Advances in Medicinal Plant Improvement in Perspective to the Changing Environment

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Abstract Global climate change has altered the natural ecosystems, and it is expected to worsen the conditions for plant growth and productivity. Elevated CO_2 and temperature impose diverse direct and indirect effects on plant species. Different biotic and abiotic stresses might adversely affect the plants. Medicinal plant species may also be threatened by changing temperature and precipitation regimes, increases in pest and pathogen populations, and natural habitat alteration. The changing environment, poverty and the loss of traditions, easy access to medicinal plant habitats, lack of sufficient knowledge about the amount and methods of sustainable harvesting of medicinal plants, the existence of a profitable trade market, and the lack of legal policies are among the effective factors in the excessive exploitation of medicinal plants and reduction of their genetic diversity. Genetics and crop improvement are technologies that can contribute to plant adaptation to the changing environment. The goals of crop improvement are to reduce adverse environmental effects, preserve heritage resources, and increase the quality and quantity of medicinal plants. It is necessary to identify the needs of each species and the degree of compatibility against negative environmental factors. Recent advances in the field of plant genetics and breeding have helped to strengthen research in crop improvement studies. However, how to breed medicinal plants to adapt to the changing climate needs more investigation. In this chapter, recent advances in medicinal plant improvement in perspective to the changing environment and environmental challenges are discussed.

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1 Introduction

Environmental changes have negatively affected agricultural production and natural ecosystems (Arunanondchai et al. 2018). Two major problems in the twenty-first century are global climate change and food insecurity. Climate change is characterized as the change in climate (long term) resulting from human activities such as ozone layer destruction and greenhouse gas emissions and natural processes (Kotir 2011). Climate changes include atmospheric CO_2 elevation, temperature increase, and precipitation pattern variations, leading to floods, drought, and various biotic and abiotic stresses (Ziska 2016). The intensity of global warming is rising gently and has disrupted the ecosystem. The greatest disturbance in the global ecosystem is still related to human activities. In 2022, the global average temperature, obtained from key monitoring stations data, was estimated to be ~1.15 °C above the average of the second half of the nineteenth century, and 2015 to 2022 were probably the eight warmest years on record (Pörtner et al. 2022).

Global warming has an important role in the challenges facing the world and threatens future development planning, global food security, prosperity, economics, water resources, and human health worldwide (Tripathi et al. 2016). Agricultural ecosystems are affected by global climate changes that can affect all aspects of agriculture such as biodiversity, productivity, and food security (Allmendinger 2018). These effects are directly related to global warming, which means that extreme changes in weather affect all regions of the world. Climate change affects agricultural systems directly (morphology, physiology, phenology, crop production, and adaptability), indirectly (soil fertility, biotic and abiotic stresses, sea level rise), and socioeconomically (food value, food security, and food trade) (Raza et al. 2019). Climate changes alter several levels of biology such as physiology, morphology, and genetic diversity, populations, species (size and location, habitat quality and quantity), communities (productivity, biomass, species relationships), and ecosystems (functions and processes) (Scheffers et al. 2016).

Medicinal plants are valuable to human life and a main portion of health care for many populations worldwide. In developing countries, the primary medicine materials for ~80% of people are supplied by medicinal plants, and they are increasingly utilized by many people in developed countries (Robinson and Zhang 2011). Worldwide climate changes have negatively affected medicinal plants and may impact the accessibility, productivity, and phytochemical content of medicinal plant populations. Environmental stresses reduce biomass production of some medicinal species and may change chemical content and affect the quality of medicinal products (Fig. 1). Therefore, conservation and local cultivation of valued medicinal plants, sustainable harvesting, preservation of traditional knowledge, programs to

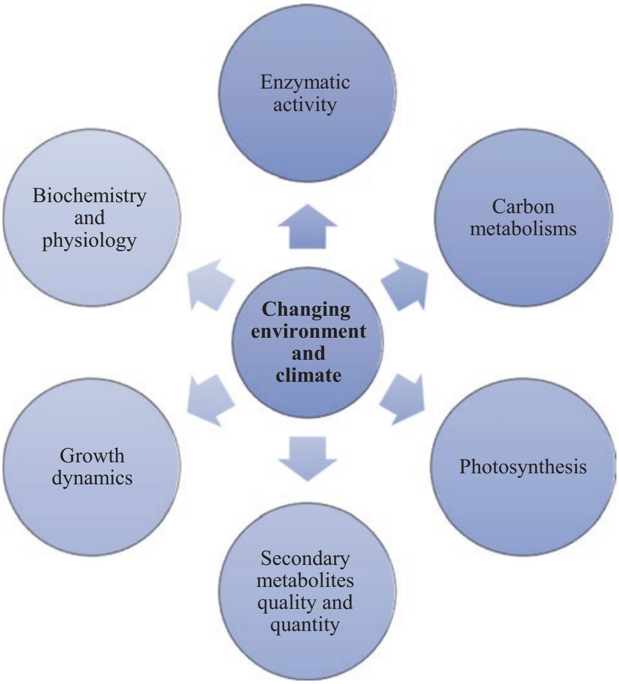

Fig. 1 Effects of changing environment on growth, physiology, and biochemistry of medicinal and aromatic plants

monitor raw material quality, and crop improvement and breeding to mitigate environmental change effects are recommended.

Plant breeding is the function of developing various plant varieties that can effectively help cropping and production systems. Population growth increases the need for food supply, and to feed the population, breeding is an ever-serious issue. Creating germplasm to solve obstacles in agriculture and enhancing value for producers, consumers, and society are the main goals of plant breeding programs (Kholová et al. 2021). Therefore, plant breeders endeavor to increase plant productivity and quality and diminish negative environmental impacts on plants. Plant breeding is important to cope with the effects of climate change and supplement crop management and policy interventions to ensure global food security (Xiong et al. 2022). Climate change has altered the breeding objectives' priority; for example, resilience breeding was put at the top priority (Langridge et al. 2021). With progressed knowledge of the gene and the development of technologies such as gene editing, plant breeders still face challenges due to limited genetic grades and indistinct climates across the globe (Zabel et al. 2021).

It is predicted that plant species will become more sensitive to pathogens and pests under climate changes, leading to a decrease in their quantity and quality and food security (Van der Fels-Klerx et al. 2016). The ecosystems will eventually be disrupted due to extreme weather changes and the increased frequency of global warming. Therefore, improving plant species, here medicinal plants, to environmental changes and global climate changes can lead to mitigating the potential adverse effects on the productivity of plants. In this chapter, recent advances in medicinal plant breeding, with a glance at the changing climatic conditions, are discussed.

2 Effects of Climate Change on Medicinal Plants

Many ecological aspects such as temperature, nutrition, light, water availability, and CO_2 concentrations increase the secondary metabolites (SMs) such as total flavonoids and phenolic content in medicinal plants (Clark and Menary 1980). SMs are bioactive compounds and might be altered by environmental stimuli. Unfavorable environmental factors affect the growth and primary metabolites of medicinal plants, which in turn affects the biosynthesis of SMs.

The SMs of medicinal plants show a wide range of adaptations to changing environments (Mishra 2016). Elevated CO_2 is predicted to alter the plant carbon/nitrogen ratio in carbon-based secondary metabolites (Heyworth et al. 1998). For example, phenolic compounds, hypericin, pseudohypericin, and hyperforin of *Hypericum perforatum* were increased at elevated CO_2 (Zobayed and Saxena 2004). The alkaloid concentrations of *Papaver setigerum* were also enhanced by raising the CO_2 concentration (Ziska et al. 2008). However, a decrease in SMs was also observed at elevated CO_2. Snow et al. (2003) observed that elevated CO_2 decreased *Pseudotsuga menziesii* terpenes, specifically monoterpenes. Time of exposure to elevated CO_2 is also a determinant factor affecting SMs. Working on *Hymenocallis littoralis*, a bulbous medicinal plant, Idso et al. (2000) observed that exposure of plants to the elevated CO_2 enhanced the alkaloids only in the first year but they decreased in the year after.

Drought is the most limiting factor of plant productivity worldwide and an undeniable climate change consequence. Drought and water scarcity adversely affect crop yield. Plant growth is practically influenced by drought; nevertheless, it depends on the growth stage and the duration, intensity, and severity of the stress (Zarghami Moghadam et al. 2021). Drought stress causes stomatal closure, limits gas exchanges, and inhibits metabolism and photosynthetic rate in plants, which subsequently leads to plant death (Vazquez and Dunford 2005). Drought stress induces different plant structural changes including morphological (root and shoot shape and growth), physiological (gas exchange variables), and biochemical (metabolic) alterations to cope with the stressful conditions. However, the duration and intensity of drought, plant species, and growth stage affect the plant's durability and its survival ability in stressful environments (Vazquez and Dunford 2005). The growth, essential oil, and proline content of *Calendula officinalis* L. plants were increased under drought conditions resulting from the increased plant height, leaf area, flower diameter, and spike stem diameter (Metwally et al. 2013). Fresh and dry weights of *Ocimum* sp. (Khalid 2006) and *Satureja hortensis* L. (Baher et al. 2002) plants were diminished by water deficit.

Seed germination behaviors are affected by genetic factors, climate change scenarios, and ecological parameters. One of the most crucial limiting factors for germination and plant establishment is the temperature (de Souza and Válio 2001). However, based on the climate change scenarios, the world temperature is rising gradually and is expected to increase by ~2 °C by 2050. This temperature increase would negatively affect all plant species in various ways. Working on *Catharanthus roseus* and *Mentha piperita* medicinal plants, Alhaithloul et al. (2019) found that a combination of drought and heat decreased total phenol, flavonoid, and saponin contents, plant height, fresh weight, and dry matter, while tannins, alkaloids, and terpenoids were increased. They concluded that the antimicrobial and anticancer activities of plants were significantly reduced when exposed to drought and heat stress.

3 Medicinal Plant Breeding: Importance and Challenges

The effects of climate change and its critical implications for food security are forcing plant breeders to act quickly, necessitating the improvement of plant species in a shorter time, which is a challenge for current "slow but successful" breeding efforts (Challinor et al. 2016). In addition to adapting to new abiotic and biotic stresses, improved crops must meet other urgent needs arising from climate change such as agricultural migration to new areas and crop management to achieve climate mitigation such as reduced fertilizer utilization, tillage, and other changes in planting practices (Henry 2020; Heredia et al. 2021).

Medicinal plants with a large number of plant species and diverse biological characteristics have a smaller cultivated area compared to other crop plants, and due to the high cost, a limited capacity for breeding investigation is considered (Pank 2009). Breeding of medicinal plants is more complex than other crop species breeding because the production, growth cycle, medicinal parts, and SMs of the plants must all be taken into consideration. Quality determines the value of medicinal plant production, which makes their breeding different in particularity. The term "top-geoherbs" is determined as medicinal substances with demonstrated higher quality produced in particular geographical zones, which has been suggested based on the relationship between the habitat of medicinal plants and their yield quality (Huang et al. 2011).

A major prerequisite for medicinal plant cultivation is the availability of germplasms with high germination rates, uniform germination, high yield quality, and economic value. While crops such as wheat, maize, rice, potato, tomato, and soybean are mainly bred for high yield, medicinal plants should be bred for stable yield and high quality (Wang et al. 2020). Environmental stresses such as extreme temperatures, drought, and salinity inhibit the growth and development of plant species

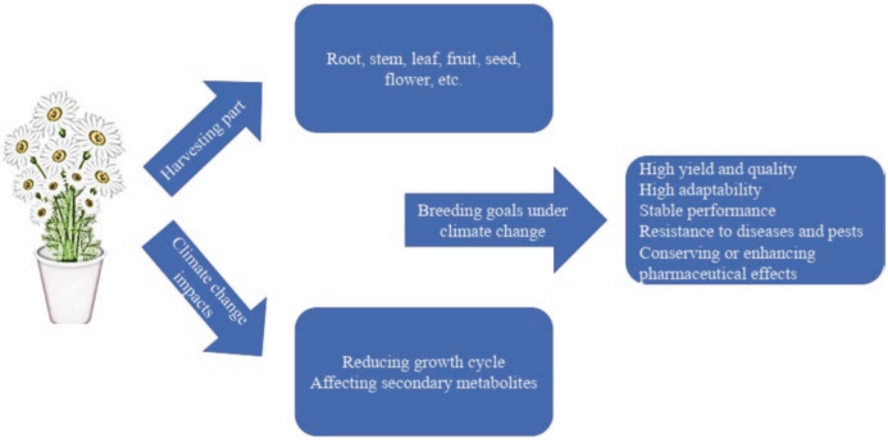

Fig. 2 Medicinal plant breeding goals under a changing climate

and might stimulate the accumulation of SMs such as alkaloids and flavonoids in medicinal plants (Huang and Guo 2007), indicating the differences between medicinal and crop plant breeding purposes (Fig. 2).

4 Recent Advances in Medicinal Plant Improvement

Medicinal and aromatic plants play vital roles in human life. Plants' biochemical and metabolic processes are genetically controlled. Controlled genetic diversity to improve performance and create environmental stability can play a role in fulfilling human goals. The creation of new diversity can occur by methods such as selective breeding, hybrid breeding, mutation breeding, tissue culture, polyploidy breeding, DNA marker-assisted breeding, and transgenic breeding (Table 1). Among the criteria that are followed in medicinal plant breeding, high adaptability and stable performance, resistance to diseases and insects, high functional value, and safety, and saving cost and sustainable production can be mentioned. In addition, drought and salt stress resistance, low input cultivation, high SM amount for economic extraction, low content of harmful metabolites to avoid heavy costs to remove them, and high dry matter content can also be considered (Ahmadi and Shabani 2020).

In general, the improvement of medicinal plants is carried out in two stages:

1. Research stage: At this stage, there is no knowledge of the ecological requirements of the medicinal plant; therefore, the plant is transferred to experimental plots in various sexual and asexual ways, and all factors such as appropriate soil type, planting depth, irrigation cycle, within- and in-row distance, and soil fertility are available to the plant as much as possible.

Table 1 Recent advances in medicinal plant species improvement

Medicinal plant species	Common name	Breeding method		Results	Climatic conditions	Reference
Pseudostellaria heterophylla (Miq.) Pax.	False starwort	Selective breeding		Higher polysaccharide content, root yield, and disease and lodging resistance		Xiao et al. (2016)
Trigonella foenum-graecum L.	Fenugreek			High ecological temperature range for germination, adaptation, and eco-evolutionary, rapid seedling growth, lower risks of low productivity and extinction	Temperature	Solouki et al. (2022)
Panax ginseng	Ginseng		Pure-line selection	Disease resistance, root shape, and root yield		Yang et al. (2006)
Coriandrum sativum L.	Coriander			High capacity of essential oil and fruit yield	Drought	Gholizadeh et al. (2019)
Bupleurum chinense DC	Bupleurum			Saikosaponin content, agronomic and morphological characteristics		Zheng et al. (2010)
Schizonepeta tenuifolia	Hairy sage			High quality and production, high active constituent levels, disease resistance		Cao et al. (2009)
Trigonella foenum-graecum L.	Fenugreek			Higher branch number/plant and 1000 seeds Weight, survival rate, and yield	Freezing stress	Mirmiran et al. (2021)
Calendula officinalis	Pot marigold			Higher flower numbers and proline content	Drought stress	Zarghami Moghadam et al. (2021)

(continued)

Table 1 (continued)

Medicinal plant species	Common name	Breeding method		Results	Climatic conditions	Reference
Gastrodia elata Bl.	Tianma	Hybrid breeding	Reciprocal crossbreeding	New hybrid lines with stable and high yields		Wang and Guo (2001)
Gastrodia uralensis	Tianma		Crossbreeding	Vigorous growth and high glycyrrhizin and total flavonoid contents		Ozaki and Shibano (2014)
Fritillaria lichuanensis P.	Checkered lily			Higher seed-setting rate, higher germination rate, and enhanced disease resistance		Ruan et al. (2004)
Platycodon grandiflorus				A low number of lateral roots and processing suitability, high saponin content and extraction suitability, and low crude fiber content, edibility, and medicinal suitability		Wei et al. (2011)
Rehmannia glutinosa (Gaertn.)	Rehmannia	Mutation breeding	Interspecific hybridization	Higher seed-setting rate of the progeny		Li et al. (2012)
Isatis indigotica fortune	Woad		Microwave radiation	Enhanced germination rate, shortened germination time, and accelerated plant growth		Chen (2005)
Chamaecrista rotundifolia (Pers.) Greene	Round-leaf cassia		Gamma rays	Squaring period, flowering period, pod stage, and mature stage		Weng et al. (2004)
Catharanthus roseus (L.) G. Don	Madagascar periwinkle		Ethyl methane sulfonate (EMS)	Rapid growth and high indole alkaline content		Xiusheng et al. (2004)
Celosia cristata L.	Cock's comb	Space mutation	High-altitude balloon	Enhanced total flavonol content of inflorescences		Debao et al. (2002)
Dendrobium nobile	Noble dendrobium		Satellite launched	Higher alkaloid and polysaccharide contents		Peng and Ye (2017)
Glycyrrhiza uralensis	Chinese liquorice		Spaceflight	Higher liquiritin and glycyrrhizic acid contents in the seeds		Zhang et al. (2011)

Echinacea purpurea	Coneflower	Tissue culture	Plant growth hormone	Enhanced transplanted seedling survival		Wang et al. (2005)
Pogostemon cablin (Blanco) Benth.	Patchouli	Polyploid breeding		Increased stem thickness and the size of leaves and stomata, higher patchouli alcohol content		Yan et al. (2016)
Stevia rebaudiana (Bertoni) Hemsl.	Candyleaf			Higher stevioside content		Xu et al. (2014)
Citrus limonia Osb.	Canton lemon			Higher resistance to hydric stress, improved membrane stability	Water deficit	Vieira et al. (2016)
Dioscorea zingiberensis	Yam			Lower electrolyte leakage, malondialdehyde contents, superoxide anions, and hydrogen peroxide, stronger antioxidant defense system, and increased heat tolerance	Heat	Zhang et al. (2010)
Citrus reticulata	Mandarin			Higher antioxidant enzymes and heat shock proteins	Salt stress	Podda et al. (2013)
Panax notoginseng	Notoginseng	DNA marker-assisted breeding		Reduced root rot and rust rot in seedlings		Dong et al. (2017)
Perilla frutescens (L.) Britt.	Beefsteak plant	Transgenic breeding		High yield and high resistance		Shen et al. (2017)
Papaver somniferum L.	Opium poppy			High morphinan alkaloid content		Frick et al. (2005)
Atractylodes macrocephala Koidz.	Bai Zhu		Gene gun-mediated method	Disease resistant		Mao et al. (1994)
Pogostemon cablin (Blanco) Benth.	Patchouli		*Agrobacterium*-mediated transformation	High disease resistance		Zhang et al. (1997)

2. Planting stage: After conducting research, the best method of planting with the highest yield (quantitative and qualitative) is obtained. When reaching this basic information, the plant has been domesticated (Afkar and Karimzade 2009).

Although crops have been bred for high yield with good quality and adaptability under certain cultivation conditions, medicinal plants are mainly cultivated using wild types or local varieties without any selection or screening (Wang et al. 2020). For instance, *Rosmarinus officinalis* Linn is widely used for ornamental and culinary purposes and has many antibacterial and anti-inflammatory effects, while no cultivars of which have been specifically selected or bred for medicinal purposes (Begum et al. 2013).

Typically, it is expected that cultivated and domesticated medicinal plants be different from their wild-type ancestors owing to the wild-type species usually growing in relatively harsh environments. For example, cumin (*Cuminum cyminum*), which originated in Western Asia including Iran, grows naturally in mountain areas with harsh climates, and it may affect the pharmaceutical effects of the plants. The rhizomes of wild *Pinellia ternata* (Thunb.) Breit. with antitussive and expectorant effects are superior to those of cultivated varieties (Gao et al. 2010). However, cultivation does not always alter the genetic factors of these plants compared with the wild types (Wang et al. 2020). Recent studies showed that some cultivated medicinal species had higher levels of active ingredients such as volatile oil in *Atractylodes lancea* (Thunb.) DC (Huang et al. 1990) and matrine in *Euchresta japonica* Hook. f. ex Regel (Yang et al. 2006) than those found in the wild counterparts.

The most important breeding method in the early stages of medicinal plant breeding has been the screening of the varieties with better performance from populations. For successful breeding using the selection method, the traits for which changes are desired should be defined clearly. Mass selection from resources of *Pseudostellaria heterophylla* (Miq.) Pax. from different areas in China helped to breed a new variety (Shitai No. 1) with high lodging and disease resistance, root yield, and polysaccharide content (Xiao et al. 2016). Solouki et al. (2022) found that the Mashhad ecotype at 39.7 °C showed the highest ecological temperature range (TR) for germination among eight ecotypes. Furthermore, 11 cultivars of Korean ginseng have been selected using the pure-line-selection method with improved root yield, root shape, and disease resistance (Yang et al. 2017).

Zarghami Moghadam et al. (2021) evaluated 13 calendula cultivars (*Calendula officinalis*) under drought stress. They found that drought stress reduced the traits attributed to flowers such as diameter and flower number while proline content was increased; however, the cultivars differed in their response to the stressful conditions. Although most of the flower numbers of the cultivars (11 out of 13) were decreased by drought stress, Citrus Cocktail and Oopsy Daisy cultivars showed higher flower numbers at 50% of field capacity (FC) than their respective under 100% FC. Only four cultivars of calendula showed a significant increase in proline content exposed to drought stress. They ultimately selected premium cultivars Neon and Candyman as the most resistant to water stress.

Seed germination and plant establishment are the most important stages in a plant life cycle; however, poor germination and plantlet establishment limit crop yield (Windauer et al. 2007). The final yield of crops can be determined by faster seed germination and desirable plant establishment (Bybordi and Tabatabaei 2009). Solouki et al. (2022) quantified cardinal temperatures of eight fenugreek (*Trigonella foenum-graecum* L.) ecotypes at nine constant temperature levels (0 °C, 5 °C, 10 °C, 15 °C, 20 °C, 25 °C, 30 °C, 35 °C, and 40 °C) by nonlinear regression models. They identified Intersected-lines and Dent-like models as the best explainable models for different fenugreek ecotypes. By increasing temperature to optimum, the germination rate and reciprocal time to median germination (R_{50}) increased. The Mashhad ecotype at 39.7 °C showed the highest ecological temperature range (TR) for germination. The adaptation and eco-evolutionary of the Mashhad ecotype for higher germination result in rapid seedling growth and avoid the risks of low productivity and extinction in the presence of abiotic stresses caused by climate change.

In hybrid breeding, the good traits of two or more varieties are combined through hybridization, where one of the most important steps in the breeding program is parent selection. The progeny shows superior performance compared with that of either parent (Fridman 2015). Despite promising results, considerable work is necessary to produce new varieties via hybrid breeding. Using reciprocal crossbreeding, four new hybrid lines of *Gastrodia elata* Bl. with stable and high yields were selected (Wang et al. 2020). The crossbreeding of a strain with vigorous growth as the father and a strain with high glycyrrhizin content as the mother resulted in releasing a new strain of *Gastrodia uralensis* (C-2) with vigorous growth and high glycyrrhizin and total flavonoid contents (Ozaki and Shibano 2014). Distant hybridization is sometimes preferred to common hybridization since it might result in varieties with more obvious heterosis. In a study on *Rehmannia glutinosa*, it was observed that interspecific hybridization of cultivated and wild types led to a higher seed-setting rate of the progeny (Li et al. 2012). Therefore, interspecific hybridization is sometimes more advantageous than intraspecific hybridization. However, the opposite results were also obtained (Wang et al. 2012; Wang et al. 2020).

Mutations induced in organisms via physical, chemical, or space processes are called mutation breeding; among those, physical mutagenesis has become one of the most effective means of obtaining new germplasm resources (Wang et al. 2020). For instance, using a CO_2 laser, a new variety (Si Jiyi 78–1) of *Coix lacryma-jobi* L. was obtained with larger seeds, greater tiller number, and dwarf form (Qiao and Cui 1981). However, some species may show significant sensitivities to radiation, or unpredictable outcome may be obtained. It was observed that increasing the intensity of gamma radiation had inhibitory effects on plant growth, especially reductions in germination rate, flowering, and fertility rate in *Melilotus officinalis* (L.) Pall., *Melilotus dentatus*, *Melilotus albus*, and *I. indigotica* (Wang et al. 2006). In *Chamaecrista rotundifolia* (Pers.) Greene under gamma rays, five varieties with various squaring periods, flowering periods, pod stages, and maturation stages were obtained (Weng et al. 2004). Chemical mutagenesis has rarely been applied in medicinal plant improvement and has usually been applied in combination with tissue culture. For example, exposure of *Catharanthus roseus* (L.) G. Don and

Lavandula angustifolia Mill. to ethyl methane sulfonate (EMS) resulted in mutant cell lines with rapid growth, higher indole alkaloid content, and enriched 1,8-cineole and borneol (Desautels et al. 2009).

Induced mutation in germplasm materials exposed to near-space physical and chemical factors for breeding of new varieties is referred to as space mutation, which is carried by return satellites and high-altitude balloons, or in high-altitude simulation tests (Yan and Lei 2002). Space breeding of two *Celosia cristata* L. varieties with a high-altitude balloon enhanced the total flavonol content of inflorescences (Debao et al. 2002). In another study, the satellite-launched *Dendrobium nobile* obtained significantly higher alkaloid and polysaccharide contents than the earth-grown plants (Peng and Ye 2017).

Polyploidy is another plant breeding method used in medicinal plant improvement and is reported to increase plant environmental stress tolerance (Zhang et al. 2002; Zhang et al. 2010). In polyploid breeding, it is tried to obtain materials through chromosome doubling to improve varieties to meet customer demands in a certain environment. It leads to obtaining polyploid plants with larger vegetative organs and higher contents of active ingredients than those of typical plants (Niazian and Nalousi 2020). Zhang et al. (2010) observed that tetraploid plants of *Dioscorea zingiberensis* showed lower electrolyte leakage and contents of malondialdehyde, superoxide anions, and hydrogen peroxide and stimulated antioxidant enzyme activities. They concluded that tetraploid plants had a stronger antioxidant defense system and increased heat tolerance. New polyploid varieties of *Citrus limonia* Osb. with higher resistance to water deficit stress have also been bred (Vieira et al. 2016).

DNA marker-assisted breeding has also been considered as a method to improve crops as well as medicinal species. This method of breeding can contribute to the breeding of new varieties with high yield, high quality, and high resistance (Dong et al. 2017). Since traditional breeding methods are time-consuming and a long-term endeavor, molecular marker-assisted breeding can accelerate and facilitate the breeding of medicinal plants; however, a few reports on the marker-assisted breeding of medicinal species have been released. In a study on *Panax notoginseng* (Burkill), DNA marker-assisted selection and systematic breeding led to introduce a new variety with reduced seedling root rot and rust rot (Dong et al. 2017). A new variety with high yield and resistance was also bred in *Perilla frutescens* (L.) Britt. using marker-assisted methods (Shen et al. 2017).

5 Conclusions

Medicinal plants have many benefits for humans, and their cash values are mainly higher than other crops. Nevertheless, less research, development, and progress of breeding programs have been conducted on medicinal plants due to limited knowledge about their genetic background, growth cycle, and heterozygosity. Besides, the diversity and various ecological habitats of medicinal species and the growth of species in a changing environment have made their breeding more complex.

Although many crops have been selected and bred for high yield, adaptability, improved stress resistance, efficiency, and productivity, to date fewer medicinal species have been bred successfully. Crop improvement programs for the fluctuating environment and climatic conditions should carry out toward introducing more resistant varieties to environmental stresses with higher productivity, yield quality, and quantity.

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