldwide. However, changes in temperature, precipitation, and other climatic variables are influencing plant physiology, reducing the abundance and potency of species crucial for antimalarial therapy. The current review examines these climate-related impacts on medicinal plants in malaria-prone regions, with case studies from sub-Saharan Africa and Asia. The findings suggest that changes in plant availability and efficacy threaten local healthcare systems and emphasize the urgency for collaborative, interdisciplinary research to sustain medicinal plant resources. Solutions may include climate-resilient plant cultivation and bolstering indigenous knowledge, which could lead to sustainable alternatives for communities affected by climate change.

Keywords: Climate change, medicinal plants, malaria, antimalarial therapy, traditional medicine.

INTRODUCTION

Significant alterations in the geographic distribution of medicinal plant species due to ongoing climate change decrease the availability of useful medicinal plants for the treatment of malaria in certain areas. A handful of medicinal plants have been identified for the treatment of malaria. With hundreds of millions of new cases of malaria each year, drugs and insecticides are rapidly losing their effectiveness, and unavailable vaccines which might still be decades away, the need for novel strategies is rapidly increasing [1, 2]. Medicinal plants are also gaining in popularity worldwide, especially in developed countries, and are more frequently being utilized for the treatment of different diseases. The effects of climate change alter various aspects of the environment and might decrease the availability and thereby the potency of these plants. Of course, climate change is not new to the Earth, as climatic parameters have been changing considerably over geologic periods. The most current changes are now occurring with such speed, due to anthropogenic actions, that nature just cannot keep up. Moreover, indigenous or traditional human populations have been utilizing the same medicinal plants that are now being hailed as potential treatments for the unsustainable health decisions of the Western world for thousands of years [3, 1].

Medicinal Plants Used in Malaria Treatment

Many medicinal or aromatic plants have been traditionally used for malaria treatment in ethnopharmacological systems and allopathy. The spectrum of such plants is diverse, and the most important species for malaria treatment are listed separately in every pharmacopoeia of folk medicines and ethnopharmacological reviews. The fact that medicinal plants are used to treat a disease highlights their specificity as well as success in curing. The widespread disease and incessant demands gave them the knowledge of plant remedies. Moreover, the potency of Indigenous plants in conventional medications is undoubtedly reliable, backed by the presence of diverse active groups like tannins and alkaloids that possess antimalarial properties [4, 5]. The availability of several antimalarial medicinal plants around the globe is scarce in ethnomedical systems, and each possesses promising findings over scientific analytical studies in antimalarial action. An exhaustive compilation of traditional antimalarial plants summed 311 plant species around the globe. The dictionary of our current ethnopharmacology circle around the globe

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begins with these two medicinal plants, quinine, and artemisinin, as the main sources of conventional malaria therapy. China and Southeast Asia have been pragmatic for centuries due to their discovery to inhibit malaria, thus they have either become a part of the local economy, the foundation of local health services, or a hotbed of research on the production of artemisinin as an important constituent for modern malaria therapy. Additionally, the traditional association and practice of antimalarial plants endemic to India and Indo-China have agreed with this data. The preferable artemisinin plant principally includes traditional cryptolepis. In the Indo-China area, the maximum reliance has been on nutmeg, another selected plant for further investigation [6, 7].

Common Medicinal Plants for Malaria

In sub-Saharan Africa, people rely strongly on traditional medicine for curing different diseases. In comparison to synthetic drugs, one of the important advantages of using medicinal plants is their few side effects after usage. In sub-Saharan Africa, malaria is a disease characterized by a high rate of prevalence. Therefore, a high number of important medicinal plants have been considered to be effective against the disease. These mentioned plants include only those that have been in use as anti-malarial drugs against the falciparum species, the most dangerous type of malarial infection to date [8, 9]. The traditional usage of these plants as agents for treating malaria has been reviewed. Many scientists have worked on those quinoline and quinonidine plant compounds that have shown therapeutic activity in treating different chronic pathological conditions. Quinine was initially extracted from the bark of the tree Cinchona calisaya after its anti-malarial properties were verified. Approximately two hundred species of herbs are collected worldwide from Cinchona spp., so different chemical compounds can be obtained for discovery rather than seeking plants from the same region. Many other plants have various traditional applications; they can be in use in the same reserve and continue their therapeutic roles as drug resistance spreads very fast for sickness such as malaria. It is necessary to refer to all medicinal plants, which are in use in every nation or tribe, to treat malaria and carry out scientific research about it. There are many anti-malarial plants; however, for most of them, only conventional therapeutic uses are documented. As a result, more scientific research is needed to identify particular compounds from these plants and to recognize new compounds with feasible potential anti-parasitic activities [10, 11]. Malaria, especially in sub-Saharan Africa, is a global health issue. Studies have recorded 324 international medicinal plant species employed in the preparation of anti-malarial drugs. The plan of anti-malarial drugs mainly includes artemisinin-based combination treatments today, with artemisinin being generated from Artemisia annua. Medicinal species of flora belong to a variety of plant divisions and normally possess phytochemicals that aid in executing these therapeutic roles [12, 13].

Climate Change and Its Impact on Medicinal Plants

Medicinal plants provide the backbone of most traditional medical practices globally. As such, climate-induced changes in the availability of these resources have the potential to significantly impact the socio-economic health and well-being of millions of people. Due to the complex interplay of environment and genetics, altered growing regions, weather variability, temperature, and precipitation impact the cultivation, availability, or phenology of these important species. Results may include medicinal plant distribution alteration, local extinction, reduced population, and changes in medicinal active compounds in plant species that are attributable to, and indicators of, changed plant health [14, 15]. Climate variability and change can affect plants at levels from enzymes, including photosynthesis, water use, and respiration, to leaf and shoot growth (the cause of shifts to altered phenology); to population distribution; and finally, via a combination of drivers, extinction effects. High temperatures and drought are associated with metabolic changes, critical nutritional lack in severely denuded areas, and climate-associated disease outbreaks. Altered phenological traits often translate into changed behavior at higher levels of ecological organization, e.g., changes in species geographic range, with crop, genetic, and conservation implications. A related bottom-up cascading effect is likely on the mammal, bird, and insect species that interact with these plants, including changing the timing of the availability of vital resources. Thus, changes in the habitable suitability of medicinal plants could potentially influence human disease dynamics by modifying relevant climatic variables related to disease transmission. Moreover, it is envisaged that climate-induced changes could also lead to the local extinction of some of the plant species that have been identified in these studies, with the potential to affect emerging diseases [16, 17].

Case Studies and Research Findings

Case study 1: Ituri Forest, Democratic Republic of Congo (DRC) In Ituri Forest, traditional Tsu fur medicine (north-eastern DRC) is an intricate entanglement of human and non-human beings, with agarwood species for ritual purposes and medicine being primary among the latter. Since 2010, the first author has been working among the Tsu fur, participating in their life in close communication with their knowledge about the social and environmental landscapes. Our research incorporates biological,

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ethnographic, social, and semi-structured interview components. Interviews were conducted with 14 traditional healers in the Boma village area. Eight aged members of the village and the communities shared experiences and perspectives on their forest and herbal medicine availability spanning from 135 to the present. Data were collected between 2011 and 2019. Findings show that as Laikipia (and Ituri) become hotter and the climate changes, the declining availability of agarwood species since October 2019 is becoming a problem because alternative medicinal plants are not as effective for treating malaria positivity and have side effects not present with agarwood [18, 19].

Case study 2: Western Kenya the study site was located in western Kenya where the use of native plants as ethno-botanicals was prevalent and commonly available for health services. The study encompassed 5 counties around the River Kuja catchment; that is, Vihiga, Siaya, Homabay, Kisumu, and Migori. Data were collected from 5 specialist interviewers and 300 household heads. A simple random sampling method was applied to the farmers to get a representative sample. Ethnobotanical data on medicinal plant species to treat malaria were recorded from 300 household heads. The relative frequency of citation approach was applied to find out the most cited medicinal plant species, and the target was to find out the highly used plant species alone or in combination to construct an act as cultural acceptance to develop a repellence cream. A ranking of the most cited plants was done to determine the most highly available plant in the community. Plants evaluated by the community members could be primary sources of potential plants that caused the biting behavior of malaria vectors. Data suggested that traditional available medicinal plants were decreasing from 0.22% in local households to 0.28% in wild-accessible areas. This study reported traditional available medicinal plant species such as Carissa edulis, Azadirachta indica, Lippia javanica, Tithonia diversifolia, Persicaria senegal, and Bacopa monnieri. Chrysanthemum cinerariifolium and Eucalyptus grandis were the best among reservoir plants compared to other potential plants. Pubescence, herbulations, and plant physical environmental availability caused very infrequency in attracting malaria vectors. Measures taken were to use natural plant repellents or address immune deficiency [20, 21].

Study 1: Impact Of Temperature Changes

An important aspect of the current study is the response of eight species after being exposed to fluctuating temperature treatments that simulate temperature shifts observed in botanical gardens. The data indicate that no general predictions on the influence of different temperature ranges and biodiversity reduction can be drawn from the current understanding of individual species' physiological stress, and this can be very important for the availability of species used for malaria treatment. The overlap between the tau and the access plan work on the A. annua species demonstrates the pertinence and relevance of continuous observation of this plant. In one of the studies reported here, the impact of increased temperature on the distribution of potential and historic distributions of useful species for providing treatment of malaria was modeled. It was found that, under future simulated climates, the suitable habitat area for a significant percentage of the species previously used for malaria treatment is likely to decrease. Providing these results are representative of wider environmental change throughout Madagascar, Jerusalem artichoke, and Tithonia tubaeformis are likely to become the main species used for malaria. As is evident from the study above on growing adult plants, the simulation study does provide rather negative results for traditional anti-malarial species and species with bioactivity against AR, demonstrating the need for our work. The study indicates that some of the newly recruited species for malarial treatment and the active ingredient in AR malarial drugs may be less sensitive to the future anticipated increased temperatures and future anticipated decreased precipitation patterns. The spreadsheets indicate in which of the reserves the species of interest are present [22, 23].

Study 2: Effects of Precipitation Patterns

Most wild medicinal species are suitable to be used broadly in chemical-free highland agriculture systems. Their continuous activity of secondary metabolites is in line with seasonal-related infectious diseases such as malaria. Moreover, they could complement the diversity within traditional medical practices. From this point of view, our focus is now on those possible land-use diversifications shaped by climate, the availability of medicinal wild plants to both farmers' and healers' fields, and which altogether can ensure tangible local health and welfare-enhancing values. Implications of changing precipitation on plant health and nutrient levels are significant. Variable precipitation distributions can influence plant health and make them susceptible to adverse conditions such as soil moisture-induced hypothermia, die-back, or the impacts of floods. Plants grown under excessive moisture conditions may become waterlogged, leading to anoxic respiration and root loss. Vegetative growth can be impaired due to soil water saturation. However, a significant reduction of evapotranspiration by high temperatures may result in sudden drought stress when temperatures exceed a critical maximum. Additionally, potentially shorter or less intense storms and increased average intensity of daily rainfall may exacerbate flooding and therefore

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have a direct effect on botanical composition and availability. Moreover, in the longer term, permanent changes between droughts and extremely heavy precipitation peaks have been revealed to be the most sensitive to climate change – a landscape including the study areas. Floristic and vegetation changes drastically compromise both the resilience and redundancy of local health-related medicinal wild plants. Pertaining research suggests that climatically determined plant activity – related to the timing of secondary metabolites in medicinal plants – could also be affected by wetter conditions. The free radical scavenging property of the plant was shown to fluctuate about the time of harvest and amount of rainfall. In the context of climate and landscape perspective, although the available seasonality and landscape-plant accessibility are unequally low in some periods, peak plant activity, if it occurs, would favor the preparation of large quantities of medication for community-wide administration. Timing of plant harvesting and procurement of medicinals is vital in the event of large-scale disease burden. It has been found that these wetter conditions were expected to result in a gain of 10 days of plant activity. The concentration of compounds decreases with the water difference from the normal levels, which has been usually studied concerning the timing of harvest. Changes in transcription brought about by water difference patterns in precipitation were recently reviewed. Coastal communities described a few plants that disappeared altogether following cyclones and related rainfall regime changes [24, 25].

Implications for Malaria Treatment and Future Research

Based on the theoretical evidence and the practical experience of traditional healers in three very different countries, it is likely that climate change is having a marked influence on the availability of medicinal plants for today's malaria treatment. Numerous cases suggest that antimalarial plant consumption is unsustainably high in many regions. One reason for an increasing temporal availability discrepancy is the lack of systematic phytochemical research into the effects of elevated CO_2 levels on the secondary metabolite concentrations in plants and the influence of temperature on secondary metabolism. This presents an area where future research can make a significant contribution toward a comprehensive understanding of the availability of antimalarial plants threatened by climate change. To date, very few studies have addressed the impacts of climate change on plant secondary metabolites. This is surprising, given that many climatically sensitive metabolite concentrations have non-negligible ecological and human health impacts. Integrated strategies for protecting plants and the people who use plants for medicine are urgently needed. Research institutions, NGOs, and governments should support the establishment of cyclical meetings with interdisciplinary experts in such fields as global climate change, biodiversity loss, traditional medicinal systems, recent advances in phytochemistry, genetics, and chemical ecology, ancient and recent pharmacology, naturopathy, ecology and population biology of malaria to engage in a sustained interdisciplinary dialogue on potential strategies for the mitigation of such problems. It cannot be forgotten that medicinal plants are 'the mainstay of primary health care for much of the world's population', while in most developed countries 20-40% of the population still rely, at least in part, on traditional or complementary medicines. Closed international workshops will be organized with the above goals in mind. The unique and urgent nature of the threats outlined above suggests that this work should be flagged for the attention of the international research, environmental, and public health communities [3, 26].

CONCLUSION

The increasing effects of climate change on the distribution, potency, and availability of medicinal plants highlight an urgent need for sustainable strategies to maintain plant-based malaria treatments. Given that these plants are central to traditional and allopathic treatments, particularly in malaria-endemic regions, climate-induced losses could severely impact healthcare access for millions. Future research should focus on identifying resilient species, understanding climate effects on phytochemical efficacy, and fostering interdisciplinary collaboration. Efforts to conserve and cultivate medicinal plants and preserve indigenous knowledge will be essential to ensure that local communities continue to benefit from these natural resources in the face of shifting environmental conditions. Addressing these issues is critical for global health equity and the sustainability of traditional medicinal systems.

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