***Review Article***

# Global climate change and its effects on Medicinal and Aromatic Plants: A review

## Abstract

Medicinal herbs have been used for a long time to cure health problems and prevent disease, including epidemics. Medicinal plants are used for different purposes and in diverse uses of human beings. People around them have a basic knowledge and using through their traditional medicine from the past several years. Natural and manmade calamities, such as rapid climate change, urban growth, industrial boom, overpopulation pollution, declining forest cover, habitat loss, over-harvesting, destructive harvesting, and floods, are the principal reasons of the reduction of wild medicinal plant species. The life cycles and distribution of the world's vegetation, especially wild medicinal plants, are being affected by climate change. The impact of global climate change on medicinal plants could have a huge influence, especially in terms of their utility in conventional medication systems and as economically useful plants. The current essay emphasises the importance of study to improve our understanding of climate influences on medicinal plants properties, phenology and metabolic responses. The purpose of this paper is to review the impact of abiotic variables on secondary metabolite formation and different adaptation measures as well as future research initiatives. Furthermore, such issues with global climate change will undoubtedly become more visible or immediate threats, putting further strain on medicinal plant species. The impact of global climate change on medicinal plants could negatively correlate with environment concerns parameters, especially in terms of their utility in conventional medication systems and as economically useful plants.

*Keywords :*Adaptation,climate change, medicinal plants, phenology, secondary metabolites

## 1.Introduction

Climate change has increasingly been considered as one of the most serious threats to humanity and all other forms of life on the planet.It is now beyond doubt that anthropogenic Greenhouse gases (GHG) emissions are the main cause for recently observed climate change.

Global warming of 1.5°C relative to 1850–1900 would be exceeded during the 21st century under the intermediate, high and very high GHG emissions scenarios (IPCC, 2021).Warming at 1°C affects all continents and is generally larger over land than over the oceans in both observations and models (Thomas *et al.*,2004). Plant growth and yield will be positively and negatively affected by climate change. Diverging effects are caused by the rising $CO^2$ concentrations, higher temperature, changing precipitation patterns, changing water availability, increased frequency of weather extremes (i.e., floods, heavy storms, and droughts), climate-induced soil erosion, and sea-level rise. Medicinal plants have been used as a source of medicine in practically all cultures. Humans employ medicinal plants for a variety of goals and in a variety of ways. Medicinal herbs have been used for a long time to cure health problems and prevent disease, including epidemics (Mishra, 2016). People developed basic knowledge of medicinal plant values and how to treat various illnesses from an ancient day (Bhat,2021). Medicinal plants are essential natural resource which constitutes one of the potential sources of new products and bioactive compounds for drug development (Gangwar*et al.*,2010). Traditional medicine, largely plant medications, is used by 60 percent of the world's population and 80 percent of the population of developing countries for primary health care (Shrestha and Dhillions, 2003). According to reports, traditional plant-based remedies are used by 70% of India's population (Gadgil and Rao, 1998). About 7500 species of higher plants in India are known to have therapeutic properties, accounting for a significant part of the total flowering plants (Gowthami *et al.*, 2021). Anthropogenic climate change has already had a significant impact on global species ranges and ecological communities, including medicinal plants. Climate change is "Unequivocal," according to the Intergovernmental Panel on Climate Change (IPCC). Temperatures are expected to rise much further, from 1.4°C to 5.8°C by 2100 and 2033, respectively. There is a need to recognise the pattern of climate change, which is one of the most serious global environmental concerns, and to understand and assess the various sorts of impacts (Cavaliere, 2009). As the climate changes and the globe heats, there is a greater chance of biodiversity mass extinction than species can adapt to (Muluneh, 2021). On the other hand, agricultural production industries and techniques are adapted to local climate variability (Marshall *et al.*,2015), particularly with medicinal plants such as Isabgol, Asalio, and many others (Dutta, 2022) in arid and semi-arid settings. Local groups in diverse places that have used medicinal plants for generations have said that there are constant threats and a rapid loss of species worldwide. Climate change causes stress in plants, which can impact the secondary metabolites and other substances they generate, which are the basis for their therapeutic activity. It is already

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causing bio diversity and ecosystems to adapt to altering habitats, life cycles, and the emergence of new physical characteristics. Plant species that are endemic to climate-vulnerable geographic locations may face serious threats in the near future. As a result, research on the effects of climate change on medicinal plants is critically insufficient (Parmesan, 2006). In the therapy of any disease, the constituents of plants that serve as active ingredients interact simultaneously, complementing or neutralising the damage. The study on medicinal plants with respect to global climate change is very infrequent and insignificant in comparison with other commercial crops. These Medicinal and Aromatic Plants (MAP's) species are critical sources of important biomolecules and neutraceuticles, and it is imperative that they not be abandoned. People living in isolated and far from metropolitan areas are fully reliant on plants and their products for their basic existence and the treatment of various maladies and diseases, therefore the conservation of threatened medicinal plants at higher altitudes is critical (Ullah*et al.*, 2014).The demand for medicinal plants is currently increasing in both developed and developing countries for various reasons. Medicinal plants have a promising future since there are around half a million plants on the planet, and most of their pharmaceutical potential has yet to be discovered, necessitating current and future research (Ghorbanpour *et al.*,2013). In compared to other commercial crops, research on medicinal plants in relation to climate change is intermittent and modest. It is likewise imperative for these plants to be protected because they are potential sources of biomolecules and neutraceuticals. While the future implications of climate change are likely to be unpredictable, they are already having an influence on MAPs and may become a much greater concern in the future. The disappearance of some MAPs could have a significant impact on the lives of a huge number of people. The problem of global warming and altered seasonal occurrences is similarly difficult to comprehend, but prompt action can likely avoid biodiversity loss.The method for assessing the influence of climate change on medicinal plants is based on contemporary literature, journal articles, and some personal observation.

## 2.Therapeutic Importance of Medicinal and Aromatic Plants

Secondary metabolites are chemical compounds that plants have evolved to synthesise in a wide variety of ways. These secondary metabolites don't appear to play a part in basic plant growth and development, thus they're only found in plants from a single species, and their levels rise at times of extreme stress, such as drought, high temperature, or bacterial infection (Taiz and Zeiger, 2006). The glycosides are secondary metabolic products that include a variety of secondary metabolites coupled to mono or oligosaccharide and uronic acid (Wang and Hou, 2009). Medicinal plants that contain cardio gycosides are commonly used in the treatment of heartfailure and cardiac arrhythmia. Cardioactive glycosides are found in a diverse groupof plant species including *Digitalis purpura* and *D. lanata* (Scrophulariaceae), *Nerium oleander* (Apocynaceae) and *Convallariamajalis* (Convallariaceae) (Bernhoft*et al.*, 2010). Plant pigments such as flavonoids and proanthocyanidins can be found in a wide variety of plant groups. Isoflavones are generated by Fabaeceae species (bean family). Flavonoids are the most widespread and widely dispersed group of plant phenolic chemicals, found in almost every part of the plant, especially the photosynthetic plant cells (Kumar and Pandey, 2013). In vascular plants, condensed tannins are the most widely distributed tannins. Hydrolyzable tannins, on the other hand, are only found in dicotyledons (Bernays *et al.*, 1989). Fagaceae (beech family) and Polygonaceae are two plant groups that have been linked to the occurrence of tannins (knotweed family). The biological actions of pyrrolizidine alkaloids, which include acute hepatotoxic, mutagenic, carcinogenic, teratogenic, anticancer, and neuroactive characteristics, make them important secondary metabolites (Asres *et al.*, 2004).

Environmental challenges in over all the world.However, there is need to become increasingly aware of the problems that surround it. Some are minor and only influence a few ecosystems, while others have a significant impact on the environment. We are in the midst of a global emergency, with environmental issues stacking up all around us. Current environmental issues demand immediate attention.

~~1.~~Environmental pollution has existed for millennia, but it was only during the industrial revolution in the 19th century that it became serious. When the natural environment is unable to degrade an element without causing injury or damage to itself, pollution occurs. The elements involved are not found in nature, and the process of destruction can take anything from a few days to thousands of years.

a) Industries: As previously stated, industries have been contaminating our environment since the beginning of the industrial revolution, particularly due to the increased usage of fossil fuels. Coal was used to help machines work quicker in the 19th century and throughout much of the 20th century, substituting human labour.

b) Agricultural Activities: Agriculture is mostly responsible for water and soil contamination. The increased use of pesticides, as well as the intensive nature of its manufacturing, are to blame. Pesticides are almost often made of chemical components and are used to keep illnesses and dangerous animals away from crops.

c) The production and exchange of commodities and services are examples of trading activities. When it comes to commodities, pollution is primarily generated by packing (which frequently entails the use of fossil-fuel-derived plastic) and transportation.

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## 3.Phenological changes

Plant life cycles follow seasonal patterns, and global climate change is altering species and ecosystems. These phenological changes are putting endangered medicinal plant species in jeopardy. Bud burst and leaf unfolding, flowering and establishing fruit, autumn or dry season leaf drop, and the linked processes of winter hardening and breaking are all important phenological events for medicinal plants that have adapted to climatic change. The advent of spring and the length of the growing season will be affected as global warming progresses (Bidart *et al.*,2008).

The alteration of plant phenology in Trifolium repens by 1–11 days has been noted as a result of increased concentrations of carbon dioxide ($CO_2$) and elevated temperatures compared to the normal conditions (Kumar *et al.*, 2020). *Aconitum heterophyllum* exhibits early flowering when exposed to elevated $CO_2$ levels( Chandra*et al.*, 2020). Elevated $CO_2$ and temperature lead to a significant reduction in the duration taken for flower initiation, 50% flowering, seed setting, and seed maturity in Valerianajatamansi (Kaundal and Kumar, 2020). Hypericum perforatum experiences a decreased timeframe from bud formation to flower formation under elevated CO2 and temperature conditions (Sharma *et al.*, 2020).

## 4.Global Warming and Climate Change

Another environmental issue that has surfaced in recent decades is climate change. The phrase "climate change" has become synonymous with modern global warming for the purposes of current and future repercussions (Demeritt, 2001). The latter, in turn, refers to variations in global mean surface-air temperature after the Industrial Revolution that are thought to have been driven by rising atmospheric carbon dioxide ($CO_2$) Fan active greenhouse gas throughout the eighteenth, nineteenth, and twentieth centuries. $CO_2$ levels in the atmosphere were around 280 parts per million by volume (ppmv) in 1765, and around 364 parts per million by volume (ppmv) in 2000, (ppmv). Other greenhouse gases (methane, nitrous oxide, chlorofluorocarbons) have also increased in the atmosphere as a result of increased economic activity and energy use during the last two centuries (Rowntree *et al.*, 2016). The cause-and-effect relationship between the increase in important greenhouse gases and the predicted rise in global mean surface-air temperature is yet unknown. This is owing to the earth's climate's complicated fluctuation and interconnectedness with a variety of terrestrial and interplanetary processes (Loaiciga, 2003).

Medicinal plants, particularly endemic medicinal plants, are extremely vital to human survival (Anderson *et al.*, 2005). Anthropogenic climate change has already had an impact on medicinal plants all across the planet. For example, heavier monsoon rainfall, more frequent and hotter summer days, less frequent and lower dry season rainfall, stronger and more frequent storms with high winds, and so on. Climate change, habitat damage, overharvesting, and a decline in natural pollinators as a result of overharvesting are all major factors influencing endemic populations (Byg and Salick, 2009).

## 5.Metabolic responses of plants

### Change in Flowering Time

Crop blossoming and maturation alter as the temperature rises. A1°C increase in mean seasonal temperature reduces wheat output by 5–8% (Wheeler *et al.*, 1996). The time of flowering is a vital period of development in the life cycle of most plants when seed quantity is determined. When temperatures (>32–36 °C) coincide with a small crucial period of only 1–3 days around the time of blooming, it has been discovered that seed set and, ultimately, crop output are considerably reduced (Amasino and Michaels, 2010).

## 6.Effect of Elevated $CO_2$ on Plant Development and Morphology

$CO_2$ has a direct influence on plants because of photosynthetic gas exchange, but it also has an indirect effect as a potent greenhouse gas that contributes to global warming (Cassino *et al.*, 2018). $CO_2$ increases photosynthetic carbon absorption rates by 31 percent on average across 40 species (Reddy and Raghavendra, 2010). Heat has detrimental effects on plant leaves, such as reduced leaf water potential, reduced leaf area, and premature leaf senescence, all of which have a negative impact on the plant's overall photosynthetic performance. The lower activity of sucrose phosphate synthase, ADP-glucose pyro phosphorylase, and invertase affects starch and sucrose synthesis (Beroza- Fernandez *et al.,* 2009).

## 7.Heat Stress and Secondary Metabolite Production

Plant metabolism aids heat stress tolerance by supplying energy and producing secondary metabolites that are necessary for cellular homeostasis. Temperature has a significant impact on plant secondary metabolite synthesis (Kumar *et al.,* 2023). Carotenoids are required for photoprotection during photosynthesis and serve as a precursor in signalling during plant development under stressful situations. They improve plant output and nutritional quality. According to many findings, plants exposed to high-temperature stress have reduced chlorophyll production (Reda and Mandoura, 2011), which is the first step in plastids to be damaged or destroyed by the high temperature.

## 8.High Temperature and Osmolyte Accumulation

Many plants use the buildup of low molecular weight water-soluble molecules known as "osmolytes" to combat environmental stressors. The most prevalent defensive mechanism used by plants in response to high temperatures is the production and accumulation of suitable solutes. Amino acids (asparagine, proline, serine), amines (polyamines and glycine betaine), and c-amino-N-butyric acid are among the compounds (GABA). Fructose, sucrose, trehalose, raffinose, and proline are all total sugars (Wani and Gosal 2010; Harsh *et al.,* 2016) as well as pools of anti-oxidants such as glutathione (GSH) and ascorbate (Ding *et al.,* 2016) accumulate in response to heat stress.

## 9.Physiological Aspects of Heat Stress

Heat stress causes plants to adapt their physiological status and metabolic level, resulting in both permanent and temporary metabolic changes. After drought, heat, and combination stress treatments, Jin *et al.,* (2015) detected changes in physiological and metabolic parameters in *Portulaca oleracea* L. Furthermore, under heat conditions, the content of the amino acid asparagine was enhanced. This is due to the connection of amino acids with protein synthesis substrates, which may aid in the rapid recovery of plant metabolism following stress. Glycine betaine is crucial in plants that are subjected to high temperatures (Oddy *et al.,* 2020). Glycine betaine is generated in chloroplasts and keeps Rubisco active by sequestering Rubiscoactivase near thylakoids, preventing it from being thermally inactivated (Allakhverdiev*et al.*, 2008).

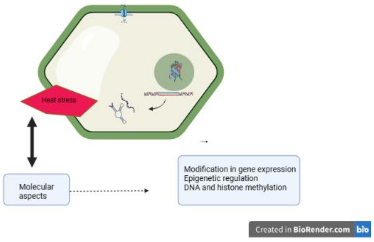

Fig 1: Molecular responses in medicinal plants to heat stress (source: Kumar *et al.*, 2010)

## 10.Effects of Ozone on Plant Secondary Metabolites

The bioprotective properties of ozone against ultra violet radiation is well established. Global agricultural yields are already being reduced by ground-level ozone pollution (from 2.2–5.5 percent for maize to 3.9–15% and 8.5–14% for wheat and soybean, respectively), to varying degrees depending on genotype and climatic conditions (de Grujil and Leun, 2000). These negative consequences can also be recognised in medicinal herbs. However, because there has been so little attention paid to $O_3$'s effects on medicinal plants and their PSM content, it has become necessary to assess its potential repercussions (Basaran *et al.*, 2020).

*Melissa officinalis*, a traditional medicinal plant used to treat dementia, anxiety, and CNS-related disorders, was found to have a significant increase in total anthocyanins, as well as phenolics and tannins, when exposed to elevated ozone concentrations (Shakeri *et al.*, 2016). A similar investigation on the Eco physiological and antioxidant features of *Salvia officinalis* under ozone stress (120 ppb for 90 days) revealed an increase in phenolic content, particularly Gallic acid (2-fold increase) and Catechinic acid (rise only once over the 90-day fumigation period) (Pellegrini *et al.*, 2015).

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## 11.Effects of Toxic Gases on Plant Secondary Metabolites

Sulfur dioxide is a prominent atmospheric pollutant that can enter the plant system through the roots as well as through stomatal opening during photosynthesis and respiration. Damage to the photosystem (Lu *et al.*, 2011), changes in stomatal density, and variations in carbon fixation efficiency are some of the reactions (Harrison *et al.,* 2020). The atmospheric $SO_2$ along with $H_2S$ also acts as sulfur source which can be up-takenthrough stomata of the plants apart from the sulphate uptake from the roots. When *Nicotiana tabacum* plants are forced to grow at a high temperature, hydrogen sulphide has been found to mediate nicotine production (Chen *et al.,* 2016).

Table 1: Effects of ozone and carbon dioxide on plant secondary metabolite

| **Component** | **Treatment** | **Affected medicinal plant** | **Affected secondary metabolite** |
|---|---|---|---|
| $O_3$ | Elevated $O_3$ | *Salvia officinalis* | Gallic acid↑, Catechinic acid↑, Caffeic acid↑, Rosmarinic acid↑ |
| $CO_2$ | Elevated $CO_2$ and Light intensity | *Labisiapumila* | Flavonoids↑, Phenolics↑ |
| $CO_2$ | Elevated $CO_2$ | *Catharanthus roseus* | Phenolics↑, Flavonoids↑, Tannins↑, Alkaloids↑ |
| $O_3$ | Elevated $O_3$ | *Melissa officinalis* | Phenolics↑, Anthocyanins↑, Tannins↑ |
| $O_3$ | Elevated $O_3$ | *Puerariathomsnii* | Puerarin↑, ABA↑ |
| $O_3$ | Elevated $O_3$ | *Hypericum perforatum* | Hypericin↑ |
| $CO_2$ | Elevated $CO_2$ | *Zingiber officinale* | Flavonoids↑, Phenolics↑ |
| $O_3$ and $CO_2$ | Elevated $O_3$ and $CO_2$ | *Ginkgo biloba* | Tannins↓, Quercetinaglycon↑, Keampferolaglycon↓, Isorhamnetin↓, Bilobalide↓ |
| $CO_2$ | Elevated $CO_2$ | *Digitalis lanata* | Digoxin↑, Cardenolide↑ |
| $O_3$ | Elevated $O_3$ | *Betula pendula* | Dehydrosalidroside ↓hyperoside↓, Betuloside↓, Platyfylloside↓, Salidroside↓, papyriferic acid↓, hyperoside↑ |
| $CO_2$ | Elevated $CO_2$ | *Papaversetigerum* | Morphine↑, Codeine↑, |

|  |  |  |  |
|---|---|---|---|
|  |  |  | Papaverine↑andNoscapine↑ |

(Source: V.Kumar*et al.*,2010)

## 12.Effect of Ultraviolet radiation

According to the International Commission on Illumination, Ultraviolet (UV) wavelength (400–200 nm) is a small part of the solar radiation reaching the Earth's surface, which is divided into UV-A (315–400 nm), UV-B (280–315 nm) and UV-C (200–280 nm), and it affects negatively all living organisms. The harmful effect of UV radiation increases towards the shorter wavelengths (Kumari and Prasad, 2013) .These rays can harm molecular and cellular structures, including proteins, DNA, and other biopolymers. This sort of radiation can also alter plant growth and development, causing changes in vegetative or reproductive biomass, height, leaf features, and flowering time (Lei *et al.*, 2017).

## 13.Impact of UV Radiation on the Synthesis of Secondary Metabolites in Medicinal Plants

In vitro cultures of *Phyllanthustenellus* grown under white light plus UV-A radiation produced more antioxidants like phenolics (geraniin and ellagic acid) and carotenoids than plants cultivated under white light alone (Victorio *et al.,* 2011). Seedlings of *Laurus nobilis* cultivated under low doses of supplementary UV-A had lower leaf concentrations of particular quercitin and kaempferol derivatives than plants grown under ambient UV light (Bernal *et al.,* 2015). After 3 and 5 days of continuous UV-A exposure, the content of total phenolics and total flavonoids in sowthistle (*Ixerisdentata*Nakai) was dramatically increased, while plant development was not impeded (Lee *et al.,* 2013).

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## 13.Effect on threats to medicinal plants species

Species that rely on one other (co-existence) may be pushed to extinction if they no longer coexist in the same time or space. Pests, illnesses, and invasive species may expand their ranges, putting additional stress on vulnerable populations, including medicinal plants. Conservation-minded species with rigorous habitat requirements or prolonged incubation times are more vulnerable to extinction (Benning *et al.*,2002).

## 14.Effect of Salinity stress on the growth and physiology of Medicinal Plants

Approximately 20% of the world's irrigated soil has a high salt level, making it harmful to agriculture (Zaman *et al.*, 2018)~~)~~.As much as 25% of the total drugs in developed countries like USA constitutes of plant drugs, whereas it is close to 80% in developing countries like China and India. The cultivation and maintenance of medicinal plants thus forms a profitable business throughout the world and must be protected. Cultivating medicinal plants on salt-contaminated soils has resulted in significant physiology and growth problems (Munir *et al.*, 2022).

## 15.Correlation Between Salt Stress and Developmental Morphology in Medicinal Plants

Salt stress inhibits germination by either killing the embryo or significantly lowering the soil potential, causing water intake to be impeded. When *Ocimumbasilicum*, *Erucasativa*, *Petroselinumhortense*, chamomile, sweet marjoram, ~~and~~*Thymus maroccanus*~~,~~ and*Achilleafragratissima* seeds were placed in salt polluted soil, germination was delayed (Ali*et al.*, 2007,Abd EL-Azim*et al.*, 2009, Mir *et al.*, 2022, Rastogi *et al.*, 2022). *Mentha piperita* var. *officinalis* and *Lipiacitriodora* var. *verbena* subjected to salt stress had considerably less leaves, leaf area, and leaf biomass (Chrysargyris*et al.*, 2019).

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## 16.Correlation Between Salt Stress and Photosynthesis in Medicinal Plants

The most significant and crucial physiological mechanism for plant development and survival is photosynthesis. This mechanism necessitates a high level of energy expenditure for maintenance, making it vulnerable to stress circumstances that alter the cell's metabolic equilibrium (Banerjee and Roychoudhury, 2017). In century*Teucriumpolium*, *Thymus vulgaris*, *Zatariamultiflora*, *Ziziphoraclinopodioides*, and *Saturejahortensis*, both chlorophyll a and b, as well as total chlorophyll content, were reduced (Chauhan *et al.*, 2023).*Hypericum perforatum* exhibited a 124% increase compared to the controlled conditions when exposed to 1000 μmol mol$^{-1}$ of carbon dioxide (Walia *et al.*, 2022). In *Podophyllumhexandrum*, there was an initial increase in response to elevated $CO_2$ during the first 30 days, followed by a subsequent decrease (Ghasemzad eh *et al.*, 2012). Additionally, *Trifolium repens* displayed a down-regulation of photosynthesis at elevated $CO_2$, indicating a reduction in the photosynthetic process under these conditions (Von Caemmerer*et al.*, 2001).

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## 17.Adaptation measures for climate change and global warming

Conservation of endangered flora and fauna can reduce the vulnerabilities of medicinal plants in the world.These will involve medicinal plant cultivation. Maintaining genetic diversity in natural ecosystems is critical for medicinal plant adaptability (Kadam and Pawar, 2020). Traditional indigenous knowledge that can help mitigate the effects of climate change should be investigated and documented, while supporting traditional art and craft-based livelihoods through local community involvement and eco-tourism as a source of revenue (Mooney *et al.*,1991).

## 18.Conclusion

Over the centuries, the use of medicinal and aromatic plants has become an important part of daily life despite the progress in modern medical and pharmaceutical industry. Endangered plant species are thought to be particularly vulnerable to climate change and may face extinction. As a result, a better understanding of the causes that cause such change need a comprehensive and ongoing field study. As the Earth's environment is constantly in battle with it, several things have an impact on it. Plants exposed to severe temperatures generally exhibit a similar response known as oxidative stress, which damages lipids, proteins, and nucleic acids. As a nutshell, for significant medicinal plants, the reaction of the plant and the mechanisms underlying its adaptation to elevated temperatures must be better understood. In addition, metabolic changes in response to stress are critical for developing stress tolerance. In analysis to define if there is an induction of hazardous metabolites, it is necessary to analyse not only the chemicals of interest for a certain plant, but also a large number of secondary metabolites.In view of the steadily rising demands on these important natural resources, attention should be paid to the sustainable forms of production and utilization. Furthermore, more research on threatened medicinal plants in a climate-change scenario is necessary for developing conservation strategies, as is cultivating medicinal plants through the involvement of local communities with traditional indigenous knowledge, which can help to mitigate the effects of climate change.

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