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CHANGING SCENARIO OF MEDICINAL PLANTS DIVERSITY IN RELATION TO CLIMATE CHANGE : A REVIEW

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Abstract

Medicinal and aromatic plants have played a fundamental role in alleviating human sufferings like diseases, ailments and disorders since times immemorial. The major causes for the decline of wild medicinal plant species are due to natural and anthropogenic calamities i.e. rapid climate change, urban development, industrial boom, overpopulation pollution, shrinking forest cover, habitat loss, over-harvesting, destructive harvesting and floods. Medicinal and aromatic plants are not resistant to the consequences of climate change like all other living members of the biosphere. This causes successively some medicinal plants endemic to geographic regions or ecosystems which could put them in danger and are particularly vulnerable to global climate change. Further, such problems with global climate change will certainly pose a more prominent or immediate threat and have the potential to exert increasing pressures upon medicinal plant species. Global climate change impact may have an incredible possible effect on medicinal plants particularly significant to their value within traditional systems of drugs and as economically useful plants.

Key words: Medicinal plants, Diversity, Phenology, Plant constituents, Climate change

Introduction

Medicinal plants have played significant roles in the lives of local peoples living in these regions by providing medicinal products. Medicinal plants are used for different purposes and in diverse uses of human beings. The use of medicinal plants is found in almost all cultures as a wellspring of medicine. Medicinal plants have been used for a large number of years to treat wellbeing issue and to avoid illness including epidemics. People had the basic information of medicinal values and curing various illnesses of medicinal plants from a period of past time (Sharma *et al*., 2020). Earth's climate is warming at an extraordinary rate which is evidenced clearly. Sea levels are being rising and impacting plant's growth and yield due to climatic effects. There are prolonged droughts in arid and semi-arid regions, results into increased flooding in mid to high latitudes, increase in extreme weather events etc (Tack *et al*., 2015). As climate is changing more rapidly and the planet warms rapidly and it leads to high risk of mass extinction of biodiversity than species can adapt (Lindzen 1990, Das 2010). There is need to identify with the pattern of climate change which is one of the most important global environmental challenges and more specifically different types of impacts are to be understood and assessed (Cavaliere 2009, Courtney 2009). In the other side of it, production industries and practices in agriculture are adapted to variability in local climate conditions (Marshall *et al.*, 2015) and more so with medicinal plants like Isabgol, Asalio and many other important ones (Das, 2010) in arid and semi-arid condition. There is a continuous threats and loss of species worldwide at a rapid rate claimed by local communities in various regions who have used medicinal plants for generations. Further, they said that these species are becoming difficult to find, which according to them could be due to climate change as a major factor. Ethno-medicine plays very significant role in human health care since from the ages. According to

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statistics released by the World Health Organization (WHO), ethno-medicine has its constant popularity in all over regions of the developing world and its use is quickly expanding in the industrialized countries. At this time, one can observe a global trend in the traditional system of medicines as well as ethnobotanical studies have become increasingly highly valuable in the development of healthcare system in different areas of the world (Sharma *et al*., 2020). To encourage nations to conserve the biodiversity United Nations declared 2010 as the Year of Biodiversity coupled with signing The Convention on Biological Diversity (CBD). As a direct result of CBD, the Biological Diversity Act was enacted in 2002, A National Biodiversity Strategy and Action Plan (NBSAP) were organized and then subsequently a National Biodiversity Authority (NBA) was constituted. On the other hand, significant initiative under this Act by NBA for the conservation and sustainable use of medicinal plants and preservation of traditional knowledge, innovations and practices of indigenous and local communities or their wider application is needed. Environmental factors like temperature, humidity, light intensity, water, minerals and CO_2 influence the growth of a plant and their secondary metabolite production. Climate change is causing noticeable effects on the life cycles and distribution of the world's vegetation, including wild medicinal and aromatic plants. These metabolites have shown potential medicinal values in treating various ailments as these plants-based drugs would be cost effective due to its abundance and temperamentally quite suiting to millions of our masses, as these plants and their remedies are in use from ancient times. The research on medicinal plants with regard to climate change is very sporadic and insignificant in comparison with other commercial crops. Polluted areas should be monitored on a regular basis and the researchers had investigated the connection between the heavy metal levels in the soil and water bodies and their levels available for plants, and the levels extractable from plants. Over the past long time, industrial activity in the mining and smelting sectors and other sectors producing effluents has caused serious environmental pollution by heavy metals on a global scale. Readily Increased concentrations of heavy metals in the air, soil, or water threaten human health both directly and indirectly by accumulation in the food chain. Heavy metals in herbal medicines and aromatic plants as well as spices, particularly if cultivated or collected in contaminated areas, frequently exceed standard safety limits and are main source of exposure through consumption uses (Barthwal *et al*., 2008). Accumulation of many heavy metals in plants (*i.e.* phytoextraction) has been well recorded under laboratory conditions (Manousaki and Kalogerakis, 2009). However, it is also essential to correlate metal levels in plants and the water as well as soil in which these plants grow. Medicinal and aromatic plants are still broadly harvested from wild habitats for individual use and production of plant-based products (Sarma *et al*., 2011). It is consequently important to highlight that the safety and benefits of plant-based products are directly related to the quality of the raw materials (Salgueiro *et al*., 2010), including the presence of heavy metals within safe limits.

Widespread effects of climate change on Medicinal Plants

Studies, surveys and mounting evidence indicate that extreme weather events such as storms, droughts, and floods have become more common and extreme across the globe in recent years (Neilson *et al*., 2005). The frequency and severity of these events are expected to increase in the future as a result of continued warming, having negative effects on human health, infrastructure, and ecosystems. Extreme weather events have been known to affect harvesters and cultivator's abilities to grow and collect medicinal and aromatic plant species, as reported in recent years. Extreme severe weather conditions in entire Europe are influencing medicinal plant production from entire cultivation process seeding to harvesting, such as chamomile in Germany and Poland (Pompe *et al*., 2008). In the first-year fennel (*Foeniculum vulgare,* Apiaceae) was recorded as having no yield at all in Bulgaria, due to drought conditions during the spring in that country. Due to long and dry summers in Serbia, escorted by other extreme weather conditions such as strong rains and winds, have sometimes made it impossible for harvesters to perform second cuttings of the aerial parts of cultivated herbs such as peppermint (Pal *et al*., 2004, Schar *et al*., 2004). Medicinal plants in other continents also have been impacted by severe weather conditions. One of the most severe droughts of the 20th century was experienced in Africa's Sahel region. In Africa, medicinal plants of the Sahel include hibiscus (*Hibiscus sabdariffa*, Malvaceae), myrrh (*Commiphora africana*, Burseraceae), frankincense (*Boswellia* spp., Burseraceae), baobab (*Adansonia digitata*, Malvaceae), moringa (*Moringa oleifera*, Moringaceae), and various aloes (Aloe spp., Liliaceae). These were basically affected due to severe and extreme drought (Held *et al*., 2005). Future droughts due to global climate change could have distressing effects on the region's ecosystems and harvesting (Idso *et al*., 2000). In India, where overall climate is mainly controlled by an annual monsoon, seems to be experiencing increasingly severe and unpredictable

precipitation. Recently it was noted and found that the overall amount of monsoon rainfall annually across central India has remained relatively stable over the past century while, moderate rainfall events during monsoon have significantly decreased but extreme rainfall events have greatly increased since the early 1980s (Bhardwaj *et al*., 2007). This rapid increase in extreme rainfall events indicates high potential for future natural disasters. Experts have claimed that the frequency and intensity of flooding has likewise been increasing in India in recent years, and hailstorms have caused huge agricultural losses across areas of India lately. Therefore, such events are to be understood and their impact on medicinal and aromatic plant species needs to be diagnosed. States like Gujarat and Rajasthan experienced hailstorms and rains in 2006, 2007 and 2008, at times when such events traditionally have not occurred within the past 50 years. Hail and rainstorms have also damaged psyllium (*Plantago ovata*, Plantaginaceae), wheat (*Triticum aestivum*, Poaceae), and cumin (*Cuminum cyminum*, Apiaceae) crops in the area. The destruction of Indian psyllium crops from hail and rainstorms resulted in a smaller than usual annual yield for 2008. Similarly, it was noted that the availability of menthol crystals was affected by heavy monsoon rainfall, which occurred earlier than usual in Northern India and reportedly damaged wild mint (*Mentha arvensis*, Lamiaceae) crops in 2008 (Bhardwaj *et al*., 2007). Such rains and hailstorms are common factors to impact medicinal and aromatic plants in general. Hurricane seasons could also be affected by climate change, although experts do not agree on the possible effects (Dean 2007). Some experts believe that hurricanes will increase in frequency, duration, and intensity; others predict that hurricanes will either not be significantly affected or might even be inhibited by factors related to warming. Irrespective, shifts (increasing or decreasing) in hurricane activity have the potential to affect the availability of medicinal plants. It appears that there is a worldwide effect of climate change on medicinal plants. For instance, evidence has shown that climate change has been affecting vegetation patterns such as phenology (the timing of lifecycle events in plants in relation to climate) and distribution (Cleland *et al*., 2007). Some wild medicinal plants shift their ranges in response to changing temperatures and weather. Shifting phenologies and ranges may seem too little importance at first glance, but they have the potential to cause great challenges to species survival. Few studies conducted on effect of atmospheric CO_2 enrichment on specific plant compounds of direct medicinal value. Increase of the air's CO_2 content increased dry weight production of medicinal and aromatic plants of foxglove (*Digitals lanata*), which produces the cardiac glycoside digoxin that is used in the treatment of cardiac insufficiency by 63% while underwater-stressed conditions the CO_2 induced dry weight increase was 83% (Stuhlfouth *et al.,* 1987). Although many of these drugs are synthesized in developing countries, the World Health Organization estimates that as many as 3.5 billion people still depend on botanical sources for medicines (WHO, 2002). It was recorded from recent work on atropine and scopolamine indicates that increasing carbon dioxide and temperature will change the concentration and or production of these plant derived compounds (Ziska 2005). The effects of climate change are superficial within ecosystems around the world, including medicinal and aromatic plant populations. Medicinal and Aromatic Plants (MAPs) in Arctic and alpine areas face main challenges associated with their rapidly changing environments, and some researchers have raised concerns regarding the possible losses of local plant populations and genetic diversity in those areas. Shifting phenologies and distributions of plants were recorded worldwide, and these factors could ultimately endanger wild MAP species by disrupting corresponding phenologies of interdependent species, exposing some early-blooming MAP species to the dangers of late cold spells, allowing invasive to enter MAP species' habitats and compete for resources, and initiating migratory challenges, among other threats. Extreme weather events already impact the availability and supply of MAPs on the global market, and projected future increases in extreme weather are likely to negatively affect MAP yields even further. Climate change may not presently represent the biggest threat to MAPs but can be a greater threat in future (Idso *et al*., 2000). Poor people depend on medicinal plants not only as their primary healthcare choice, but also as an important source of income. The potential loss of medicinal plants species from effects of climate change is likely to have major difficulties on the livelihoods of large numbers of vulnerable populations across the world. Further, the problems associated with climate change are likely to be much tougher to combat than other threats to these medicinal and plant species.

Shifts in phenology

The lifecycles of plants correspond to seasonal indications, so shifts in the timing of such cycles provide some of the most convincing evidence that global climate change is affecting species and ecosystems (Cleland *et al*., 2007). Available evidence indicates that spring emergence has generally been occurring progressively earlier since the 1960s. Such accelerated spring onset has generated noticeable changes in the phenolgical events of many plant species, such as the timing of various plants

events like bud bursts, first leafing, first flowerings, first seed or fruit dispersal, etc. There is a lot of variability between species, and it is difficult to predict how climate change affects the phonologies of different plants (Cleland *et al*., 2007). It was noted that there were always variations in the timing of the seasons, and collectors of wild medicinal plants are supposed to adjusting their harvesting schedules accordingly. Early blooming can be unfavorable if an area is prone to cold spells late in the spring season. If a cold spell occurred a few days or weeks after early blooming has commenced, then those early buds or fruits froze, potentially killing or affecting the production of some economically useful plants (Zobayed *et al*., 2005). Apple orchards of North Carolina suffered severely, and the medicinal plant blood root (*Sanguinaria canadensis*, Papaveraceae) is also susceptible to frost following early blooming (Shea, 2008).

Shifting Ranges

Changes in climate are also causing plants to migrate into new ranges. Their ranges have begun to shift towards the poles and to higher elevations in an effort to retrieve appropriate growing zones. Habitat loss and migratory challenges related to climate change could result in extinctions of many endemic species throughout the world (Keutgen *et al*., 1997).

Effect of raised up CO_2 on yield and quality of medicinal plants

It has been noted that beneficial effects of elevated CO_2 on productivity and quality of various products and constituents of medicinal plants. Elevated CO_2 levels (3,000 µl CO_2/litre of air) increased fresh weight and leaf and root numbers in cultures of lemon basil (*Ocimum basilicum* L.), oregano (*Origanum vulgare* L.), peppermint (*Mentha piperita),* spearmint (*Mentha spicata* L.) and thyme (*Thymus vulgaris* L.) shoots compared with cultures grown on the same media under ambient air (Tissartn B, 2002).

Effect of elevated ozone levels

Changes in O_3 concentrations can alter the production of secondary chemicals in plants. Plant physiological stress imposed by augmented O_3 levels may stimulate the induction of metabolic pathways (*e.g.,* salicylic acid and jasmonic acid pathways) involved in the production of secondary (Van der J.C. Leun and F. Daniels, 2002).

Effect of Ultraviolet radiation

These radiations can cause molecular and cellular damage; for example, it can damage proteins, DNA and other biopolymers. (Bidart-Bouzat MG and Imeh-Nathaniel A, 2008) Furthermore, this type of radiation can affect plant growth and development and result in changes in vegetative or reproductive biomass, height, leaf characteristics, and flowering time (J.F. Bornman and A.H. Teramura, 1993).

Climate warming versus secondary metabolite production

The responses of secondary chemicals to increased temperature are less understood, although, an increase in volatile organic compounds has been generally detected (Loreto et al., 2006).

Co-existence

Species that rely on each other (Co-existence) if no longer co-occur in the same time or space, in such cases, both may be driven to extinction. Pests, diseases and invasive species may spread into new ranges putting overall more pressure on delicate communities including medicinal plants. Conservative species with specific habitat requirements or long generation times are more prone to the threat of extinction (Benning *et al.*, 2002).

Heavy Metal Contaminations in Soil and Water Bodies

Atmosphere, water and soil are constantly polluted with toxic chemicals and heavy metals due to active development of industries, mining and motorization along with widespread use of pesticides and fertilizers. These toxic pollutants and heavy metals from the different sources are getting deposited in the plants growing in the polluted areas, which afterward enter the human general food chain via plant parts and its extracts. The rapidly increasing frequency of environmental pollution, particularly water and soil contamination with toxic pollutants and heavy metals has resulted to their uptake in the general human food chains through various plant parts. Accumulation and magnification of main heavy metals in human tissues through consumption of herbal remedies available from different medicinal plant species can cause harmful impacts on health. It has been recorded from the studies of some researchers that, chemical profiling of major 9 heavy metals (Mn, Cr, Pb, Fe, Cd, Co, Zn, Ni and Hg) was undertaken in plant parts like stem and leaf samples of 10 medicinal plants namely *Acacia nilotica, Bacopa monnieri, Commiphora wightii, Ficus religiosa, Glycyrrhiza glabra, Hemidesmus indicus, Salvadora oleoides, Terminalia bellirica, Terminalia chebula* and *Withania somnifera* collected from different environmentally diverse regions of North-Western India. The results were recorded that cultivation of medicinal and aromatic plants, dietary herbs and other useful species should be reduced near environmentally polluted area and industrial areas (Kulhari

et al., 2013). Accumulation of toxic industrial effluents in the water bodies and ultimately into soil is rapidly increasing due to developing fast urbanization and extensive pollution of the environment. Among these toxic substances, presence of heavy metals (atomic weights 63.5–200.6 g mol^{-1} and a specific gravity greater than 5 g cm^{-3}) which are ubiquitous in nature, cause serious harmful effects on these plants. Plants are susceptible to environmental conditions and they accumulate these Heavy Metals in their harvestable plant parts (via root uptake, foliar adsorption and deposition in leaves) and intensity of this general uptake process changes the overall elemental composition of the plant. Uptake, accumulation and concentration of Heavy Metals in plants is influenced by various attributes including atmospheric depositions (depend on traffic densities, metal mining and smelting operations), concentration and bioavailability of Heavy Metals in Water bodies and soil (through addition of pesticides and sewage sludge), the nature of soil where herbs are grown (pH and organic matter concentration), individual plant performance (maturity of the plant, harvest time) and manufacturing and production conditions of herbal drugs (grinding weights, lead-releasing containers and manufacturing utensils) etc. Different Heavy Metals have different transmitting rates from soil to plant, based on transfer coefficients of metals namely Cd, Tl and Zn are readily taken up by plants because of higher transfer coefficient, whereas Cu, Co, Cr and Pb are stably bound to the soil structures and show minimum transfer to plants from soil due to lower transfer coefficient (Kulhari *et al*., 2013). Some metals (Mg, Mn and Zn) play a vital role in proper growth and development of the plant being directly or indirectly involved in various biological functions of enzyme activation and molecular metabolism. Currently very little information is available about possible influence of metals on pharmacological activity of natural drugs obtained from medicinal plants. Metal mediated hazardous impacts can be direct or indirect via binding of metals with pharmacologically active substances or by manipulating the pharmacokinetics .Consumption of raw herbal drugs from the medicinal plants grown in polluted sites can cause severe consequences on human health. Higher levels of these elements are carcinogenic and affects the central nervous system (Hg, Pb and As), cause kidney damage and liver dysfunction (Hg, Pb, Cd and Cu), are toxic to skin, bones and teeth (Ni, Cd, Cu and Cr) and have adverse effects on memory and reproductive system. For getting desirable therapeutic benefits, quality of these herbal products must be ensured in terms of metal contamination. So, there is need for quick evaluation of these heavy metals in medicinal and aromatic plants to control the level of contaminants in herbal raw materials. Generally, three methods-atomic absorption spectrophotometry (AAS), inductively coupled plasma (ICP) and neutron activation analysis (NAA) (Kulhari *et al*., 2013) have been employed for quantitative estimation of metals present in herbal raw material as an admixture or in trace amounts. It has been recorded from this study designed to analyzed the levels of 9 heavy metals (Mn, Cr, Pb, Fe, Cd, Co, Zn, Ni and Hg) in different plant parts like leaf and stem samples of 10 medicinal plants (*Acacia nilotica, Bacopa monnieri, Commiphora wightii, Ficus religiosa, Glycyrrhiza glabra, Hemidesmus indicus, Salvadora oleoides, Terminalia bellirica, Terminalia chebula* and *Withania somnifera*) collected from environmentally diverse regions of North Western India using AAS on the basis of presence of contaminated water bodies, soil and atmospheric polluting units like presence of industries and factories, heavy traffic sites and site located near to petrol pumps while some of the medicinal plants were selected on the basis of their large importance in the Ayurveda along with their frequent uses in various novel pharmaceutical preparations, preparation and formulations of traditional drug, food and energy supplements and their diverse medicinal properties (Kulhari *et al*., 2013).

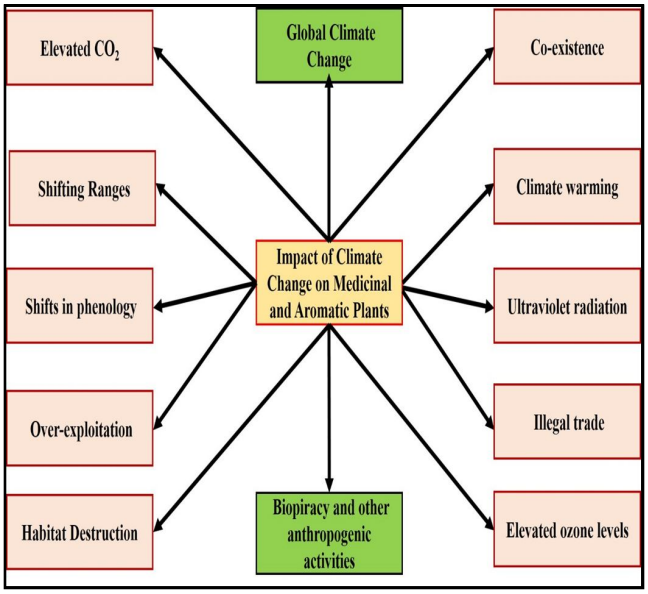

Fig. 1: Factors causing threats to Medicinal and Aromatic plants.

Linkages between climate change, plants and livelihoods

Vast population of world's poor depends directly on harvesting non-timber forest products, edible, medicinal and aromatic plants for livelihood and sustenance. Many of these species are under threat from increasing anthropogenic pressure and loss of natural vegetation

accentuated further by climate change. Consequently, the people who depend on them are getting affected. Several chemicals derived from medicinal and aromatic plants are historically acknowledged as having pharmaceutical value is shown in table 1 (Ziska 2005). For developing countries, however, the World Health Organization (WHO) reported that more than 3.5 billion people depend on medicinal and aromatic plants as components of their primary health care. In both developed and developing countries, there are a number of economically important pharmaceuticals derived totally from plants (*e.g.* tobacco), with high economic value.

Major loss of diversity of Medicinal and Aromatic Plants and its impact

India is ranked sixth among 12 mega-diversity countries of the world and is habitat to a huge variety of ethno-medicinally important plant species. Medicinal and aromatic plants (MAPs) are basically traded as both as raw material and yielded highly processed final products. The collection and marketing of (MAPs) has provided a vital source of earnings for communities living in the hilly mountain areas. Medicinal plants as a group comprises of at least 8000 species and account for approximately 80% of all higher flowering plant species of India (Sharma *et al*., 2020). Medicinal and Aromatic plants constitute approximately 40% of the known diversity of vascular plant species of India. It is an important issue of high priority Conservation of Indian Medicinal flora (Goswami *et al*., 2006). Possibly, there are 6 medicinal plant species of high conservation concern namely *Aconitum heterophyllum, Coscinium fenestratum, Decalepis hamiltonii, Picrorhiza kurroa, Saraca asoca* and *Taxus wallichiana* (Malcolm *et al*. 2006, Bhardwaj *et al*. 2007). These species are valuable medicinal plants which are presently being used in high quantities by India's herbal industry and drug industry leading to sharply rapid decline of their populations in wild and are of supreme concern. The plant parts which are of medicinal use of these species are obtained entirely from the wild and their medicinal uses are described in the standard codified Indian systems of medicine, namely Ayurveda, Siddha and Unani. These MAPs species are being used to treat many disorders, ailments and disease conditions, namely inflammatory, analgesic, anti-diarrheal, antipyretic, anti-diabetic, anti-cancer, in liver diseases as well as gynecological disorders. The great loss of these species will adversely affect the

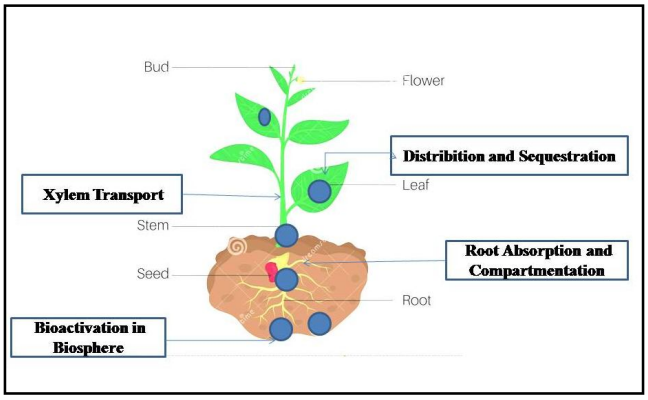

Fig. 2: Major processes proposed to be involved in heavy metal hyper accumulation by Plants.
Source: (Ghorbanpour and Varma 2017 (eds.), Medicinal Plants and Environmental).

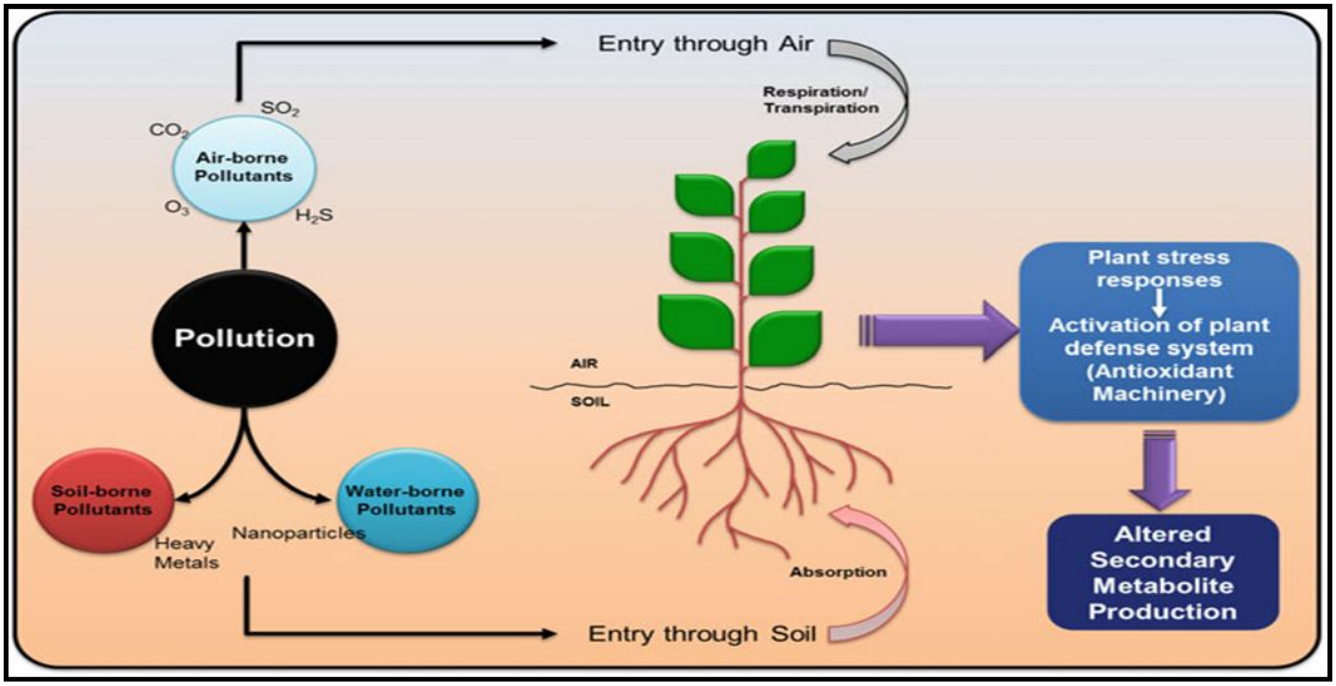

Fig. 3: Uptake of heavy metals from Medicinal and Aromatic plants.

current usage for basic health care and treatment of such conditions. Further, their extinction will be a severe loss to the wild gene pool, which evolved over several millennia. It is to be understood that once lost, these species will not be reproducible through any synthetic means and result will be a huge loss for our future generations to suffer. Indians peoples generally used the exotic spices having great medicinal value (Sharma *et al*., 2020). To scientifically assess and enlist the decline and loss of medicinal and Aromatic plant species and to systematically check and review threat to wild populations of prioritized Medicinal plant species (Denyer, 2007). Article 8d of CBD specifically states: 'Promote the protection of ecosystems, natural habitats and the maintenance of viable populations of species in natural surroundings. However, the Ministry of Environment and Forest (MoEF), has to have long-term programme, strategy or dedicated funding for monitoring viable populations and undertaking assessment of medicinal and aromatic plants. National Medicinal Plant Board (NMPB) and Indian Council of Agricultural Research (ICAR) located at New Delhi may have to take the lead in this direction. To further validate, on a relatively small scale, some efforts have been undertaken using IUCN Red List Categories and Criteria (Bhardwaj *et al*., 2007). According to such studies, 335 wild medicinal and Aromatic plants of India have been identified as being under various categories of threats of extinction ranging from Near Threatened, Vulnerable, Endangered to Critically Endangered. 84 of these species of conservation concern were recorded in high volume trade (Bhardwaj *et al*., 2007). However, it is a continuous cycle and such kind of species is believed to be threatened, if strict actions and sincere efforts are not taken. The rapid decline and loss of wild populations of valuable wild Indian medicinal and Aromatic plants is basically due to the combined impact of habitat loss, its degradation, as well as over-exploitation (Goswami *et al*., 2006). Climate change is also noted as a reason but no serious and detail studies have been undertaken in our country for medicinal and aromatic plants in particular (Harish *et al*., 2012). However, a few noticed recent studies, outside India, have speculated about the fragmentation and decline of wild populations of some MAPs plant species in the hilly mountains ecosystems due to overall climate change (Thomas *et al*., 2004). A national agenda and rules are implemented for conservation of medicinal and aromatic plants should be made.

Table 1: Plant derived pharmaceutical drugs and their clinical usages (Ziska 2005).

S. No.	Drugs	Action/ Clinical use	Species
1	Acetyl digoxin	Cardiotonic	*Digitalis lanata*
2	Allyl isothiocyanate	Rubefacient	*Brassica nigra*
3	Atropine	Anticholinergic	*Atropa belladonna*
4	Berberine	Bacillary dysentery	*Berberis vulgaris*
5	Codeine	Analgesic, antitussive	*Papaver somniferum*
6	Danthron	Laxative	*Cassia spp.*
7	L-Dopa	Anti-Parkinson's	*Mucuna spp.*
8	Digitoxin	Cardiotonic	*Digitalis purpurea*
9	Ephedrine	Antihistamine	*Ephedra sinica*
10	Galanthamine	Cholinesterase *inhibitor*	*Lycorissqua migera*
11	Kawain	Tranquilizer	*Piper methysticum*
12	Lapachol	Anticancer, antitumor	*Tabebuia spp.*
13	Ouabain	Cardiotonic	*Strophantus gratus*
14	Quinine	Antimalarial	*Cinchona ledgeriana*
15	Salicin	Analgesic	*Salix alba*
16	Taxol	Antitumor	*Taxus baccata/ T. wallichiana*
17	Vasicine	Cerebral stimulant	*Vinca minor*

Medicinal and aromatic plants in other threatened regions

Although Arctic and alpine areas are experiencing some of the most rapid changes from global warming, other ecosystems are also considered particularly threatened by the ongoing effects of climate change which is recorded on islands and rainforests (Dean 2007). Islands are seeming especially at risk from rising ocean levels, changing temperatures and weather patterns. The world's oceans also absorb additional heat from the atmosphere, and as water warms it expands in volume which will similarly contribute to overall global sea level rise (Walther *et al*., 2002). Despite all these threats, it has been recorded that island MAPs may not be significantly affected by conditions related to climate change. Many of the plants used by island communities are common species that are widely spread and highly adaptable. Common medicinal plants of the Pacific islands were recorded as noni (*Morinda citrifolia*, Rubiaceae), naupaka (*Scaevola* spp., Goodeniaceae) kukui (*Aleuritesmoluccana*, Euphorbiaceae) and milo (*Thespesiapopulnea*, Malvaceae). These and other medicinal and aromatic plant species of the area grow relatively fast, have high reproduction rates, and are characteristically resistant to salt water and wind, making them more flexible to some of the predicted effects of global climate change (Law and Salick 2005, Walther *et al*., 2002). Similarly, study was recorded from medicinal plants of the

Mediterranean islands do not appear to be under any considerable threat from conditions of climate change (Yoon 1994). According to de Montmollin, most wild collected MAPs, such as thyme (Thymus spp., Lamiaceae) and rosemary (Rosmarinus spp., Lamiaceae), are rather widespread and located at lower altitudes, making them less vulnerable to climate change than plants with narrower ecological necessities (Parmesan and Yohe 2003). Rainforest ecosystems are also considered to be threatened by climate change. Climate modeling studies have indicated that these regions are likely to become warmer and drier, with a substantial decrease in precipitation over much of the Amazon (Neilson *et al*., 2005). There is not much, if any, published evidence on MAPs that could be at risk in the rainforest from climate change, and experts are unable to comment on specific MAPs that may be vulnerable to climate change in rainforests. However, the predictable loss of general biodiversity in the Amazon, as noted in the IPCC report, specifies the potential to lose both known and undiscovered MAP species (IPCC 2007).

Challenges of climate change on medicinal and aromatic plants

Even though the terms "global warming" and "climate change" are often used interchangeably, "climate change" is often the ideal term of many environmental organizations and government agencies (IPCC 2007). Climate change refers to any major change in measures of climate (such as temperature, precipitation, or wind) over along-extended period of time (decades or longer). Global warming refers to an increase in the temperature of the atmosphere that can contribute to change in global climate patterns. The Intergovernmental Panel on Climate Change considers "climate change" to mean any change in climate over time, whether due to natural variability or as a result of human activity (IPCC 2007). The United Nations Framework Convention on Climate Change defines "climate change" as a change in climate that is attributable directly or indirectly to human activity that alters atmospheric composition. The success of mankind's ability to meet the challenges of climate change will depend on how well it conserves the existing biodiversity of plants species including highly valuable medicinal and aromatic plants. Wild plant conservation has three mutually

Table 2: Status of some medicinal plants in context of climate change (Mishra, 2016).

S. No.	Name	Local Name	Status	Uses
1	Aconitum *ferox*	Vatsa-nabha	Vulnerable	Extremely poisonous; used in leprosy, fever, cholera, nasal catarrah, tonsillitis, sore throat, gastric disorders and debility.
2	*Centella asiatica*	Brahmi, Gotu-kola	Endangered	Used in chronic dysentery, poultices are applied on carbuncle, cuts as antiseptic in wounds.
3	*Dalbergia latifolia*	Satisal	Vulnerable	Used for fuel and timber. Bark is used for body ache, ulcers, wounds, eczema and pimples.
4	*Drymaria cordata*	Laijabori	Vulnerable	Leaf paste is used in headache and in sinusitis. It is also used as vegetable and used for rejoining of broken bones.
5	*Gloriosa superb*	Kalihari	Endangered	In ancient times used in arrow poison, causes powerful contraction of uterus, used in the treatment of gout, infertility, open wounds, snakebite, ulcers, arthritis, kidney problems and typhus.
6	*Nelumbo nouchali*	Bagabhet	Endangered	Known as a neutraceutical. Fruits are eaten raw and the flowers are eaten fried.
7	*Pterocarpus santilanus*	Chandan	Endangered	Tree is commercially valuable for its timber, medicine and cosmetic property.
8	*Rauwolfia serpentina*	Sarp-gandha	Endangered	The drug is important therapeutic agent as anti- hypertensive. Root extract is used in relief of various central nervous system disorders like anxiety, schizophrenia and epilepsy.
9	*Rhododendron leptocarpum*	Burans, Kavak	Critically Endangered	Flower is effective in diarrhoea and dysentery. The dried twigs and wood are used against phthisis and chronic fever.
10	*Saussurea obvallata*	Brahma kamal	Endangered	It has bitter taste and used to treat fevers, liver ailments and urogenital disorders.
11	*Swertia chirayita*	Chirayita	Vulnerable	Reduces fever, odema and very effective in malarial fever.
12	*Withania somnifera*	Ashwa-gandha	Vulnerable	An adaptogen, used in debility, ulcers and Cardiovascular ailments.

dependent aims:

(i) Maintaining plant species and their genetic diversity.

(ii) Achieving sustainable use of wild plant resources.

(iii) Safeguarding plants and natural vegetation as providers of ecosystem services.

These aims are most likely to be achieved where efforts are focused on maintaining plants within vigorous ecosystems. However, the ability of national level government to accomplish these aims is under increasing pressure because of climate change; the impact of which is already visible at all levels of species survival and conservation (Marshall, 2015). Many will find it difficult to 'follow the climate', lacking adequate means of dispersal and finding their paths being impeded by human destruction of wild habitats (Hawkins *et al*., 2008). Like all living members of the biosphere, medicinal and aromatic plants are not resistant to the effects of climate change. Climate change is causing serious effects on the lifecycles and distributions of the world's vegetation, which includes wild MAPs. Some MAPs are endemic to particular geographic regions or ecosystems are particularly vulnerable to climate change, which could easily put them at risk (Neilson *et al*., 2005). Climate change is affecting medicinal and aromatic plants around the world and could ultimately lead to major losses of some important key species. This conclusion is based on the research, observations, and opinions of multiple medicinal plant researchers and conservationists, as reported in the cover article of the latest issue of Herbal Gram (Cavaliere 2008, 2009), the quarterly journal of the American Botanical Council (ABC). It has been noted the endemic nature of the species to different ecosystems that are especially vulnerable to climate change, such as arctic and alpine regions, and could be have at maximum risk (Cavaliere 2008). For example, *Rhodiolaro sea* of the Canadian Arctic and snow lotus (*Saussurea laniceps*) of the Tibetan mountains are medicinal species that face major threats from climate change. The study further explores effects of climate change that appear to be impacting plants including medicinal and aromatic plants throughout the world. For example, climate change has led to shifts in seasonal timing and ranges for many plants, which could ultimately endanger some wild medicinal plants populations. Some more events like extreme weather events, meanwhile, have begun to impact the yield and harvesting of various medicinal plants around the world. For example, recently it has been noted in Germany and Poland that abnormally hot summers have prevented reseeding of MAPs such as chamomile (*Matricariare cutita*) and also in Hungary increasingly severe flooding has reduced harvests of fennel (*Foeniculum vulgare*) and anise (*Pimpinella anisum*) in that country (Pompe *et al*., 2008). Although, the primary focus concerns medicinal plants, much of the threat to these plants includes aromatic plants harvested for their essential oils, which could be used for medicinal, fragrance, culinary, and other purposes (Cavaliere 2009, Tack *et al*., 2015). Climate change has become one of the greatest challenges to mankind and all other life on the planet earth. Worldwide changes such as seasonal patterns, weather events, temperature ranges, and other related various phenomena were reported and attributed to global climate change. Various experts in a wide range of scientific disciplines have warned that the negative impacts of climate change will become much more intense and frequent in the future- particularly if environmentally destructive human activities continue unabated (Walther *et al*., 2002). There is concern over its overall impact affecting secondary metabolites of many medicinal and aromatic plants which are very much important economically and commercially. Though scientists do not know whether climate change poses a more prominent or immediate threat to MAPs species than other threats, it does have the possible potential to exert increasing pressures upon MAPs species and populations in the coming years. The possible effects on MAPs may be particularly significant due to their value within traditional systems of medicine and as economically useful plants. The future effects of climate change are largely uncertain, but current evidence suggests that these phenomena are having an impact on MAPs and that there are some potential threats worthy of concern and issue. Some studies have demonstrated that temperature stress can affect the production secondary metabolites and other compounds that plants produce, which are the basis for their medicinal activity (Schar *et al*., 2004). But few studies were conducted *in-situ* or *ex-situ* to mimic conditions of global warming (Das *et al*., 1999). The taste and medicinal value of some Arctic plants could possibly be affected by climate change (Gore 2006). It was noted that such changes could either be positive or negative, although it seems more likely that the effects would be negative since, secondary metabolites are produced in larger quantities under stressed conditions and for Arctic plants, warmer temperatures would likely alleviate environmental stress. However, the production of plants secondary metabolites is influenced by many factors like diseases, competition between plants, animal grazing, light exposure, soil moisture, etc. and these factors may

mitigate the effects of overall climate change on plants secondary metabolites (Dean 2007). It was noted that through collection of samples of medicinal plant species from Greenland, Nord Gen, an organization based in Alnarp, Sweden could go for preservation and evaluation of Angelica (*Angelica archangelica*, Apiaceae), yarrow (*Achillea millefolium*, Asteraceae), *Rhodiolaro sea*(aka golden root, Crassulaceae) and thyme (*Thymus vulgaris*, Lamiaceae). These four medicinal plants are not presently endangered in Greenland, nor are they presently listed on the (CITES) Convention in Trade in Endangered Species (Pal *et al*., 2004). These excessive percent of useful flora confirms the significance of the Himalayas for Tibetan medicinal drug and reflects the risks posed through potential plant losses from climate change. However, some medicinal alpine species are restrained to the higher alpine zone, inclusive of *Artemisia genipi* (Asteraceae) and *Primula glutinosa* (Primulaceae). These species may revel in greater influences from warming temperatures, in all likelihood main to local endangerment (Pal *et al.,* 2004).

Implications for plant conservation and rural livelihoods

Climate change is rapidly happening and its effects will definitely increase in the coming years ahead due to overall increasing temperature and unpredictable patterns of rainfall. The effects of climate change on medicinal and aromatic plants is evident that with changing climatic conditions plants may up shift, change their structure and habitat etc. Climate change is already causing remarkable effects on lifecycle as well as distribution of the world's vegetation. Climate change may become a more critical issue for the herbal community, potentially affecting users; harvesters and manufacturers of MAP species. There is an utmost need to assess the effect of climate change and global warming and particularly effect of elevated CO_2 on medicinal and aromatic plants with a focused method on the accumulation of different secondary metabolites (Courtney 2009, Harish *et al.,* 2012). The research on medicinal plants is random and trivial and it is high time that this group of plants as potential sources of neutraceuticals is given appropriate attention. A number of studies should be required to be carried of MAPs species. Out which are as follows:

1. Systematic list of overall Rare and Endangered (RET) species of MAPs.

2. Impact on morphological, physiological and biochemical factors as well as phenology of plants in precise environments and field.

3. Varietal improvement on abiotic and biotic stress and to assess the genetic integrity of MAP species.

4. Setting of different techniques for long term exposure of high CO_2 and temperature on MAPs and development of innovative techniques to study the impact of CO_2 enrichment and high temperature as in *Eucalyptus camaldulensis* (Kirdmanee *et al*., 1995) and *Rehmannia glutinosa* (Seon *et al*., 1995).

5. Organic farming practices of MAPs for conservation of medicinal properties.

6. Develop relevant strategies for the conservation of endangered flora of high medicinal and aromatic value.

7. Compilation and documentation of indigenous knowledge of herbal, medicinal and aromatic plants cultivation against elements of climate change.

8. Changes in the composition of profile of secondary metabolites in diverse climatic situations.

The influence of climate change is very significant on medicinal plants both cultivated and wild. The need of the hour is to have a focused research approach especially on the accumulation of secondary metabolites of health significance and economic usefulness (Harish *et al.,* 2012). The study on medicinal plants with respect to global climate change is very infrequent and insignificant in comparison with other commercial crops. It is the high time of concern that, these MAPs species should not be left as they are vital sources of important bio-molecules and neutraceuticles. Conservation of threatened medicinal plants in the higher altitude is important because people living in isolated and far from urban areas are completely dependent on plants and their products for their basic livelihood and curing different ailments and diseases (Ullah and Rashid, 2014). Therefore, it is necessary issue of concern to carry out solid bold steps for the conservation of medicinal plants. Furthermore, conservation of medicinal plant population in their native habitat is also an important issue. To achieve this, extending of their existing protected areas is needed to be done by government authorities to prevent losing in suitable ranges of medicinal plant species. However, *ex-situ* conservation might also be considered to provide insurance against disastrous loss and to facilitate for reintroduction. In addition, legislation and monitoring will be a key importance for conservation and sustainable use of threatened medicinal and aromatic plants species (Mishra, 2016).

Conclusion

Medicinal plants are sources of a large number of active principles of herbal and modern medicine. Indian people have a tremendous passion for medicinal plants

and use them for a wide range of health related applications from a common cold to cancer and treatment of poisonous snake bites to a cure for genetic disorders like muscular dystrophy. India has one of the richest herbal medical cultures in the world that is of tremendous contemporary relevance ensuring health security to millions of people. However, continuous increase in environmental pollution is leading to built up of these pollutants including heavy metals in the plant parts which eventually enter the human food chain. Therefore, regular screening of raw material is must to check the levels of these pollutants in the plant parts and extracts before using them for human consumption. The probable effects on MAPs may be particularly substantial due to their immense value in traditional system of medicine and for economic usefulness. While future effects of climate change are likely uncertain, have an impact on MAPs, and will possible to become much greater threat in future. Potential loss of some MAPs may affect living of large number of people. The problem of overall warming temperature and disrupted seasonal events also cannot be easily understood, but timely action can certainly prevent the loss of biodiversity.

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