J. Appl. Environ. Biol. Sci., 1(7)115-125, 2011

ISSN 2090 – 424X

Journal of Applied Environmental and Biological Sciences

www.textroad.com

Influence of Global Climate Change on, Growth Stages and Production of Secondary Chemicals in Medicinal and Aromatic Plants

Mahdi Faravani[1], Baki Hj. Bakar[2] and Baratali Gholami[1]

[1]Khorasan Razavi Agricultural and Natural Research Resources Center, Mashhad, Iran

[2]Institute of Biological Sciences, University of Malaya, Kuala Lumpur, Malaysia

ABSTRACT: The concentration of carbon dioxide in the Earth's atmosphere has reached to approximately 390 ppm in 2010. The present level is higher than at any one time during the last 800 thousand years and likely to be higher than in the past 20 million years due to *inter-alia,* the industrial revolution and uncontrolled use of fossil fuels, land degradation and deforestation principally in the tropical rainforest regions. Such level of emission of carbon dioxide into the atmosphere plays a significant deleterious role in the greenhouse effect. Global climate change is known as one of the greatest challenges to the humankind and all other life-forms on Earth. Worldwide changes in seasonal patterns namely early flowering, late cold spring, weather events, temperature ranges, and other related phenomena have all been shown as the resultant effect of global climate change. Global climate change is causing noticeable effects on the life cycles, growth and active ingredients of herbs and these may lead to parallel short- and long-term changes to the spatio-temporal distribution of medicinal plants around the world, and the phenology of local species. These changes may be partially attributed to invasive plant species entering into particular habitat(s) and ecosystem(s) leading to competition over space and resources between the invasives and their endemic counterparts. Climate change may not directly initiate chemical changes in the profile of metabolites and constituents produced by plants but it could add to existing stresses among competing plants, and can affect secondary metabolites and other compounds that plants produce, and these in effect could impact on their medicinal activity.

Keywords: Climate change, herbs, phenology, carbon dioxide, active ingredients.

INTRODUCTION

Global warming is the increase in the average temperature of the Earth's near-surface air and oceans by approximately 0.68°C over the past 100 years with two main periods of warming, between 1910 and 1945 and from 1976 onwards. The rates of warming during the latter period has been approximately double that of the first and, thus, greater than at any other time during the last 1,000 years [1]. The inter-governmental panel on climate change concludes that most of the observed temperature increases since the middle of the 20th century was caused by increasing concentrations of greenhouse gases resulting from anthropogenic activities such as fossil fuel burning and deforestation. The most commonly discussed measure and global warming is the trend in globally averaged temperature near the Earth's surface. Variations in solar output have been the cause of past climate changes. The world around us will be drastically altered by Global Climate Change. More discussions should focus on "what will change, how much, when and how" mankind will be affected following irreversible of Global Climate Change. It is widely believed that the consumption of fossil fuels, necessary for economic well-being, is the primary cause of Global Climate Change. Global climate change will have multiple effects on human health [2]. Information relating to the effect of climate change on medicinal plants and traditional medicine has become increasingly recognized as one of the challenges to humankind and all other life-forms on Earth. Access to relevant information by the public, decision makers and local communities is still very limited. The Convention on Biological Diversity, an international treaty that has been signed by more than 160 member states of the United Nations provides an international legal framework for the conservation of biological diversity including access to and exchange of genetic materials [3, 4].

The correlation between tropical mean annual temperatures and annual CO_2 is a fairly strongly positive since 1960, in concordat with the generally held view that the tropics play a major role in determining inter-annual variability in CO_2 increment, with a major CO_2 pulse following a warm years in the tropics. Northern summer temperatures in the region 30-60 °N - and especially in the land area corresponding to the central east USA - have become relatively more

***Correspondence Author:** Mahdi Faravani, [1]Khorasan Razavi Agricultural and Natural Research Resources Center, Mashhad, Iran.
Email: faravani@yahoo.com

closely correlated with CO_2 increment. This trend has become increasingly stronger in recent years, suggesting an increasing role for growing season processes in the northern mid-latitudes as affected by global CO_2 increment [8].

Plants grown at reduced levels of UV-B radiation invested less biomass in flowers and more in stem materials compared to plants grown at ambient UV-B levels. The CO_2 enrichment resulted in a stimulation of net photosynthesis of faba bean seedlings after 26 and 38 d of treatment. The UV-B reduction did not alter this response. Under prevalent experimental conditions, UV-B radiation did not affect the measured physiological parameters because of most open-top chambers used for climate change research are constructed from materials which do not transmit UV-B radiation. As such, the result of 'chamber effects' on plant height often described in the literature might be explained by the absence of solar UV-B radiation in these chambers [9].

Only species that can adapt to the maximum to new conditions will have a high net photosynthetic rate response to light, increased CO_2, higher light compensation point, higher light saturation point, and higher quantum yields. Increasing CO_2 level leads to increases in maximum temperatures in different region and growing situation. [10].

Climate change has remarkable effects on the life cycles and distributions of wild medicinal plants (MAPs). Some MAPs are endemic to particular geographic regions or ecosystems are in effect especially vulnerable to climate change, and this could put them at risk. Concerns regarding the secondary metabolites, the survival and genetic integrity of some MAPs in the face of such challenges are need to be studied due to their inherent values within traditional systems of medicine and rural development.

In this review, we discuss and expose a coherent pattern of phenology, distribution, and yield quality and quantity of medicinal plants under ecological changes across ecosystems that are being occasionally cited as being particularly threatened by future climate change.

Survey of Medicinal and Aromatic Plants Spices in Threatened Regions by Climate Change

Over 100 years ago, people worldwide began burning more coal and oil at homes, factories, and transportation. Burning these fossil fuels releases CO_2 and other greenhouse gases into the atmosphere. These added greenhouses gases have caused the Earth to warm more quickly than it has been in the past. There is unequivocal evidence that the Earth's climate is warming at an unprecedented rate. Temperature increases are geographically inequitable. Some regions, particularly at high altitudes and latitudes, are warming more than other areas. Other climatic effects, including prolonged droughts in arid and semi-arid regions, increased flooding in mid to high latitudes, and more extreme weather events are also on the increase and keep on increasing. Sea levels are rising. Climates are changing more rapidly than species can adapt and there is a high risk of mass extinctions of biodiversity as the planet warms. Warming is occurring more rapidly in the Arctic than anywhere else in the world [5, 6]. Any changes in precipitation, temperatures, snow and ice cover are affecting the distribution of some Arctic vegetation and their green vegetation. This is happening in the Canadian Arctic as aerial photographs of tree and shrub lines indicated changes over the past few decades as they grow taller and in more open areas because of little competition from other species. The taller plants then become barriers to snow, fencing it in and changing the surrounding biodiversity [4]. With increased warming, more plants will encroach, and compete for resources with native plants, and there is no option for them to move any further north to decrease competition [4].

Some studies have demonstrated that temperature stress can affect the secondary metabolites and other compounds that plants produce [7, 8], and these are usually the basis for their medicinal activities.

Taste and medicinal effectiveness of some Arctic plants could possibly be affected by climate change, and 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, that the production of plants' secondary metabolites are influenced by multiple factors - including diseases, competition between plants, animal grazing, light exposure, soil moisture, etc., and that these other factors may mitigate the effects of climate change on plants' secondary metabolites [4].

NordGen, an organization based in Alnarp, Sweden, that collects and conserves samples of genetic plant materials from the Nordic countries, recently collected samples of 4 medicinal plant species from Greenland for preservation and evaluation: angelica (*Angelica archangelica*, Apiaceae), yarrow (*Achillea millefolium*, Asteraceae), *Rhodiolarosea* (aka golden root, Crassulaceae), and thyme (*Thymus vulgaris*, Lamiaceae)[9]. Capturing genetic diversity becomes increasingly important since it is possible that populations will loose genetic diversity in response to the changing environment [4].

Rhodiolarosea is circumboreal, growing primarily in Arctic areas of Europe, Asia, and North America. It has been used traditionally to treat fatigue, depression, and infections, strengthen the immune system, and protect the heart [10, 11].Canadian populations of wild *R. rosea* may be significantly impacted by increased competition with invasive species due to climate change, and rising sea levels generated by global warming could pose further threats to the plant's survival specially in the seashore thought rising sea levels brought by melting glaciers [12].

After Polar Regions, mountain areas are being impacted at a faster rate by climate change than any other areas on Earth. Plants growing in mountain environments may also be particularly impacted by climate change. These areas are very important for traditional medicine as collected plants come from the mountains [13].

Advancing tree lines and extinctions of montane plant populations have become increasingly apparent and documented by researchers worldwide in recent years, and these have been attributed as evidences of the impact of climate change on alpine ecosystems [14]. On a global scale average, temperature decreases 6.5°C per 1000 m increase in altitude [15].

Researchers have found that some cold-adapted plant species in alpine environments have begun to gradually "climb" [read: migrate] higher up the mountain summits - a phenomenon correlated with warming temperatures. 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[16, 17]. Native alpine plants considered medicinally useful by local traditional healers and they determined that many of them could potentially invade (or escape to) higher elevations as a result of global warming and that the plants' risk of extinction under predicted scenarios appears to be relatively low. A few medicinal alpine species are restricted to the upper alpine zone, such as *Artemisia genipi* (Asteraceae) and *Primula glutinosa* (Primulaceae). These species may experience greater impacts from warming temperatures, possibly leading to locally being endangered [4].

Some of the most drastic climate changes in the world outside of polar regions, with temperature increases of 5-6°C and precipitation increases of 20 - 30% and some medicinal plants that they 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 [14]. For example, snow lotus (*Saussurea laniceps*, Asteraceae), a plant that has been traditionally used in Tibetan medicine to treat high blood pressure, heart conditions, and women's conditions and it is endemic to the Eastern Himalayas, is currently considered by local experts to be in danger from both over-harvest and the negative effects of climate change, even though this herb has not yet been officially listed as "threatened" anywhere. In light of these perceived threats, repeated attempts have been made to cultivate snow lotus, largely without success.

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. Among these ecosystems are islands and rainforests. Islands are considered especially at risk from rising ocean levels, in addition to changing temperatures and weather patterns[18]. According to the 2007 IPCC Report, global sea levels are currently rising at around 3.2 mm a year, and up to 65% of some islands in the Northwestern Hawaiian Islands could be submerged by the year 2100[5, 19]. Climate change is expected to accelerate this process through the melting of glaciers and polar ice caps, which adds water into the oceans[20]. The world's oceans also absorb excess heat from the atmosphere, and as water warms it expands in volume, which will similarly contribute to global sea level rise[21].

Despite these threats, experts have indicated 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 widespread and highly adaptable [4].

Common medicinal plants of the Pacific islands include noni (*Morinda citrifolia*, Rubiaceae), naupaka (*Scaevola* spp., Goodeniaceae), kukui (*Aleurites moluccana*, Euphorbiaceae), and milo (*Thespesia populnea*, Malvaceae) are very tough and well adapted to storms and damage much like climate change will throw at them. These and other medicinal plant species of the area grow relatively fast, have high reproduction rates, and are typically resistant to salt water and wind, making them more resilient to some of the predicted effects of global climate change [4] 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 requirements [22].

Rainforest ecosystems are also considered to be particularly 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 tropical region. According to the global climate data, the temperature in Peninsular Thailand will increase from 26.6 °C in 2008 to 28.7 °C in 2100, while the annual precipitation will decrease from 2253 mm to 2075 mm during the same period. Changes could ultimately convert areas of the Amazon's tropical forest into dry savannah and result in significant loss in biodiversity, according to the latest IPCC report. Climate change in 2100 will significantly change or deteriorate the current distribution pattern and the status of many species and they may be added for listed threatened species [23, 24].

Perspectives of Ecological, Physiological and Phenology Events of Adaptations of Plants to Climate Change

Some wild plants, including MAPs, have begun to flower earlier and shift their phenological patterns and ranges in response to changing temperatures and weather patterns. Shifting phenologies and ranges may seem of little importance at first glance, but they have the potential to cause great challenges to species' survival. Global mean temperatures have increased during the last century [25]. In the Northern Ecosystems, species have changed their physiology, distribution and phenologyduring the last decades [13], and evidence of changes in the phenology of plants and animals is gathering rapidly [26]. The responses of both flora and fauna span an array of ecosystems and organizational hierarchies, from the species to the community levels despite continued uncertainty as to community and ecosystem trajectories under global change [4, 13]. The rates of range shifts vary greatly among and within species, implying differential dispersal abilities.With climate change, non-native species from adjacent areas may cross frontiers and become new elements of the biota. Anthropogenic activities promote species movement, their subsequent reproduction and the spread at the new locations imply altered site conditions due to climate change [27].

Over the whole period, a global temperature increase of about 0.6°C has been observed and most climate projections reveal that this trend is likely to increase rapidly in the next 50 years. The implications of such large-scale, consistent responses to relatively low average rates of climate change are large and the projected warming for the coming decades raises even more concern on its ecological and also socioeconomic consequences. The most recent models estimate that global average surface temperature will rise by between 1.4°C and 5.8°C over the next hundred years, with a best guess of about 3°C (Fig. 1.). The significant margin of uncertainty is due to the uncertainty over the precise role of the greenhouse feedbacks and the uncertainty surrounding the precise growth in greenhouse gas emissions during the 21st century [28].

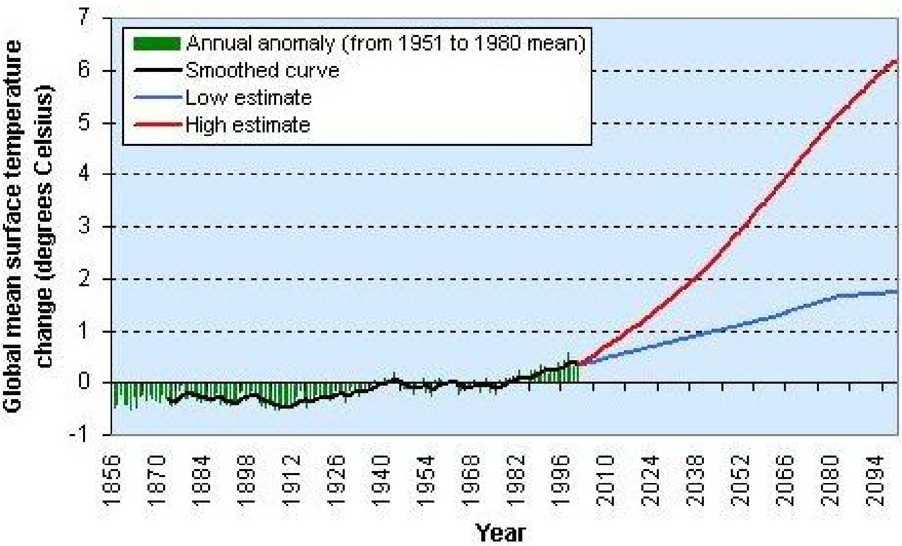

Fig. 1. Estimated models global warming during 21st Century global average surface temperature will rise by between 1.4 and 5.8°C over the next hundred years, with a best guess of about 3°C *(derived from http://www.greenhouse-warming.org.uk/10.php)*

The physiological responses of plants to climate change

The diversity and distribution of the world's terrestrial vegetation is the product of a complex suite of interactions between individual plants and a multitude of climatic and environmental variables. Plants are major regulators of the global climate, and their collective responses to increased atmospheric CO_2 concentrations have clearly played an important role in mitigating climate change up to this point. The uptake of CO_2 by plants during photosynthesis is the major pathway by which carbon is stored. By looking into the future, it is increasingly critical to understand how plants respond on a basic level to the changes imposed upon them by continued increases in atmospheric CO_2 as well as the cascade of climatic and environmental changes triggered by this increase. While plant responses to changes in single variables, such as CO_2 or temperature, are increasingly well-understood, we have only just begun to understand how the interaction of these changes impacts plants and their role in regulating the global climate. Recent discoveries reveal just how much remains to be learned while illustrating the many ways in which the world's plants can all-too-easily loose their ability to act as a global carbon sink, becoming instead yet another carbon source [29]. Phenology has recently received great prominence as it has been demonstrated that there has been considerable change in the timing of the development stages of plant species as a consequence of the relatively modest levels of climate warming so far experienced. This has been very important to demonstrate to policy makers and the general public that, using examples which they can understand; real changes have already taken place [30]. Important phenological events for medicinal plants are adapted to climate change might be considered as, (i) Bud burst and Leaf unfolding, (ii) Flowering and setting fruit, (iii) Autumn or dry season leaf drop, and (iv) The related processes of winter hardening and breaking[31]. Phenological events have received increased interest in the light of global warming [32]. As global warming progresses, it will affect the arrival of spring and the length of the growing season. The growing season of trees has been extended in temperate and boreal zones (Fig. 2).

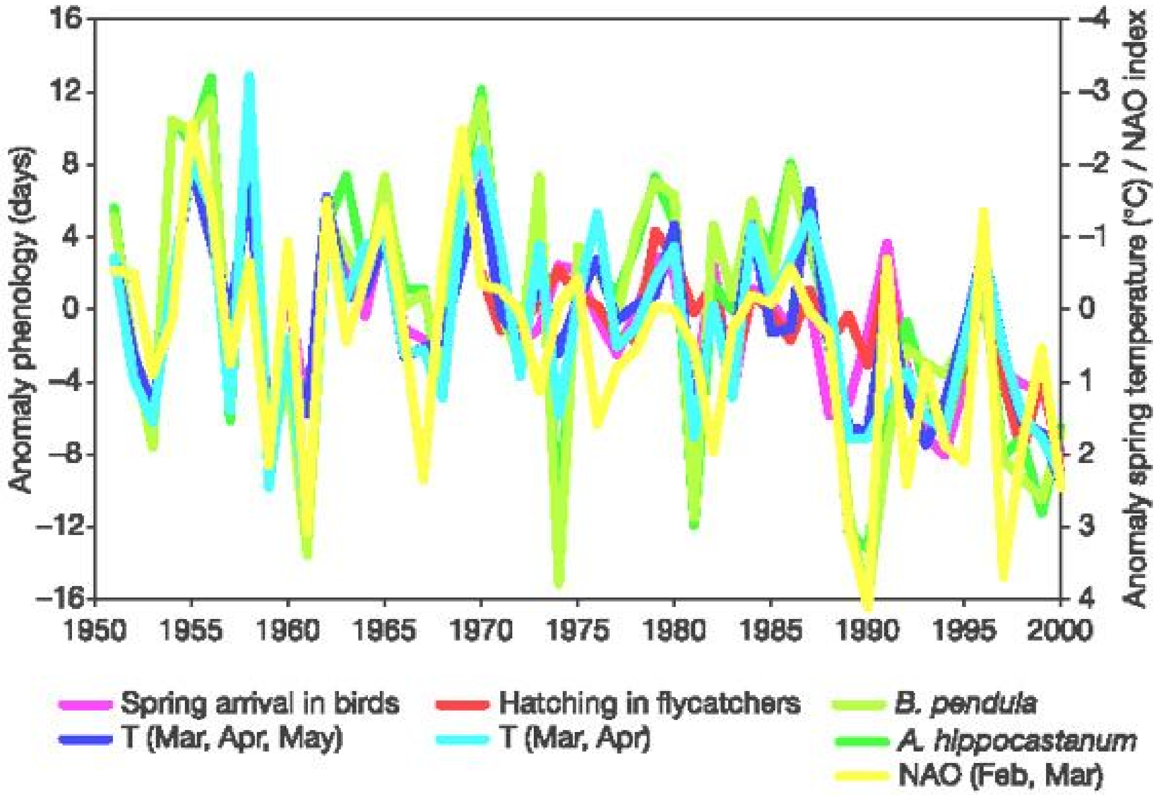

Fig. 2. Common changes in the timing of spring activities include earlier shooting and flowering of plants at temperate latitudes have advanced by 2.5 days per decade since 1971 (derived from Walther, G. R 2002).

The date of first flowering has advanced by 3 - 26 days, depending on species (Table 1). First flowering of trembling aspen is advanced by *ca*. 26 days, an apparent response to warming surface waters in the northern Pacific and higher atmospheric temperatures in western Canada. Plants in the wild appear to be more disposed toward phenological shifts than cultivated plants [4].

The proximate factors causing mast seeding in *Fagus crenata* Blume were analysed in a 13-year time series of seed production in relation to both previous reproduction and weather conditions in Hokkaido, northern Japan. In an autocorrelation analysis, observed a significant negative correlation in 1-year time lags for the log-transformed total seed crop. The critical minimum temperature from late April to mid-May for total seed crop at all five sites was about 1.0 °C higher than the 22-year (1979–2000) mean of the minimum temperatures, above which very few seeds were produced. These results show that a weather cue triggers the cessation of reproduction in *F. crenata* [33].

Table 1: Phenological changes in selected tree species

Location	Species	Time period	Change in first flowering	References
North America	American elm	1956-1997	- 8days	[34]
Europe-North America	Numerous plant species	1960s	1.4±3.1days per decade earlier 1.2±2.0 (3.8)	[13, 35]
Canada	Aspen	1901–1997	- 26 days	[36]
Canada	Trembling aspen, Choke cherry,	1936–2000	- 8 days	[36]
United States	89 Species	1970-1999	- 4.5 days	[37]
US northeast	American beech, Sugar maple, Yellowbirch	1957–2004	-5 to10 days	[38]
United States	11Species	1970-1999	+3 to 10 days	[37]

(Derived from Walther, G. R 2002 and Cavaliere, C 2009)

Flowering and fruiting phenology of plants are sensitive to environmental cues such as temperature and moisture, and climate change is likely to alter community-level patterns of reproductive phenology. In a controlled warming experiment, Sherry *et al* (2007) reported that early-flowering grass and herb species flowered earlier, while late- summer flowering species flowered later than in the control (Fig. 3). Responses by individual species to climate change may disrupt their interactions with others at the same or adjacent trophic levels. When closely interacting or competing species display divergent responses or susceptibilities to change, the outcome of their interactions may be altered, as long-term data on both terrestrial and marine organisms indicate [13]. Range extensions or contractions may occur. Range extension may be facilitated by extension of favourable climate out of current range. Range contraction over time if climate shifts beyond adaptive envelopes of key phenophases (e.g. seed germination).

The warming-induced divergence of flowering and fruiting toward the two ends of the growing season resulted in a gap in the staggered progression of flowering and fruiting in the community during the middle of the season. A double precipitation treatment did not significantly affect flowering and fruiting phenology. Variation among species in the direction and magnitude of their response to warming caused compression and expansion of the reproductive periods of different species, changed the amount of overlap between the reproductive phases, and created possibilities for an altered selective environment to reshape communities in a future warmed world [39].

Factors Influencing Plant Phenology

The timing of phenophases is thought to be under strong genetic control, leading to regionally adapted ecotypes that are influenced by: (i) *Temperature***:** Leaf unfolding and budburst respond strongly to temperature; (ii) *Frost*: If late season frosts occur after budburst or flowering, reproductive failure and reduced growth of the tree in that season can occur [40]; (iii) *Chilling***:** Full winter dormancy may require periods of chilling that includes super-cooling and desiccation of cell protoplasm; (iv) *Photoperiod:* Photoperiod initiates dormancy adaptation in latitudinally adapted tree ecotypes; (v) *Evapotranspiration:* increased surface temperature and likely reduced summer precipitation, and (vi) *Drought:* Seasonal drought during the growing season which lead to reduce the growth of the tree.

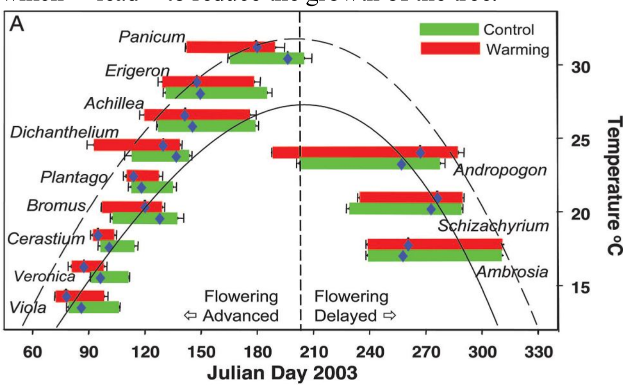

Fig. 3. Effects of simulated warming on overlapping of reproductive stages in selected plant species. Early-flowering grass and herb species flowered earlier, while late- summer flowering species flowered later than in the control (derived from Sherry, R. A. *et al* 2007).

A 2003 meta-analysis of 9 phenological studies from various countries, involving 172 plant and animal species, found a mean shift toward earlier spring timing of 2.3 days per decade [41]. Many studies have shown that plant species that normally flower in early spring are experiencing some of the greatest acceleration from warming, whereas species active later in the growing season can be unresponsive or experience delayed phenological events [42]. Researchers on medicinal plants indicate that many of the medicinal plants wormwood (*Artemisia absinthium*, Asteraceae), feverfew (*Tanacetum parthenium*, Asteraceae), and cranberry (*Vaccinium macrocarpon*, Ericaceae). St. John's wort (*Hypericum perforatum*, Clusiaceae) now flowers 6 days earlier than as plants are now flowering more than a week earlier than 150 years ago, and peppermint (*Mentha*x *piperita*, Lamiaceae) now blooms 10 days earlier [43] and also data from Nature's Calendar provides evidence that many UK plants have begun to bloom earlier, including such widely used medicinal plants as hawthorn (*Crataegus monogyna* and *C. laevigata*, Rosaceae) and horse chestnut (*Aesculus hippocastanum*, Hippocastanaceae).

Shifts in plant phenology could lead to any of several disruptive ecological effects. The timing of a plant's life cycle can have effects on optimal seed set, whether it reaches before the end of the growing season or otherwise. Phenological variations between plant species in the same ecosystem can reduce competition for pollinators and other resources, and, conversely, phenological similarities can benefit plants that rely on other species to attract pollinators. The timing of growth stages can also determine the length of the growing season. Furthermore, it is possible that inter-dependent species—such as particular plants and their pollinators - may not shift their phenologies in harmony with one another, and such mistimed relationships could pose a danger not only to the plant species' survival but also the pollinators, having a concomitant cascade effect on the rest of the ecosystem [13, 44]. Phenological shifts may lead to "winners" and "losers" among sympatric species, *viz.* some species may benefit from phenological shifts; others may become threatened by these shifts. Most medicinal plant species are relatively common in their pollinators, so they are less likely to be under significant risk of threat from these phenological changes. Rare MAP species occurring in small populations, however, would be more endangered by any form of environmental stress, including climate change as there is a lot of time-sensitive relationships [4].

Early blooming can become detrimental if an area is prone to cold spells late in the spring season. If a cold spell occurs a few days or weeks after early blooming has commenced, then those early buds or fruits could freeze, potentially killing or affecting the production of some economically useful plants like bloodroot (*Sanguinaria canadensis*, Papaveraceae) is susceptible to early frost following early blooming [4]. For the last 5 to 10 years, climate change in Europe has caused an abrupt transition from winter to summer with temperatures in April and May that are more typical for summer temperatures. This has caused, for example, that throughout Europe spring planting of chamomile [*Matricaria recutita*, Asteraceae] has been disastrous with an average loss of yield of 80% [4].

The Impact of Climate Change on Plant Distribution

Climatic regimes influence species' distributions, often through species-specific physiological thresholds of temperature and precipitation tolerance. Changes in climate are also causing plants to migrate into new ranges shifted towards the poles or higher altitudes. Factors affecting species distribution interact in complex ways, and it is not surprising that simple correlations with temperature changes are not always observed. Range shifts are often episodic rather than gradual or monotonic [13, 41]. Rates of range shifts vary greatly among and within species, implying differential dispersal abilities, whereas the magnitude of elevational shifts of alpine plant species lags behind the isothermal shift of 8±10m per decade matching the upwards and northwards shifts of temperature [13]. The results of the moderate climate change scenario suggest that German flora would be affected negatively by future climate change and land use patterns. Species that are currently not recorded in Germany could migrate into the country as the climate warms, potentially disrupting existing species pools [4].

Many uncertainties exist regarding how the ranges of plant species might be affected by future climate change, including the extent to which cultivated crops may be affected. It is not entirely clear what type or degree of range shifts might take place. There is some indication that agricultural crops will be more adaptable to climate change than natural ecosystems, but some regions may become significantly less productive. A recent report published by Botanic Gardens Conservation International noted that changes in patterns of crop distribution will have to occur with altered temperature ranges and rainfall availability. Some areas of the world are expected to gain increased suitable cropland, whereas others—particularly developing regions of Africa and South Asia—are predicted to experience marked declines in crop yields[4, 45].

The range shifts of wild plants from climate change could ultimately jeopardize the survival of some species. All ecosystems contain a spectrum of species with varying degrees of migratory potential. At one end of this spectrum are those species that can migrate rapidly and aggressively, and at the opposite end are the specialist species with limited mobility. Vegetation will migrate in bands, with the fastest, most invasive species at the front, the slowest at the rear, and all others in between [45]. This could cause situations where early successive species invade areas with slow-moving endangered species, and the 2 species may have to compete with one another. Moreover, some slow-moving species may not be able to migrate quickly enough to keep pace with range shifts generated by climate change. Natural and human-made barriers to migration could also affect the survival of some species undergoing climate-induced range shifts.

Some modeling programs do indicate that habitat loss and migratory challenges related to climate change could result in extinctions of many endemic species throughout the world because of the migratory challenges that some species will face as they respond to climate change [46].

Medicinal plants on all continents have also been impacted by severe weather conditions. Mounting evidence indicates that extreme weather events such as storms, droughts, and floods have become more prevalent and intense across the globe in recent years [47]. 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 cultivators' abilities to grow and/or collect medicinal plant species, and such difficulties have certainly been reported in recent years [48].

Extreme weather conditions throughout Europe are impacting medicinal plant production from seeding to harvesting. The extremely dry soil conditions resulting from recent abnormally hot summers has prevented successful fall re-seeding of some medicinal plants, such as chamomile in Germany and Poland and also in 2007 no seed yield in the first year of fennel (*Foeniculum vulgare,* Apiaceae) was observed in Bulgaria, due to drought conditions during the spring in that country [4].

Since only a very small minority of cultivated medicinal plants in Africa are growing through irrigation, the impact of global warming and low rainfall is extremely serious. The prices of medicinal plants have already risen substantially in many areas due to increased collection costs and declining yields. Africans may ultimately begin to move away from wild harvesting practices and reliance upon rain-fed crops in favor of irrigation, where possible, and there may also be a shift of production toward the more humid tropics [4].

Increasing evidence and studies have thus shown that at least some types of extreme weather events have been striking more frequently and with greater force throughout the world [49]. Although particular weather events cannot be definitively blamed on climate change, the negative effects of some recent droughts, storms, and floods on herbal crops demonstrate the threat that increased extreme weather could pose to the availability and supply of MAPs [4].

The Impacts of Global Climate Change on Secondary Metabolic Compounds

Impending climate change is just one factor that could contribute to the loss of MAPs. The region is also being negatively affected by deforestation and burning, unwise exploitation of the land, and rapid population growth [4, 50]. Loss of MAPs, coupled with loss of traditional knowledge by the indigenous peoples of these areas, could prevent important health discoveries and options in the future [51]. Yield and composition of secondary metabolites in plants, *viz.* the volatile components and those occurring in essential oils, can be affected in a number of ways as climate change effect on (a) environmental conditions; geographic variations, genetic factors and evolution; (b) political and social conditions; and also (c) amount of plant material/space and manual labour needs [52]. 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 [4]. Total alkaloid content of *Datura metel* L. has been shown to peak in the hot dry season and at its lowest during the rainy season in Ibadan [4].

Lodgepole pines, are encountering increased abiotic stress and pest activity due to recent increases in temperature and changes in precipitation throughout their range. This tree species counters these threats by producing secondary metabolites, including phenolics and terpenoids. It had consistently greater foliar levels of almost all measured secondary metabolites in the Coastal Western Hemlock and Interior Cedar/Hemlock bio-geoclimatic zones than did other stands [50].

The chemical compositions of the essential oils of *Piturantho schloranthus* have 150 compounds and these contents varied with respect to both the geographical area and the season. Limonene, camphene, geraniol and β-damascenone were likely to be specific for the essential oils of this species collected from the different regions of Tunisia [50, 53]. *Achillea collina* can be considered as a very good source of bioactive phenolic compounds, and growing at high altitude. Climate (as influenced by altitudes from 600-1050 m)) was shown to be the main environmental factor influencing on antioxidant capacity (1/IC (50) values from 4.35 +/- 0.72 to 8.90 +/- 0.74), total phenolic content (from 31.39 +/- 4.92 to 49.36 +/- 5.70 mg gallic acid equivalents (GAE) g(-1) DW) and properties[6]. Ecological condition had significant impacts on yield

and secondary metabolites of *Alisma orientalis* were cultivated in Dujiangyan in China. Alisol content was significantly higher than those of other regions [4].
Temperature and sunshine-hours were the major effective factors under the climatic conditions of Guangxi which, influenced on artemisinin content of *Artemisia annua*, followed by the rainfall amount, the humidity showed less influence, and wind speed had no effect; while the climatic factors of seedling stage and the flowering season were the most influences to the artemisinin content [10].

Conclusions

The primary focus of this article 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/or other purposes. The effects of climate change are apparent within ecosystems around the world, including medicinal and aromatic plant populations. MAPs in Arctic and alpine areas face 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 have been recorded worldwide, and these factors could ultimately endanger wild MAP species by disrupting synchronized phenologies of interdependent species, exposing some early-blooming MAP species to the dangers of late cold spells, allowing invasives 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.
What makes medicinal plants unique from other flora is the fact that they, along with other economically useful plants, are collected for human use. Therefore there is a need for more research into the effects of climate fluctuations on plants in general and especially for research ethnobotanical information (such as the perceived availability of species, changes in collection practices, etc.) and this is pertaining to effects of climate fluctuations on MAP species.
Climate change may not currently represent the biggest threat to MAPs, but it has the potential to become a much greater threat in future decades. Many of the world's poorest people rely on medicinal plants not only as their primary healthcare option, but also as a significant source of income. The potential loss of MAP species from effects of climate change is likely to have major ramifications on the livelihoods of large numbers of vulnerable populations across the world [54].
Climate change and its effects will certainly increase in the near future, although the extent to which they do so cannot presently be determined. The effects of climate change on medicinal plants, in particular, has not been well-studied and is not fully understood. As the situation unfolds, climate change may become a more pressing issue for the herbal community, potentially affecting users, harvesters, and manufacturers of MAP species.
Arctic plants typically produce phenolic, anthocyaninsn and Flavonoids compounds. Phenolic compounds protect plant cells from free radicals resulting from photo-inhibition. Anthocyanins are reddish color to attenuate the amount of light reaching photosynthetic cells and therefore reduce the risk of photoinhibition in reddish color and have been shown. Flavonoids are also common in Arctic plants, and they protect against UV damage such as cell apoptosis related to DNA breakage. If Arctic plants begin to produce less of these compounds as a result of higher temperatures, they may partly lose their ability to serve as antioxidants for human health benefit.
As a result of the widespread loss and fragmentation of habitats, many areas which may become climatically suitable with future warming are remote from current distributions, and beyond the dispersal capacity of many species. Consequently, species with low adaptability and/or dispersal capacity will be caught by the dilemma of climate-forced range change and low likelihood of finding distant habitats to colonize, ultimately resulting in increased extinction rates.
According to recent climate models that simulate the effects of increasing greenhouse gas concentrations, global average surface temperature may rise by between 1.4 °C and 5.8 °C by 2100, depending on the rate of global development. This rate of climate change is faster than at any time during Earth history. If nations fail to respond, the world may experience numerous adverse impacts as a result of global warming in the decades ahead. Climate data are dramatically increasing in volume and complexity, just as the users of these data in the scientific community and the public are rapidly increasing in number. It is needed to ensure that society can reduce vulnerability to climate variability and change, while at the same time exploiting opportunities that will occur [55].

REFERENCES

1-Singh, P., et al., Basin-wide assessment of temperature trends in northwest and central India. Hydrological Sciences Journal, 2008. 53(2): p. 421-433.

2-Sheffield, P.E. and P.J. Landrigan, Global climate change and children's health: threats and strategies for prevention. Environ Health Perspect, 2011. 119(3): p. 291-8.

3-Padulosi, S., D. Leaman, and P. Quek, Challenges and opportunities in enhancing the conservation and use of medicinal and aromatic plants. Journal of Herbs, Spices & Medicinal Plants, 2002. 9(4): p. 243-267.

4-Cavaliere, C., The effects of climate change on medicinal and aromatic plants. Herbal Gram, 2009. 81: p. 44-57.

5-IPCC, A.R., Intergovernmental Panel on Climate Change. 2007.

6-Giorgi, A., et al., Influence of environmental factors on composition of phenolic antioxidants of Achillea collina Becker ex Rchb. Nat Prod Res, 2010. 24(16): p. 1546-59.

7-Zobayed, S., et al., Plant–environment interactions: accumulation of hypericin in dark glands of Hypericum perforatum. Annals of Botany, 2006. 98(4): p. 793.

8-Kirakosyan, A., et al., Antioxidant capacity of polyphenolic extracts from leaves of Crataegus laevigata and Crataegus monogyna (Hawthorn) subjected to drought and cold stress. Journal of Agricultural and Food Chemistry, 2003. 51(14): p. 3973-3976.

9-Protecting medicinal plants from climate change. 2006, Nordic Gene Bank, September 8,: Sweden.

10-Sauve, A.A., et al., The biochemistry of sirtuins. Annu. Rev. Biochem., 2006. 75: p. 435-465.

11-Brown, R.P., P.L. Gerbarg, and Z. Ramazanov, Rhodiola rosea-a phytomedicinal overview. Herbalgram, 2002. 56: p. 40-52.

12-Hussein, M.A.S., A. Singh, and T. Aung, Rise and fall of sea level in Nauru area over a nodal cycle. The South Pacific Journal of Natural and Applied Sciences, 2011. 28(1): p. 63-68.

13-Walther, G.R., et al., Ecological responses to recent climate change. Nature, 2002. 416(6879): p. 389-395.

14-Salick, J., Z. Fang, and A. Byg, Eastern Himalayan alpine plant ecology, Tibetan ethnobotany, and climate change. Global Environmental Change, 2009. 19(2): p. 147-155.

15-Lutgens, F.K., E.J. Tarbuck, and D. Tasa, The atmosphere: an introduction to meteorology. 1995, New Jersey Prentice Hall.

16-Rodenhouse, N.L.R.N.L., et al., Climate change effects on native fauna of northeastern forestsThis article is one of a selection of papers from NE Forests 2100: A Synthesis of Climate Change Impacts on Forests of the Northeastern US and Eastern Canada. 2011.

17-Yoon, C.K., Warming moves plants up peaks, threatening extinction. The New York Times, 1994. 21: p. C4.

18-Richardson, K., W. Steffen, and D. Liverman, Climate change: global risks, challenges and decisions. 2011: Cambridge Univ Pr.

19-Braganza, K. and J.A. Church, Observations of global and Australian climate. Books Online, 2011. 2011(1): p. 1-14.

20-Gore, A., An inconvenient truth: The planetary emergency of global warming and what we can do about it. 2006: Rodale Books.

21-Hu, A., et al., Effect of the potential melting of the Greenland Ice Sheet on the Meridional Overturning Circulation and global climate in the future. Deep Sea Research Part II: Topical Studies in Oceanography, 2011. 58(17-18): p. 1914-1926.

22-de Montmollin, B. and W. Strahm, The Top 50 Mediterranean Island Plants: Wild plants at the brink of extinction, and what is needed to save them. 2005, Oxford, Uk: World Conservation Union. 110.

23-Trisurat, Y., R.P. Shrestha, and R. Kjelgren, Plant species vulnerability to climate change in Peninsular Thailand. Applied Geography, 2011. 31(3): p. 1106-1114.

24-Gosling, S.N., et al., A review of recent developments in climate change science. Part II: The global-scale impacts of climate change. Progress in Physical Geography, 2011. 35 (4): p. 443-464.

25-Easterling, D., et al., Observed variability and trends in extreme climate events: a brief review. BULLETIN-AMERICAN METEOROLOGICAL SOCIETY, 2000. 81(3): p. 417-426.

26-Tøttrup, A.P., K. Thorup, and C. Rahbek, Patterns of change in timing of spring migration in North European songbird populations. Journal of Avian Biology, 2006. 37(1): p. 84-92.

27-Thorpe, J., N. Henderson, and J. Vandall, Ecological and policy implications of introducing exotic trees for adaptation to climate change in the western boreal forest. 2006: Saskatchewan Research Council Saskatoon, No. 11776-1E06. ,Canada.

28-Hoegh-Guldberg, O., Climate change, coral bleaching and the future of the world's coral reefs. Marine and freshwater research, 1999. 50(8): p. 839-866.

29-Cox, P.M., et al., Acceleration of global warming due to carbon-cycle feedbacks in a coupled climate model. The Warming Papers, 2011: p. 331.

30-Sparks, T. and A. Menzel, Plant phenology changes and climate change. Encyclopedia of Biodiversity, 2010.

31-Sparks, T. and A. Menzel, Plant Phenology Changes and Climate Change, in Encyclopedia of Biodiversity, A.L. Simon, Editor. 2007, Elsevier: New York. p. 1-7.

32-Körner, C. and D. Basler, Phenology under global warming. Science, 2010. 327(5972): p. 1461.

33-Kon, H., et al., Proximate factors causing mast seeding in Fagus crenata: the effects of resource level and weather cues. Canadian journal of botany, 2006. 83(11): p. 1402-1409.

34-Chuine, I. and E. Beaubien, Phenology is a major determinant of temperate tree range. Ecology Letters, 2001. 4: p. 500–510.

35-Sparks, T.H. and A. Menzel, Observed changes in seasons: an overview. International Journal of Climatology, 2002. 22(14): p. 1715-1725.

36-Beaubien, E. and H. Freeland, Spring phenology trends in Alberta, Canada: links to ocean temperature. International Journal of Biometeorology, 2000. 44(2): p. 53-59.

37-Abu-Asab, M.S., et al., Earlier plant flowering in spring as a response to global warming in the Washington, DC, area. Biodiversity and Conservation, 2001. 10(4): p. 597-612.

38-Richardson, A.D., et al., Phenology of a northern hardwood forest canopy. Global Change Biology, 2006. 12(7): p. 1174-1188.

39-Sherry, R.A., et al., Divergence of reproductive phenology under climate warming. Proceedings of the National Academy of Sciences, 2007. 104(1): p. 198.

40-Selås, V., et al., Climatic factors controlling reproduction and growth of Norway spruce in southern Norway. Canadian Journal of Forest Research, 2002. 32: p. 217-225.

41-Parmesan, C. and G. Yohe, A globally coherent fingerprint of climate change impacts across natural systems. Nature, 2003. 421(6918): p. 37-42.

42-Cleland, E.E., et al., Shifting plant phenology in response to global change. Trends in Ecology & Evolution, 2007. 22(7): p. 357-365.

43-Nickens, T., Walden warming. 2007, National Wildlife: October/November. p. 36-41.

44-Law, W. and J. Salick, Human-induced dwarfing of Himalayan snow lotus, Saussurea laniceps (Asteraceae). Proceedings of the National Academy of Sciences of the United States of America, 2005. 102(29): p. 10218.

45-Nelson, R., et al., The vulnerability of Australian rural communities to climate variability and change: Part II--Integrating impacts with adaptive capacity. Environmental Science & Policy, 2010. 13(1): p. 18-27.

46-Graham, C.H., et al., Species Distribution Modeling and the Challenge of Predicting Future Distributions. Climate Change and Biodiversity in the Tropical Andes., 2011.

47-Huber, D.G. and J. Gulledge, Extreme Weather and Climate Change. 2011.

48-Wedawatta, G., et al., Extreme weather events and construction SMEs: Vulnerability, impacts, and responses. Structural Survey, 2011. 29(2): p. 106-119.

49-Drine, I., Climate Change Compounding Risks in North Africa. Working Papers, 2011.

50-Wallis, C.M., D.P.W. Huber, and K.J. Lewis, Ecosystem, Location, and Climate Effects on Foliar Secondary Metabolites of Lodgepole Pine Populations from Central British Columbia. Journal of chemical ecology, 2011: p. 1-15.

51-Jin, Y., Necessity: Enacting Laws to Protect Indigenous Intellectual Property Rights in the United States. Transnat'l L. & Contemp. Probs., 2011. 19: p. 950-977.

52-Figueiredo, A.C., et al., Factors affecting secondary metabolite production in plants: volatile components and essential oils. Flavour and Fragrance Journal, 2008. 23(4): p. 213-226.

53-Neffati, A., et al., Influence of growth phase and geographic origin on the essential oil composition of Pituranthos chloranthus from Tunisia. Nat Prod Commun, 2009. 4(11): p. 1585-94.

54-Hawkins, B., S. Sharrock, and K. Havens, Plants and climate change: which future?, in Plants and climate change: which future? 2008, Botanic Gardens Conservation International, Richmond, UK. pp. 96.

55-Overpeck, J.T., et al., Climate Data Challenges in the 21st Century. Science, 2011. 331(6018): p. 700.