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Review

Influence of climate change on production of secondary chemicals in high altitude medicinal plants: Issues needs immediate attention

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Medicinal plants are highly valuable to human livelihood and the Indian Himalaya is well recognized amongst unique and globally important medicinal plant rich areas. Studies on possible effects of climate change on medicinal plants are particularly significant due to their value within traditional systems of medicine and as economically useful plants. There are evidences that climate change is causing noticeable effects on life cycles and distribution of the plant species. However, it is largely unclear about climate change effects on secondary chemicals production in plants and particularly in high altitude medicinal plants of Indian Himalaya. Elsewhere this perspective has been given renewed attention recently. A need for research to improve our understanding of these effects on high-altitude medicinal plants is stressed in the present article.

Key words: Indian Himalayan region, climate change, conservation, medicinal plants, secondary metabolites.

INTRODUCTION

Medicinal plants are essential natural resource which constitutes one of the potential sources of new products and bioactive compounds for drug development (Gangwar et al., 2010). It is estimated that 60% of the world population and 80% of the population of developing countries rely on traditional medicine, mostly plant drugs, for their primary health care needs (Shrestha and Dhillions, 2003). Reports show that 70% of population of India is dependent on traditional plant based medicines (Gadgil and Rao, 1998). Out of the 17000 species of higher plants in India, about 7500 are known for medicinal uses, which comprise a considerable proportion of total flowering plants (Shiva, 1996). The utilization of plants for medicinal purposes in India has long history, and the proportion of medicinal plants is the highest proportion of plants known for their medicinal purposes in any country of the world for the existing flora of the respective country (Kala et al., 2006).

The Indian Himalayan Region (IHR) harbors remarkable plant diversity derived from steep gradients of both elevation and precipitation and has traditionally been an important source of medicinal plants. The Indian Himalaya has a rich flora of medicinal and aromatic plants and so far 1748 species have been reported medicinally important (Samant et al., 1998). 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 (Kala, 2008). Realizing the importance of high altitude medicinal plants, recently the National Medicinal Plants Board (NMPB), an apex body of the Government of India, has set up a Task Force on the High Altitude Medicinal Plants

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(HAMP) and many issues have been discussed for developing suitable policy guidelines for medicinal plants. 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 (Kala, 2009). At the same time the IHR 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.

Oerlemans (2005) has attempted a surface temperature reconstruction based on the response of glaciers to climate change and indicated that the Himalaya and surrounding areas have warmed by approximately 0.68°C since the middle of the 19th century. Currently, evidences of the influence of climate change on natural ecosystems worldwide is increasing and studies show the changes in weather events, seasonal patterns, temperature ranges and the related phenomena and attributed these to climate change (e.g. Parmesan and Yohe, 2003; Root et al., 2003; Thomas et al., 2004; IPCC, 2007 a, b). The consequences of climate change are already being felt in many places across the globe and its effects on seasonal activity in terrestrial ecosystems are significant and well documented (Walther et al., 2002; Root et al., 2003). Available evidence suggests that range shifts of individual species are likely to result in changes in community composition, as a result of local extinction and dispersal/migration (Benning et al., 2002; Hansen et al., 2001).

In the IHR, particularly in alpine areas, changes in snow patterns and temperatures are already affecting the distribution and phenology of some plant species (Nautiyal et al., 2004). Recently, Khanduri et al, (2008) 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 (Panigrahy et al., 2010). Thus, alpine plant species has various morphological and physiological means of adaptation against adverse climatic conditions. It is well known that the growth response of plants to climate depends on their life history characteristics and ecophysiology and largely differs between species. Despite the high ecological and economic importance of Himalayan medicinal plants, the effects of climate change on secondary metabolite production are still poorly known.

CLIMATE WARMING VS. SECONDARY CHEMICAL PRODUCTION

Besides changes in plant phenology, climate change influences the shift in species distribution, loss of habitat and altered species composition and in recent years much focus is being given to understand such phenomenon in climate change research. Among others, there has been little focus on investigating effects of climate warming on medicinal plants and their secondary metabolite production. This aspect is very much relevant as a sizeable proportion of population in developing countries relies on traditional medicines derived from plants for treating various ailments (De Silva, 1997). Climate change may directly alter plant fitness (Galen and Stanton, 1991, 1993; Wookey et al., 1993), as well as alter the reproductive success of plants and their interactions through impacts on flowering phenology (Hughes, 2000; Beattie et al., 1973; Schemske, 1977; Gross and Werner, 1983; Lacey and Pace, 1983; Schmitt, 1983; English-Loeb and Karban, 1992; Peterson, 1997; Bishop and Schemske, 1998).

Studies also show that recently in addition to shifting phenology, plant species have begun to adapt to recent climate changes through altered species ranges (Parmesan, 2006). The phenological behavior of different growth forms in an alpine pasture of North-West Himalaya, India was observed by Vashistha et al. (2009). These authors suggested that climate change and temperature may lead to long-term irregularities in interspecific interaction and may alter plant population dynamics, community structure and ecosystem functioning in the region. 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 (Zobayed et al., 2005; Salick et al., 2009). 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 (Mooney et al., 1991).

Several studies have examined the effects of increased temperatures on secondary metabolite production of plants, but most of these studies have contradictory results (Jochum et al., 2007). Some report that secondary metabolites increase in response to elevated temperatures (Litvak et al., 2002), while others report that they decrease (Snow et al., 2003). As such the responses of secondary chemicals to increased temperature are less well understood, although, an increase in volatile organic compounds has been generally detected (Loreto et al., 2006). Recently, Bidart-Bouzat and Imeh-Nathaniel (2008) provided a comprehensive review on individual effects of major global change factors on plant secondary chemistry and its implications mostly for insect herbivores. These authors highlighted that the effect of global change factors on plant secondary chemistry appears to be plant species-specific (and genotype-specific) as well as dependent on the chemical type and may be related to the type of environmental stressor as well. In the Indian Himalayan context, such studies are highly limited. However, 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 (Chaturvedi et al., 2007). Therefore, studies on climate response in medicinally important plants of high-altitude region of Himalaya needs greater attention to understand the underlying phenomenon. For long-term supply of quality raw material to pharmaceutical industries and effective use of medicinal plants for curing ailment, studies on effects of climate change on plant secondary metabolic production and composition become essential.

FUTURE RESEARCH AVENUES

Much of research on high altitude Himalayan medicinal plants has so far focused on status assessment and distribution patterns in the wild, analyze economic implications of elite identification (in terms of producing biomass and availability of secondary metabolites), *in vitro* propagation protocols, mass propagation through conventional (vegetative and seeds) methods, development of agrotechniques and understanding reproductive biology. However, there is a growing opportunity to initiate studies for addressing effects of climate change on phenology, species range shifts, habitat alternation and secondary metabolite production of high-altitude medicinal plants. Experts have warned that the medicinal plants which are already threatened by over-harvest, the additional challenges posed by climate change could push some important species to extinction and may result in decrease in number of endemic species in the region as species composition, structure and functioning of sensitive habitats (including timberline zone and alpine meadows) can change both because of increased temperatures and changing snow pattern.

The need for establishing Long Term Ecological Research (LTER) station network in different ecoregions of India is recently highlighted by Tripathi (2010), where detailed ecological observations (Taylor, 2008; Lubchenco et al., 1991; Canadell et al., 1999) like long-term changes in climate, vegetation dynamics including phenological observations (Kushwaha and Singh, 2008), and other important observations can be recorded. Also it was suggested that it is high time to initiate such long-term ecological observations in different ecosystems in India to record long-term large-scale response of ecosystems in the changing environment scenario in the 21^{st} century. This type of observation network may guide long-term studies on climate change impact on different aspects of medicinal plants in high-altitude region of Himalaya, as such type of studies are very limited and need immediate attention. Researchers have found that due to rise in temperatures, some cold adopted alpine species are migrating upward until there are no higher areas to inhabit, at which point they may be faced with extinction (Salick et al., 2009). Therefore, a complete understanding of potential impacts of elevated CO_2, temperature warming and enhanced ultraviolet radiation on secondary plant metabolites is an important task for the future.

Monitoring long-term effects of climate change factors as well as their interactive effects on plant secondary chemistry should be included in high altitude medicinal plant research agenda in the future. Moreover, as also highlighted by other authors, some most important points for the future research on climate change for medicinal plants of high-altitude areas, include; plant ecological and evolutionary responses to recent climate change; effects of climate change on concentration and intraspecific variability of different secondary metabolites, temperature warming and elevated CO_2 effects on foliar chemistry, species upward migration, long-term dynamics of endemic medicinal plants and analyzing extinction risks from climate change. Nevertheless, for understanding the potential impact of climate change on functional plant ecology of high altitude ecosystems (particularly sub-alpine and alpine), long-term observational plots essentially needs to be established in representative sites.

CONCLUSION

As highlighted by various researchers, currently the major conservation issue related to medicinally important plant resources (medicinal and aromatic plants) in the Indian Himalaya is the over harvesting due to increasing demand and trade pressure. The IHR is a rich reservoir of plant diversity including valuable native, endemic and rare medicinal taxa. Particularly, the endemic plant species are considered more vulnerable to climate change and may face high risk of extinction due to their confined geographic distribution. Studies in other parts of the world indicated that climate change is causing noticeable effects on life cycles and distribution of the high-altitude plants. Therefore, an improved knowledge of the factors responsible for such changes requires intensive and continuous field measurements at representative sites in the IHR. Moreover, further research on the habitat range and secondary chemical production efficiency of threatened Himalayan medicinal plants under climate warming scenario is essential for developing conservation strategies as well as agrotech-nologies for cultivation. As pointed out by Bidart- Bouzat and Imeh-Nathaniel (2008) these studies are also important because variation in plant chemical induction can have significant ecological and evolutionary implications for plants and their interactions with insect herbivores.

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