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IMPACT OF CLIMATE CHANGE ON DIVERSITY OF HIMALAYAN MEDICINAL PLANT: A THREAT TO AYURVEDIC SYSTEM OF MEDICINE

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ABSTRACT
Climate change and global warming are well acknowledged threats today, which affected the whole world biodiversity. Review of the literature revealed that regions with higher elevations are more vulnerable to the bad effect of climate change. The Indian Himalayan region, one among the mega hot spot of biodiversity is also the repository of valuable medicinal plants described in Ayurveda. Due to climate change the medicinal plant diversity of this region is on high stress or may be extinct in long run. From climate change, it has been observed the changes of alpine ecosystem, habitat fragmentation, shifting range of distribution, change in phenology pattern, change in secondary metabolites and invasion of new species, which have negative impact on the existing resources of medicinal plants.
Ayurveda, the ancient system of medicine which solely depends on the plant resources for alleviating the illness will be highly affected in future due to the impact of climate change.
Key words: Climate change, Himalayan medicinal plants, Ayurvedic medicine

INTRODUCTION

Climate change and global warming are the warning calls and very well acknowledged threats today, worldwide and almost all the species of world bio-diversity are affected by the same[1]. In recent times, the climate change and global warming have already knocked the doors of existing biological resources world-wide and exerting a pressure, apparently or non- apparently, on the living style and resources practices by the people of Ayurveda conceivably, the old and pioneer of all medicinal system of world uses various resources like plants, animal and minerals for alleviation of illness[2,3]. Climate change may not merely a biggest threat to the Ayurvedic system, but it is well acknowledged that, the existing resources used by the practitioners of this system will be highly affected in future due to increasing threat from anthropogenic pressure and climate change.

Methods

The impact of climate change on Himalayan medicinal plant diversity are assessed based on the review of climatic variability observed in the Himalayan states, study of the recent literatures, journals and personal observation during Medico-ethno-botanical survey of North west Himalayan region. The changes in altitude and phenological behavior of the plants also observed after comparing the Herbarium of both recent and past, repetitive survey done by the Regional Research Institute of Himalayan Flora, Tarikhet, Uttarakhand, India. Further the link between Ayurveda and medicinal plants diversity of Himalayan region and relation with climate change has been conferred from the review of literature.

Himalayan Biodiversity and Ayurveda

Ayurveda refers that the best herbs should be collected from the north region especially in Himalaya; Acharaya Charaka told, "Himavanousadha bhuminam''[4] means Himalaya is considered to harbours most sacred and potent medicinal plants described in Ayurveda. The Ayurvedic formulary of India, an authentic book on Ayurvedic formulations, includes 351 drugs of plant origin are described out of which maximum species are from Himalayan region. The pharmaceutical sector is using 280 medicinal plant species, out of which 175 are from the Himalayan region[5] and maximum numbers of medicinal plants have been reported from an 1800 m elevation range[6]. According to modern researchers also, the Himalayan region is the mega hot spots in the globe and well known for the habitat of valuable medicinal plants. The Indian Himalayan region supports the tropical, sub-tropical, temperate, sub-alpine vegetation with a altitudinal range (200-8000 m, amsl) and it has a rich flora of medicinal and aromatic plants and so far 1748 species have been reported medicinally important[7]. High altitude medicinal plants are of great concern throughout the Himalayan region, because they are important for traditional health care and in large scale collection for trade. Among these, important medicinal plants species (e.g. species of *Aconitum, Taxus, Ephedra, Dactylorhiza, Fritillaria, Polygonatum, Podophyllum, Picrorrhiza, Nardostachys* etc.) and many other high altitude Himalayan plants have huge market potential but due to overexploitation and many other anthropogenic and environmental factors are now restricted to either inaccessible areas or to the protected habitats[8]. The high

altitude plants of the Himalayas which remains under the snow cover for a considerable period of time and exposed to the extreme environmental conditions holds a vast potential to serve as remedy for various chronic diseases[9]. At the same time the IHR (Indian Himalaya Region) is well known for the richness and diversity of valuable but highly sensitive species of medicinal and aromatic plants. Some of these species are typically found in high altitude areas particularly in stressful environment, grow slowly and are totally confined to this region. Experts warn that the plant species which are endemic to geographic regions particularly vulnerable to climate change may face high risk in near future and the IHR is no exception.

The Indian forest are already subject to multiple stresses, including over exploitation, forest fire, livestock grazing, tourism, fuel wood collection and habitat degradation. The changing environmental conditions will be an additional stress, which may have an over-arching influence on plant diversity, through other stresses (insect and pest incidence, diseases etc) may lead to the extinction of these species from natural habitat. The extreme climatic conditions, i.e., sub-zero temperature with great diurnal variation, scanty and erratic rain fall, heavy snow fall, howling winds, ultraviolet radiation, desiccating exposure to the sun, landslides, snow slides, avalanches, soil erosion etc are the cause of damage to the vegetation[10]. Further loss or unavailability of genuine drug material leads to adulteration, which definitely impose an adverse effect on the efficacy of the Ayurvedic system.

Bio-Diversity and Climate Change

Climate change refers to the variation in the earth's climate or in regional climates over time. It is estimated that there will be further increase in temperatures of 1.4^0C to 5.8^0C by the year 2100. This will undoubtedly have severe consequences on bio-diversity. Climate change is already forcing bio-diversity and eco-system to adopt shifting habitat, changing life cycle and the development of new physical traits. A rapidly changing climate might favour species that can extend their ranges quickly or that can tolerate a wide range of climatic conditions, both these traits shared by many invasive plant species.

The projected shift in vegetation type may lead to a large forest die back and loss of biodiversity especially in the transition between forest types, as at higher altitude increase in temperature will result in shifts of lower altitude sub-temperate and temperate forest, to higher altitude sub-alpine and alpine forests resulting in the extinction of some temperate vegetation types. The mountainous forest (sub-alpine and alpine forest, the Himalayan dry temperate forest and the Himalayan moist temperate forest) are susceptible to the adverse effect of climate change. This is because climate change is predicted to be larger for regions that have greater elevations[11].

It has been observed that, the Himalaya and surrounding areas have warmed by approximately 0.68°C since the middle of the 19th century[12].

There are various issues related to climate change affecting the existing resources of medicinal plants used by the Ayurvedic practitioners such as; Changes of alpine ecosystem, Habitat fragmentation, shifting range of species distribution, shifting phenology of plants, habitat encroachments/invasion, changes in secondary metabolites, and arrival of new genotype of medicinal plants, which will have negative impacts on the existing resources and thus on Ayurvedic system in near future and in longer run.

Climate change and alpine ecosystem

Alpine regions are important for the Ayurvedic practitioners because medicinal plants accounted for 62% of all plant species are from alpine Himalayan sites. Most of the medicinal plants have shifted to higher altitudes due to increasing temperature. Overall species richness was found to decline with elevation from the lowest summits to the highest, the proportion of useful plants stayed approximately constant. Several Tibetan medicinal plants are already threatened by over-harvest, and the additional challenges posed by climate change could push some species which might otherwise have been sustainable to extinction. After polar regions, alpine areas are changing faster than any other areas on Earth," Plants growing in alpine environments are impacted by climate change. Advancing tree lines and extinctions of montane plant populations have become increasingly apparent and documented by researchers worldwide in recent years and have been attributed as evidence of the impact of climate change on alpine ecosystems[13]. This high percentage of useful plants confirms the importance of the Himalayas for Ayurvedic system and reflects the dangers posed by potential plant losses from climate change. Depletion of ethno-medical practices is also due to climate changes coupled with other socio-economic factors on the loss of traditional knowledge has been observed[14].

"Researchers have found that some cold-adapted plant species in alpine environments have begun to gradually climb higher up mountain summits[15]. In some cases, these plants migrate upward until there are no higher areas to inhabit, at which point they may be faced with extinction. Additionally, the upward migration of plant species can lead to increased competition for space and resources, causing further stress among alpine plant populations.

In the IHR (Indian Himalaya region), particularly in alpine areas, changes in snow patterns and temperatures are already affecting the distribution and phenology of some plant species [16]. Recently, Khanduri *et al*,[17] have explored some phenological changes in more than 650 temperate species, which have indicated the average advancement of 1.9 days per decade in spring events and average delay of 1.4 days per decade in autumnal events. Alpine ecosystems are known to react sensitively to climate warming since most plant species have altitudinal limits that are set by various climatic parameters and limitation of resources[18]. Thus, alpine plant species has various morphological and physiological means of adaptation against adverse climatic conditions.

Habitat fragmentation

It is a key factor that may impede the ability of species to track contemporary climate change in regions where the climate is becoming more favorable for certain species. Habitat fragmentation reduces dispersal ability and contributes to lags in distributional change. The loss and fragmentation of natural habitat affect distribution of biodiversity. There is an urgent need to restore a

substantial fraction of the wilderness that has been depleted in the past. Many species that are today widespread will experience large range reductions. Initial data on shifting of distributional range clearly indicate vegetation zones shifting towards higher elevations to save themselves from extinction. Efficient dispersal may be able to shift their ranges to take advantage of newly suitable habitats, but most species will at best experiences a time lag before extensive colonization is possible, and hence, in the short of term will show range diminishment[19].

Shift in vegetation towards higher altitudes

It has been observed that species of higher elevations are projected to shift higher[20]. When climatic condition change, unexpected results may follow each species will respond in an individual fashion according to its climate tolerance and its ability to disperse in to a new location, altering its phonological behavior and breeding dates and those species that are unable to adapt will face extinction.

Spread of Invasive species

It has been observed that a rapidly changing climate might favour species that can extend their ranges quickly or that can tolerate a wide range of climatic conditions, both these traits are shared by many invasive species[21]. Alien weeds, viz *Lantana camara*, *Parthenium* and *Ageratum* have invaded and altered community structure and population dynamics of native flora and fauna of the hilly region of Himalaya[22].

Changes in phenological behaviour

There is also Phenology shift of medicinal and aromatic plants and animals due to climate change. These changes in plant phenology act as important early warnings of impending ecological change, and may be direct causes of community change by altering the timing of activities that allow species to coexist. Life cycle of many wild plants and their foragers are closely linked to the passing of the season and climate change can lead to loss synchronization of interdependent species.

Climate change may directly alter plant fitness[23,24], as well as alter the reproductive success of plants and their interactions through impacts on flowering phenology[25-35]. Studies also show that recently in addition to shifting phenology, plant species have begun to adapt to recent climate changes through altered species ranges[36]. The phenological behavior of different growth forms in an alpine pasture of North-West Himalaya, India was observed by Vashistha *et al*. (2009). Early bud break in *Betula utilis* has been recorded in 2010 as compared to earlier years[37]. The changes in phenological behavior of species may be a strong indicator of climate change since many species are highly sensitive even to the smallest change in the long prevailing climate of any ecosystem. It was possible to confirm that changes in phenology may provide strong evidence of global warming.

Impact of climate change on Secondary metabolite of medicinal plants

Besides above, climates change can also altered species composition and in recent years, researchers postulated that climate change could affect the chemical composition and, ultimately the survival of some medicinal plants in high altitude region. Particularly, the temperature stress can affect secondary metabolites and other compounds that plants produce, which are usually the basis for their medicinal activity[38]. Generally when plants are stressed, secondary metabolite production may increase because growth is often inhibited more than photosynthesis, and the carbon fixed not allocated to growth is instead allocated to secondary metabolites[39]. Several studies have examined the effects of increased temperatures on secondary metabolite production of plants[40-42]. It is hypothesized that the warming temperature and rising CO_2 level will alter growth cycles of alpine plants and active constitutes of the plants may change due to physiological changes[43].

Personal Observation

The authors are working in the Regional Research Institute of Himalayan Flora, a leading institute dedicated on survey of medicinal plants in the western Himalayan region of India since 1964. Since then extensive and intensive plants explorations work have been done in the all virgin Himalayan pockets and botanical hotspots ranging from 300m to 4500m.The institute holding 70000 herbarium specimens with acronym RKT. Repetitive survey was carried out after every 10 years in same region. From past and present studies observation are as followed in the context of climate change.

- Shift in vegetation from lower elevation to higher elevation (up to a variation from 200-500 m)
- Changes of Phenological pattern, early flowering was observed in most cases
- Long period of seed dormancy observed in high altitude plants like; *Saussurea obvallata*
- Low seed germination rate of seed of the high altitude medicinal plant
- Spread of invasive species up to sub-temperate Himalayan region
- Erect habit of some plants changes to prostate habit in some cases
- Migration of alpine region species towards cold desert condition
- Yielding and division of corms of *Crocus sativus* L. has been diminished in Ranikhet area due to low chilling rate of the corms resulted due to increase in temperature of local region in recent years.
- In the case of faunal diversity studies on Himalayan Musk Deer it was observed that due to climate changes, fertility rate is declining day by day and mortality rate has been increased. Habitual abortion also observed.

Conservation Strategies of Medicinal Plant Diversity with Special Reference to Climate Change Initiatives to be taken

There are many threats causing loss of medicinal plants diversity of Himalaya region. Here some suggestions to mitigate the vegetation loss due to climate change are given.

1. Quantitative assessment and identification of threatened and commercially viable medicinal plants in respect to climate change and particular attention needs to be paid to those species on which people's livelihood depends.
2. There is an urgent need of prioritizing study areas on biodiversity and climate change, the indicators, easy way

to handle, and on monitoring mechanism to combat the global warming and limiting bio-diversity loss

3. To adopt more realistic approach through recent techniques like RS and GIS by continuous monitoring, suggestions and amendments of conservation plan without going in a long run of fix attitude of people, stereo-type management and preconceived policies, which may not work in future.
4. Implementation of environmental education improves awareness among society towards biodiversity conservation and climate change.[44]
5. Interventions in existing technology and adaptive mechanism are required to establish a balance among aerosols (gaseous, particulate and liquid pollutants), climate change and biodiversity conservation[45].
6. Traditional success stories with regard to adaptation and mitigation due to climatic uncertainties need to be documented and understood.
7. Establishment of well-equipped laboratories in the Indian Himalaya States at different altitude for identification of eco-physiological characteristics of alpine and other Himalayan medicinal plant species. Further strategies to be developed for adaptation and mitigation based on these experiments[46].
8. To conserve and protect the floristic diversity (vulnerable or endangered species) in their own habitat because of their interdependent of species in the ecosystem their survival (in-situ conservation).
9. Promotion of community based conservation.
10. To supplement in-situ conservation, attention should be paid to ex-situ conservation of rare, endangered, endemic, and threatened species through scientific and technical inputs. viz; tissue culture, MAP nurseries etc.
11. Establishment of Herbaria, which has an indirect role in detection, assessment and monitoring of rare and threatened important medicinal plant species there by augmenting both in-situ and ex-situ conservation initiatives.
12. Establishment of medicinal plant garden in selected areas for ex-situ conservation.
13. Create awareness and educate the local inhabitant about the utilitarian aspects of the plants with reference to their traditional medicinal and economic value.
14. To develop conservation technology i.e, in-vitro and agro technology of commercially viable threatened / economically important medicinal plants, which will not only help in promoting mass cultivation but also, help in reducing pressure on the natural habitat[47,48].
15. Invasive taxa and all alien species need to be characterized for its stage of invasion as they have management implication.
16. A '4P' management strategy of Prediction, Prevention, Prescription, and Public awareness needs to be adopted to stem out the tide of biological invasion.

CONCLUSION

The entire ecosystem around the world and the Himalayan environment in particular is affected by the climate change. The Ayurvedic system of Medicine mostly dependent on the plant sources for medicine is mainly obtained from the Indian Himalayan region. From the review of literatures and from personal observation it is evident that; climate change may not currently represent the biggest threat to Ayurvedic system, but 80% of world populations rely on medicinal plant as their primary health care also will be affected with the vanishing of the sources. Hence a set up of collaborative study from the scientists and researchers of various disciplines like Ayurveda, Modern medicine, Forest and Environment, Geology with involvement of other technocrats, Govt. organizations, Non Govt. organizations, farmers is the need of the hour to understand and document the climate change.

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