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A review of medicinal and aromatic plants and their secondary metabolites status under abiotic stress

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Abstract
In developing countries, aromatic and medicinal plants are still used in traditional and alternative medicines. In India, medicinal plants are used in traditional medicine to cure various ailments. In the past decades, several studies highlighted the therapeutic properties and biological activities of medicinal and aromatic plants (MAPs). These MAPs include *Andrographis paniculata, Artemisia annua, Allium cepa, Allium sativum, Cymbopogon flexuosus, Ferula asafoetida, Foeniculum vulgare, Mentha piperita, Ocimum sanctum, Piper nigrum, Solanum nigrum, Tagetes minuta* and *Trigonella foenum-graecum*. The MAPs contain bioactive secondary metabolites like alkaloids, flavonoids, steroids, terpenes, sesquiterpenes, diterpenes, phenolics and saponins. These secondary metabolites possess antimalarial, anthelminthic, anti-inflammatory, analgesic, antimicrobial, antiartheritic, antioxidant, antidiabetic, antihypertensive, anticancer, antifungal, antispasmodic, cardio protective, ant thyroids and antihistaminic properties. These MAPs are also used in Indian traditional medicine for cure of several diseases like diarrhoea, indigestion, pains, congestion, coughs, sinusitis, fever, flu, sore throats, chills, sickness, rheumatism, sprains and muscular pains. Apart from the pharmaceutical industries, MAPs also have significance in industries related to perfumery, cosmetic, liquor and nutrition. Secondary metabolites play a major role in the adaptation of plants to the changing environment and stress condition. Secondary metabolites in plants are affected by both biotic and abiotic stress. High levels of stress in medicinal and aromatic plants can affect the secondary metabolite production. Abiotic (cold, heat, drought, salinity) stress leads to the production of reactive oxygen species (ROS) in the cellular compartments of plant cell. Here we provide a review of the effect of abiotic stress on secondary metabolites of different medicinal and aromatic plants.

Keywords: Medicinal and Aromatic Plants (MAPs), abiotic stress, secondary metabolites,

Introduction
The natural products which contain a curative capacity use for the treatment of major and minor human disease (Verma and Singh, 2008) [41]. According to World Health Organization (WHO), the majority of the populations in the world chiefly depends on the traditional medicines and herbal drugs for primary health care requirements. In India recently 20,000 medicinal plant spices have been recorded out of these 800 plant spices are phytochemically used for curing disease (Kamboj, 2000) [38]. Development and synthesis of new drugs, medicinal plants play an important role and approximately more than 100 plants based drugs have been introducing in the market and it gives a remarkable contribution to current therapeutics. In Ayurveda, Siddha and Unani medicinal plants are used for the treatment of various ailments and curing for a different disease. In Indian subcontinent medicinal plant is a vast repository and used as a traditional medicine for the treatment of various chronic diseases, a huge amount of polyherbal formulation is used and in recent research suggested that combination therapy give effective response for the treatment of complex disease (Chopra *et al.*, 1956, Pertrovska, 2012) [19, 62]. Regular scientific investigations have highlighted the contribution and importance of the many plant families i.e. Asteraceae, Apocynaceae, Liliaceae, Rutaceae, Caesalpinaceae, Solanaceae, Piperaceae, Ranunculaceae, Apiaceae, Sapotaceae etc. are used as a medicinal plants and their bioactive compounds which is present in the plants should undergo studies and development of new drugs. During 1950-1970 approximately 100 plants based new drugs were introduced in the market and in 1971 to1995, new drugs such as paclitaxel, toptecan, irinotecan, teniposide, ectoposide, guggulsterone,

plaunotol, z-guggulsterone, gomishin, nabilone, lectinan, artemisinin etc. have been developed in all over the world. In plant-based drugs provide a remarkable contribution in modern therapeutics; for example in *Rauwolfia serpentine* plant serpentine compound is isolated from the root, possess a hypertension and blood pressure lowering capacity and in Catharanthus roseus plant Vinblastine is isolated and used for the treatment of Hodgkins, choriocarcinoma and neck cancer (Farnsworth *et al*., 1967) [26]. Many plant species have been reported to carry many active compounds that have significant role in management of various human chronic disease such as cancer, diabetes, cardiovascular disorders and so on. In addition to this, many active compound of the herbal plant combine with the other substance to give an effective response in context to biological properties (Kennedy and Wightman, 2011; Shariff, 2001) [39, 72]. Medicinal plant and their product are used as medicinal supplements all around the world because it contains antiseptic, insecticidal and parasiticidal properties and less or no toxicity and cost effective. Presence of polyphenol compound such as flavonoids and phenol which contained free radical scavenging molecule that are rich in antioxidant activities. Antioxidant work as to neutralize the action or activity of the free radical which cause the tissue injury or damage (Tayyab *et al*., 2016) [79]. Even today, plants are not only indispensable in health care but form the best hope of source for safe future medicines and also the important source of income for poor people, local communities as well as for the herbal dealer and in India, almost 70% of modern medicines are derived from natural products (Shinwari, 2010) [75]. A summary of various MAPs are given in Table 1.

Table 1: Medicinal Plants, their uses and secondary metabolites

Plant	Family	Useful part	Uses	Secondary metabolites	References
Acanthospermum hispidum	Asteraceae	Leaves	Used in cardiovascular disease, cancer, inflammation, allergies. Antimicrobial	Acanthospermol galactoside, flavones, cafeic acid, cis-cis-germacranolides, melampolides, β-caryophyllene.	Edewor *et al*. (2011) [23]
Allium sativum Linn.	Liliaceae	Bulbs	Antiarthritic, digestive, expectorant, febrifuge, stimulant.	S-allyl cysteine sulphoxide (ACSO)	Manoharachary *et al*. (2016) [48]
Allium cepa Linn.	Liliaceae	Bulbs	Antimicrobial, analgesic, antioxidant, anti-inflammatory, antidiabetic, anti-hypertensive	S-trans-prop-1-enyl cysteine sulphoxide (PECSO)	Jones *et al*. (2004) [37] and Teshika *et al*. (2018) [80]
Artemisia annua L.	Asteraceae	Leaves	Antimalarial, anti-inflammatory, anti-cancer	Artemisinin, arteanuin, artemether, arteether, artemetin, casticin, chrysoplenetin, cirsilineol	Weathers *et al*. (2012) [86].
Atropa belladonna L.	Solanaceae	Leaves, fruits	Antispasmodic, mydriatic	Atropine, hyoscyamine, hyoscine	Okigbo *et al*. (2008) [58]
Bacopa monnieri	Scrophulariaceae	Shoot	Antioxidant, anti-inflammatory, antiarthritis, antistress and antiulcergenic	Bacoside	Sharma *et al*. (2015) [73]
Cleome rutidosperma	Cleomaceae	Leaves	Analgesic and Anti-inflammatory	Terpenes, alkaloids, flavonoids,	Abdullah *et al*. (2016) [1], Edeoga *et al* (2005)
Cymbopogon flexuosus	Poaceae	Leaves	Anti-inflammatory, analgesic, anti-fungal	Citral, geranium, geranyl acetate, neral, β-myrcene	Boukhatem *et al*. (2014) [15]
Ferula asafoetida Regel.	Apiaceae	Root gum	Used in cough, jaundice, gastritis and rheumatism. Anthelminthic, antispasmodic, antimicrobial, antiseptic, laxative, diuretic	Ferulic acid esters, free ferulic acid, coumarin derivatives	Moghaddam *et al*. (2015) [54]
Foeniculum vulgare Mill.	Apiaceae	Seed	Diaphoretic, diuretic, carminative, expectorant, febrifuge, stomachic, stimulant, appetizer, cardiac stimulant, vermifuge	Furocoumarins imperatorin, psoralen, bergapten, xanthotoxin, isopimpinellin, quercetin, kaempferol	Nassar *et al*. (2010) [56]
Matricaria chamomilla	Asteraceae	Leaves	Spasmolytic, anti-inflammatory, antibiotic.	Herniarin, umbelliferone	Eliasova *et al*, (2004) [24]
Mentha piperita Linn.	Lamiaceae	Leaves	Carminative, spasmolytic, anti-tumour, anti-diabetes, anti-nociceptive, etc	Hesperidin, rosmarinic acid, didymin, buddleoside, diosmin	Zhao *et al*, (2018) [88]
Ocimum sanctum	Lamiaceae	Leaves, stem, seeds, flower, root	Anticancer, antidiabetic, antifungal, hepatoprotective, cardioprotective, analgesic, antispasmodic	Eugenol, rosmarinic acid, carvacrol, oleanolic acid	Prakash *et al*. (2005) [64]
Papaver somniferum L.	Papaveraceae	Flower, seeds	Analgestic, narcotic	Morphine, thebaine, papaverine, narceine, codeine	Okigbo *et al*. (2008) [58]
Piper nigrum Linn.	Piperaceae	Dried fruits	Anti-inflammatory, antihypertensive, anti-thyroids, hepato-protective, anticonvulscent, appetizer, antihistaminic, counterirritant, antiflatulant	Piperine	Damanhouri *et al*. (2014) [21]
Rosa laevigata	Rosaceae	Roots, Leaves, fruits	Astringent, anticancer, antibacterial, carminative, stomachic	Daucosterol, Euscaphic acid, betulinic acid, rosamutin, tomentic acid, rubuside	Mehboob *et al*. (2017) [49]
Scrophularia	Scrophularia	Roots	Antifungal, antirheumatic,	Aucubin, catalpol, harpagide,	Wang *et al*. (2010) [65].

ningpoensis	ceae		antipyretic, diuretic, febrifuge, antihypertensive, antiarthritic, antimalarial	harpagoside, cinnamic acid	
Solanum nigrum Linn.	Solanaceae	Fruits, leaves, roots	Used in chronic enlargement of liver, cough, skin disease, rheumatism and gout, eye diseases	Solasodine	Bhat *et al*. (2008) [14]
Tagetes minuta L.	Asteraceae	Leaves	Anti-leishmanial, antimalarial, antispasmodic	Quercetin-3-methyl ether, quercetin, axillarin-7-O-β-D-glucopyranoside, quercetin-3,6-dimethyl ether.	Musayeib *et al*. (2014) [55]
Trachyspermum ammi	Apiaceae	Seeds	Anti-spasmodic, antioxidant, antinociceptive, antihypertensive, antilithiasis, diuretic, antitussive, nematicidal	Thymol, para-cymene, α- and β-pinene and γ-terpinene.	Bairwa *et al*. (2012) [11]
Trigonella foenum-graecum Linn.	Fabaceae	Seeds	Aphrodisiac, curminative, astringent, demulscent, suppurative, aperients, diuretic, emollient, anti-inflammatory	Trigonellin, saponins, diosgenin	Mehrafarin *et al*. (2010) [50]
Vitex negundo Linn.	Verbenaceae	Leaves	Anti- arthritic, anodyne, appetizer, cephalic, cardiac, astringent, emmenagogue, demulscent, febrifuge, expectorant	Viridiflorol, β-caryophyllene, sabinene, 4-terpineol, globulol, protocatechuic acid, oleanolic acid, flavonoids	Vishwanathan *et al*, (2010) [84]; Singh *et al*. (1999) [76]; Surveswaran *et al*. (2007) [77]
Withania somnifera	Solanaceae	Roots	Antioxidant, anti-inflammatory, antineoplastic, antiproliferative, antifibrotic, cardiovascular, amnesia, neurodegenerative	Withanine, withananine, somniferine, somnine, withanolides, withaferin A.	Brant *et al*. (2016) [16]; Bharti *et al*. (2016) [12]; Chauhan *et al*. (2015) [18]
Zingiber officinale Rosc.	Zingiberacea e	Rhizomes	Rheumatoid arthritis, dyspepsia, anorexia, nausea, antispasmodic	Gingerols, zingiberene, geranial, geranyl acetate.	Sasidharan *et al*. (2012) [70]

Abiotic stress

Various kinds of abiotic stresses are prospective harmful to the plants like temperature, salinity, drought, flood, radiation, chemical as well as mechanical stresses which affect the concentration of various secondary plant products and reduces the yield of the crops. (Tuteja, 2007) [82]. One of the most significant abiotic stress is drought which affect the growth and development of the plant by reducing the available water level in the soil. (Xu, *et al*., 2010) [44].

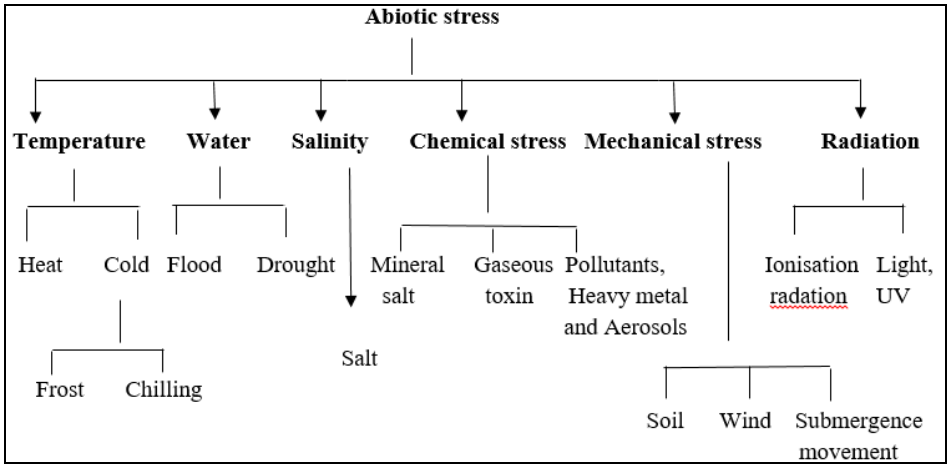

Fig 2: Several abiotic stress signalling affect plants (Akula, *et al*., 2011) [8].

Abiotic stress give a deleterious effect on plants by drastically alter the metabolic activity of the cell by producing the excess quantity of reactive oxygen species (ROS) in plant. In plant Reactive oxygen species play a dual role such as toxic nature as well as work as key regulators for many biological processes like growth, programmed cell death, cell cycle, hormone signaling and cell responses and development (Miller, G., 2008) [51]. In most of the higher plants primary metabolite is responsible for the synthesis of secondary metabolites and the concentrations of various secondary plant products are strongly dependent on the growing conditions. The significant application of secondary metabolite in nutritive, medicinal, food additive, flavor, pharmaceutical and industrially important pharmaceutical. In most of the cases, presence of abiotic stresses the production of secondary metabolite is enhances in the aromatic and medicinally important higher plants, which rise up the phytomedicine production and also promote the essential oil production in aromatic plant (Pradhan, *et al*., 2017) [63]. In this article first of all we give the general information of medicinal important of aromatic and higher plants and the effect of abiotic stress on secondary metabolite of plants.

Cleome rutidosperma belongs to the family cleomaceae. It contains many chemical classes like flavonoid, terpenes, alkaloids etc. Cleome supplement with a diverse array of secondary metabolites like essential oil, alkaloids, terpenoids, flavonoids and phenolics which is used as culinary and therapeutic purpose. *Cleome droserifolia* commonly known as 'Samwa' and traditionally used as hypoglycemic agent (Aboushoer *et al*, 2010) [2]. The *Alliums* are a vast genus

having 700 species, inclusive medicinal value, ornamental flowers and vegetables (Jones *et al*, 2004) [37]. From the last decade, the medicinal values of *Allium sativum* L. (garlic) and *Allium cepa* L. (onion) oils have been studied and review will include the general properties like antifungal, antimicrobial, insecticidal and antibacterial (Fenwick *et al*, 1985) [28]. *A. cepa* traditionally used for its remedial characteristics. It was used as blood purifier in ancient Greece. It having pharmacological characteristics including antioxidant, analgesic, hypolipidemic, anti-diabetic, immunoprotective and hypertensive effects (Teshika *et al*, 2018) [80]. *A. sativum* has been used as a medicinal means from thousand of years. It is a traditional medicinal plant and having beneficial effects like antithrombotic, antiarthritic, hypoglycemic and antitumor activity. A number of organosulpher compounds derived from garlic are garlic oil, aged garlic and fresh garlic extract and it is used to demonstrate the chemopreventive activity of garlic by using these garlic preprations (Thomson *et al*, 2003) [81].

Artemisia annua L. is a native of China, and commonly known as qinghao. Artemisinin, yields from *A. annua* which is a derivative of this compound and potent to antimalarial drug. Artemisinin effective against multidrug-resistant malaria which act on *P. falciparum*, causes cerebral malaria (Mahomoodally *et al*, 2013) [47]. The artemisinin-based compound has enlarged to their anti-cancer properties in their last decade. However, artemisinin is a bioactive compound and traditionally used in the herbal tea, and shows different biological activities which collaborate the effects of artemisinin against malaria and cancer (Ferreira *et al*, 2010) [29]. *Bacopa monnieri* L. commonly known as 'Brahmi', an annual creeping herb, mainly used to increase the memory and learning power. Medicinally, used in depression, epilepsy, stress, insomnia, insanity, also used in the treatment of tumors and leprosy (Pareek *et al*, 2014) [60]. *B. monnieri* also having the property of anti-inflammatory, sedative, antipyretic, analgesic, antistress (Kishore *et al*, 2005 and Russo *et al*, 2005) [69].

Cymbopogon flexuosus is an aromatic and medicinal plant and used as traditional medicine in developing countries, also used for the treatment of bacterial and fungal infection in Algeria. Essential oil of lemongrass is used as anti-rheumatic, anti-tussive and also treat back ache, sprains in different countries (Boukhatem *et al*, 2014) [15]. Citral is a main component of lemongrass essential oil (LEO) which is used for anti-inflammatory effect in both human and animals (Han *et al*, 2017) [17]. Cytotoxic and antimicrobial effect of lemongrass was tested on human dermal fibroblast with the help of disk diffusion method (Adukwu *et al*, 2016) [3].

Mentha arvensis L. is an perennial herb, commonly known as mint, found in China, Siberia, Koria (Lim *et al*, 2012) [46]. Commonly used as flavouring agents in chewing gums, cosmetics, tobacco, candies, drinks (Khadraoui *et al*, 2014). It was studied that Menthae Herba used as traditional medicine like fever, cold, cough, indigestion, asthma and influenza, also used in facial lotions and toothpaste (Mkaddem *et al*, 2009). Recently it was investigated that Menthae Herba contains various medicinal uses like anti-tumour, anti-inflammatory, anti-diabetes, anti-nociceptive activity etc. (Qian and Wang 2010, Lim *et al*. 2012, Sharma *et al*. 2017, Zhao *et al*. 2017) [49, 46, 17].

Scrophularia ningpoensis is a medicinal plant, commonly known as Ningpo figwort and Chinese figwort. Oleic acid, palmitic acid, caffeic acid, flavonoids, harpagoside, phytosterol, rhamnose, cinnamic acid, catalpol, harpagide, saponins, ursolic acid and volatile oil are found as effective nutrients in *S. Ningpoensis*, in which aucubin, harpagoside, cinnamic acid contains main medicinal value (Tasdemir *et al*. 2008, Jeong *et al*. 2008 and Li *et al*. 2000) [78]. *Tagetes minuta*, belongs to the family Asteracea. *Tagetes* genus consist of 30 species approximately, it is native to central and southern part of America. It is used as condiments, beverages, medicinal decoction and ornamentals. Its oil is used to flavour the food products like pudding, candy, condiments, etc (Musayeib *et al*, 2014) [55]. Main components present in the essential oil of this plant is (Z)-β-ocimene and dihydrotageton which is used as antibacterial activity against the test bacteria. Essential oil also contains limonene and epoxyocimene, having the properties of antimicrobial, antioxidant and cytotoxic acivity. Among the bioactivities and therapeutic properties it includes germicides, stomachic, antispasmodic, diaphoretic, antiseptic, sedative, repellancy, antihelminthic, bactericidal etc (Gakuubi *et al*, 2016) [30].

Trigonella foenum-graecum L. is an aromatic plant, genus includes 260 species approximately under diffused worldwide, belonging to the family fabaceae (Chaudhary *et al*, 2018) [17]. It is a medicinal herb and also used as spices, and cultivated throughout the world. It is rich in secondary metabolites that's why it is known traditionally for therapeutic and medicinal value (Baatour *et al*, 2010) [17]. Sterols, coumarins, essential oils, flavonoids (Ivanov *et al*. 1979, Kwon *et al*. 2002, Ozbek *et al*. 2003, Parejo *et al*. 2004) [35, 59,61] chemicals are present in the *Foeniculum* species. Certain medicinal activities have been ascribed to some species of *Foeniculum* like antimicrobial and antioxidant activities from the aerial parts (Ruberto *et al*, 2000) [68], analgesic and anti-inflammatory activities from the fruits of the *F. vulgare* Mill. (Eun and Jae, 2004) [25].

Vitex negundo L. is an aromatic shrub, hardy growing to small tree. It is commercially grown as a crop plant in North America, Asia, West Indies. All parts of the plant like leaves, root, seeds, fruits possess phytochemicals or secondary metabolites which helps in making synthetic drugs and artificial medicines. This plant is also used as traditional medicine. (Vishwanathan *et al*, 2010) [84]. *Zingiber officinale* Roscoe used as medicinal purposes and has been used in nausea and vomiting, and can be nutritionally used for cooking (Hanway *et al*, 2018) [34]. It is an aromatic herb and mostly distributed in tropical Australia and East Asia and a traditional medicine in India used for arthritis, rheumatism, congestion, coughs, diarrhoea, sinusitis, sore throats, sickness (Badreldin *et al*, 2008, Sasidharan *et al*., 2012) [10, 70].

Status of MAPs under abiotic stress

Salinity stress known to cause oxidative stress and leads to produce reactive oxygen species. *Artemisia annua* L. under salinity stress causes negative effect on growth of the plants (root, shoot length and dry weight). Total chlorophyll content and photosynthetic parameters are reduced under salinity stress. It significantly increases the electrolyte leakage and proline content. Different treatments of sodium chloride (NaCl) 0, 50, 100, 150 and 200 mM to the soil and the activities of antioxidant enzymes like catalase (CAT), peroxidase (POX) and superoxide dismutase (SOD) were significantly increases (Aftab *et al*, 2010) [4]. Antioxidant enzyme activity and proline activity significantly increases under different concentrations of salt stress and promoted the inhibitory effect on growth and photosynthetic activity. Uptake of different chemical elements like Na^+, Mg^{2+} and K^+ but inhibiting the absorption of Ca^{2+} (Li *et al*, 2014) [44].

Coban *et al*. 2016 studied that the salinity stress shows

inhibition in growth, biochemical properties, development and secondary metabolite deposition in peppermint (*Mentha piperita* L.). Various concentration of NaCl (0, 100 and 150mM) causes decrease in fresh and dry weights of shoot and dry leaf weight decreases with the elevating level of salt. 150mM NaCl shows negative effect on plant that they died on this concentration. Antioxidant enzyme activity, lipid peroxidation and proline content increases significantly and essential oil content decreases as salinity increases. *Matricaria chamomilla* were studied under abiotic stress, in aqueous solution of $CuCl_2$ secondary metabolites has been evaluated and ene-yne-dicycloether concentration in leaves decreased by 40% (Eliasova *et al*, 2004) [24]. *M. chamomilla* cultivated in different concentrations of copper (3, 60 and 120µM) for 10 days. Dry mass production, chlorophyll, water and nitrogen content significantly decreases at 120µM of Cu in both the leaf rosettes

Ocimum tenuiflorum has been studied for its secondary metabolites and genome information. Under abiotic stress like cold, drought, flood and salinity stress, it shows different modifications. *O. tenuiflorum* was more defenceless against cold stress among cold, drought, flood and salinity stresses. It directly affects the secondary metabolites of the plant under severe treatments of all these abiotic stresses. It decreases the eugenol content which is the main secondary metabolite of the plant (Rastogi *et al*, 2019) [66]. In earthen pots, flood treatment was given to plants by regularly maintaining the water level 0.5 inches above the soil (Barnawal *et al*, 2012) [12]. *Scrophularia ningpoensis* Hemsl under drought stress different medicinal components were studied like harpagide, aucubin, catalpol, harpagoside and cinnamic acid. Three levels of osmotic stress for 10 days on *S. ningpoensis* at seedling stage were investigated and the content of components were detected by HPLC analysis. Therefore, the four iridoids glycosides content in roots were higher under osmotic stress than the no osmotic stress, although cinnamic acid decreased (Wang *et al*, 2010) [65].

Solanum nigrum L. under salinity stress enhanced the production of solasodine content which is a steroidal alkaloid. Solasodine is alternative to diosgenin, used as progenitor for the commercial production of steroidal drug. Various treatments (0-150mM NaCl) was given on *Solanum nigrum* on various *in vitro* grown tissues like regenerative callus, non-regenerative callus and microshoot derived leaves. In different concentrations of NaCl during *in vitro* production of solasodine, the role of plant growth regulators was studied and concluded that the *in vitro* yield was compared with the field grown plants and the solasodine content was maximum in regenerative callus on the 150mM NaCl grown medium (Bhat *et al*, 2008) [14].

Trigonella foenum graecum L. under salinity stress with different concentrations of NaCl (0, 50, 100, 150 and 200mM). Salinity causes disturbance in the mineral nutrition and affect the growth, phenolic content, antioxidant properties and physiological activities of the plants. (Baatour *et al*, 2010) [9]. *Foeniculum vulgare* Mill. shows inhibitory responses in the fresh and dry weights and reduces the chlorophyll a, b and β-carotene content of the seedling, under the effect of salt with different concentrations (25, 50 and 75mM NaCl), Nitrogen deficiency (0N and 0.5N of Hoagland's solution), Iron deficiency (0Fe and 0.5Fe of Hoagland's solution), 2℃ cold (2, 3 and 4 hrs) and drought (3, 5 and 7 days). Antioxidant activities significantly increases under all the stresses except 5 to 7 days of drought (Nourimand *et al*, 2012) [57].

Zingiber officinale Roscoe such as ginger, under chilling stress it may characteristically exhibits structural injuries and suffer from metabolic decomposition when they are exposed to chilling stress. Enzymatic activities and photochemical activities were inhibited due to chilling stress and produces reactive oxygen species like superoxide, hydroxyl radicals and hydrogen peroxide leads to cause serious oxidative damage (Li *et al*, 2014) [44].

Conclusion

There has been tremendous increase in the consumption and demand for medicinal plants in last decade. Scientific research on MAPs, is opening new horizons in the potential of medicines and other natural products. Although, only 20% of the plant flora has been studied and around 60% of synthetic medicines are originated from plants. The essential oil, flavours, fragrances of aromatic plants at industrial level contribute to economy of developing countries by export earnings and import substitution. Chemotherapeutic agents play a significant role in general and management of human clinical conditions. Many cancer, diabetic, tumour, thyroid, malarial chemotherapeutic agents extracted from plant sources and have been produced in large quantities by using plant hormones which are grow in abiotic stress condition.

References

1. Abdullah W, Elsayed WM, Abdelshafeek KA, Nazif NM, Singab ANB. Chemical constituents and biological activities and cleome genus: A brief review. International Journal of Pharmacognosy and Phytochemical Research. 2016; 8(5):777-787.
2. Aboushoer MI, Fathy HM, Abdel-Kader MS, Goetz G, Omar AA. Terpenes and flavonoids from an Egyptian collection of *Cleome droserifolia*. Natural Product Research. 2010; 24(7):687-696.
3. Adukwu EC, Bowles M, Jones VE, Bone H. Antimicrobial activity, cytotoxicity and chemical analysis of lemongrass essential oil (*Cymbopogon flexuosus*) and pure citral. Applied Microbiology and Biotechnology. 2016; 100(22):9619-9627.
4. Aftab T, Khan MMA, Idrees M, Naeem M, Hashmi N Moinuddin. Effect of salt stress on growth, membrane damage, antioxidant metabolism and artemisinin accumulation in *Artemisia annua* L. Plant Stress. 2010; 4(1):36-43.
5. Aftab T, Khan MMA, Silva JATD, Idrees M, Naeem M, Moinuddin. Role of salicylic acid in promoting salt stress tolerance and enhanced artemisinin production in *Artemisia annua* L. J Plant Growth Regul. 2011; 30:425-435.
6. Ahmad I, Ahmad MSA, Ashraf M, Hussain M, Ashraf MY. Seasonal Variation in Some Medicinal and Biochemical Ingredients in *Mentha longifolia* (L.) Huds Pak J Bot. 2011; 43:69-77.
7. Ajasa AMO, Bello MO, Ibrahim AO, Ogunwande IA, Olawore NO. Heavy trace metals and micronutrients status in herbal plants of Nigeria. Food Chemistry. 2004; 85(1):67-71.
8. Akula R, Ravishankar GA. Influence of abiotic stress signals on secondary metabolites in plants. Plant signaling & behavior. 2011; 6(11):1720-1731.
9. Baatour OLFA, Zaghdoudi MAHA, Bensalem NADA, Ouerghi AZ. Effects of NaCl on plant growth and antioxidant activities in fenugreek (*Trigonella foenum graecum* L.). Bio Sci. J. 2010; 34(3):683-696.

10. Badreldin HA, Gerald B, Musbah OT, Abderrahim N. Some phytochemical, pharmacological and toxicological properties of ginger (*Zingiber officinale* Roscoe): a review of recent research. Food and Chemical Toxicology. 2008; 46:409-420.
11. Bairwa R, Sodha RS, Rajawat BS. *Trachyspermum ammi*. Pharmacognosy Review. 2012; 6(11):56-60.
12. Barnawal D, Bharti N, Maji D, Chanotiya CS, Kaira A. 1-Aminocyclopropane-1-carboxylic acid (ACC) deaminase-containing rhizobacteria protect *Ocimum sanctum* plants during waterlogging stress via reduced ethylene generation. Plant Physiol Biochem. 2012; 58:227-235.
13. Bharti VK, Malik JK, Gupta RC. Chapter 52 – Ashwagandha: Multiple health benefits. Nutraceuticals Efficacy, Safety and Toxicity, 2016, 717-733.
14. Bhat MAMA, Ahmad S, Aslam J, Mujib A, Mahmooduzzfar. Salinity stress enhances production of solasodine in *Solanum nigrum* L. Chemical and Pharmaceutical Bulletin. 2008; 56(1):17-21.
15. Boukhatem MN, Ferhat MA, Kameli A, Saidi F, Kebir HT. Lemon grass (*Cymbopogon citratus*) essential oil as a potent anti-inflammatory and antifungal drugs. Libyan Journal of Medicine. 2014; 9(1):25431.
16. Brant SMG. Chapter 7 – Nutraceuticals in hepatic diseases. Nutraceuticals Efficacy, Safety and Toxicity, 2016, 87-99.
17. Chaudhary S, Chaudhary PS, Chikara SK, Sharma MC, Marcello IRITI. Review on fenugreek (*Trigonella foenum-graecum* L.) and its important secondary metabolite diosgenin. Not Bot Horti Agrobo. 2018; 46(1):22-31.
18. Chauhan NB, Mehla J. Chapter 27 – Ameliorative effects of nutraceuticals in neurological disorders. Bioactive Nutraceuticals and Dietary Supplements in Neurological and Brain Disease, 2015, 245-260.
19. Chopra RN, Nayar SL, Chopra IC. In glossary of Indian medicinal plants, Vol. I. Council of Scientific and Industrial Research, New Delhi, 1956.
20. Coban O, Baydar NG. Brassinosteroid effect on some physical and biochemical properties and secondary metabolite accumulation in peppermint (*Mentha piperita* L.) under salt stress. Industrial Crops and Products, 2016; 86:251-258.
21. Damanhouri ZA, Ahmad A. A review on therapeutic potential of *Piper nigrum* L. (Black pepper): The king of spices. Medicinal and Aromatic Plants. 2014; 3:161.
22. Edeoga HO, Okwu DE, Mbaebie BO. Phytochemical constituents of some Nigerian medicinal plants. Afr J Biotechnol. 2005; 4(7):685-688.
23. Edewor TI, Olajire AA. The flavones from *Acanthospermum hispidum* DC and their antibacterial activity. International Journal of Organic Chemistry. 2011; 1:132-141.
24. Eliasova A, Repcak M, Pastirova A. Quantitative changes of secondary metabolites of Matricaria chamomilla by abiotic stress. Zeitschrift fur Naturforschung C. 2004; 59(7-8):543-548.
25. Eun MC, Jae KH. Anti-inflammatory, analgesic and antioxidant activities of the fruit of *Foeniculum vulgare.* Fitoterapia. 2004; 75:557-565.
26. Farnsworth NR, Blowster RN, Darmratoski D, Meer WA, Cammarato LV. Studies on Catharanthus alkaloids IV. Evaluation by means of TLC and cericammonium sulphate spray reagent. Lloydia. 1967; 27:302-314.
27. Farombi EO. African indigenous plants with chemotherapeutic potentials and biotechnological approach to the production of bioactive prophylatic agents. Afr. J. Biotechnol. 2003; 2(12):662-671.
28. Fenwick GR, Hanley AB, Whitaker JR. The genus allium-part. Journal of Critical Reviews in Food Science and Nutrition. 1985; 22(3):199-271.
29. Ferreira JFS, Luthria DL, Sasaki T, Heyerick A. Flavonoids from *Artemisia annua* L. as antioxidants and their potential synergism with artemisinin against malaria and cancer. Molecules. 2010; 15:3135-3170.
30. Gakuubi MM, Wanzala W, Wagacha JM, Dossaji SF. Bioactive properties of *Tagetes minuta* L. (Asteraceae) essential oil: A review. American Journal of Essential Oils and Natural Products. 2016; 4(2):27-36.
31. Gopalakrishnakone P, Samy Perumal R. Current status of herbal and their future perspectives Nature Precedings. 2007; 1176:1.
32. Hamburger M, Hostettmann K. Bioactivity in plants: the link between phytochemistry and medicine. Phytochemistry. 1991; 30:3864-3874.
33. Han X, Parker TL. Lemongrass (*Cymbopogon flexuosus*) essential oil demonstrated anti-inflammatory effect in pre-inflamed human dermal fibroblasts. Biochimie Open. 2017; 4:107-111.
34. Hanway PJMD. Chapter 41 - Irritable bowel syndrome. Integrative Medicine (Fourth Edition), 2018, 423-432.
35. Ivanov S, Seher A, Schiller H. Natural antioxidants. IV: Antioxidants in the fatty oil of *Foeniculum vulgare* Mill. 2. Fette, Seifen, Anstrichm. 1979; 81:105-107.
36. Jeong EJ, Lee KY, Kim SH, Sung SH, Kim YC. Cognitive-enhancing and antioxidant activities of iridoid glycosides from *Scrophularia buergeriana* in scopolamine-treated mice. Eur. J. Pharmacol. 2008; 588:78-84.
37. Jones MG, Hughes J, Tregova A, Milne J, Tomsett AB, Collin HA. Biosynthesis of the flavour precursors of onion and garlic. Journal of Experimental Botany. 2004; 55(404):1903-1918.
38. Kamboj VP. Herbal medicine. Cur. Sc. 2000; 78(1):35-39.
39. Kennedy DO, Wightman EL. Herbal extracts and phytochemicals: plant secondary metabolites and the enhancement of human brain function. Advances in Nutrition. 2011; 2(1):32-50.
40. Khadraoui A, Khelifa A, Boutoumi H, Hammouti B. *Mentha pulegium* extract as a natural product for the inhibition of corrosion. Part I: electrochemical studies. Nat Prod Res. 2014; 28:1206-1209.
41. Kishore K, Singh M. Effect of bacosides, an alcoholic extract of *Bacopa monnieri* Linn. (Brahmi), on experimental amnesia in mice. Indian J Exp. Biol. 2005; 43:640-645.
42. Kwon YS, Choi WG, Kim WJ, Kim WK, Kim MJ, Kang WH. Antimicrobial constituents of *Foeniculum vulgare*. Archives of Pharmacol Research. 2002; 25:154-157.
43. Li L, Zhang H, Zhang L, Zhou Y, Yang R, Ding C, *et al*. The physiological response of *Artemisia annua* L. to salt stress and salicylic acid treatment. Physiology and Molecular Biology of Plants. 2014; 20(2):161-169.
44. Li X, Gong B, Xu K. Interaction of nitric oxide and polyamines involves antioxidants and physiological strategies against chilling-induced oxidative damage in *Zingiber officinale* Roscoe. Scientia Horticulturae. 2014; 170:237-248.

45. Li YM, Jiang SH, Gao WY, Zhu DY. Phenylpropanoid glycosides from *Scrophularia ningpoensis*. Phytochemistry. 2000; 54:923-925.
46. Lim HS, Kim JH, Ha HK, Seo CS, Shin HK. Comparative study of the anti-inflammatory effects of Menthae Herba from Korea and China. Korean J Pharmacogn. 2012; 43:231-238.
47. Mahomoodally MF, Fakim AG. Chapter 15- Harnessing traditional knowledge to treat existing and emerging infectious diseases in Africa. Fighting Multidrug Resistance with Herbal Extracts, Essential oils and their components, 2013, 223-235.
48. Manoharachary C, Nagaraju D. Medicinal plants for human health and welfare. Annals of Phytomedicine. 2016; 5(1):24-34.
49. Mehboob H, Iqbal M, Ejaz M, Bibi G, Sarwar U, Iftikhar S, *et al*. A review on secondary metabolites of *Rosa laevigata* Michaux: An important medicinal plant. Biochemistry and Analytical Biochemistry. 2017; 6:326.
50. Mehrafarin A, Qadri A, Rezazadeh S, Badi HN, Noormohammadi G, Zand E. Bioengineering of important secondary metabolites and metabolic pathways in fenugreek (*Trigonella foenum-graecum* L). Journal of Medicinal Plants. 2010; 3(35):1-18.
51. Miller G, Shulaev V, Mittler R. Reactive oxygen signalling and abiotic stress. Physiologia plantarum. 2008; 133(3):481-489.
52. Mitchell SA, Ahmad MH. A Review of Medicinal Plant Research at the University of the West Indies, Jamaica, 1948–2001. West Indian Med J. 2006; 55(4):243.
53. Mkaddem M, Bouajila J, Ennajar M, Lebrihi A, Mathieu F, Romdhane M. Chemical composition and antimicrobial and antioxidant activities of *Mentha* (*longifolia* L. and *viridis*) essential oils. J Food Sci. 2009; 74:358-363.
54. Moghaddam M, Farhadi N. Influence of environmental and genetic factors on resin yield, essential oil content and chemical composition of *Ferula assa-foetida* L. populations. Journal of Applied Research on Medicinal and Aromatic Plants. 2015; 2(3):69-76.
55. Musayeib NMA, Mohamed GA, Ibrahim SRM, Ross SA. New thiophene and flavonoid from *Tagetes minuta* leaves growing in Saudi Arabia. Molecules. 2014; 19(3):2819-2828.
56. Nassar MI, Aboutabl ESA, Makled YA, El-Khrisy EDA, Osman AF. Secondary metabolites and pharmacology of *Foeniculum vulgare* Mill. Subsp. Piperitum. Rev. Latinoamer. Quim. 2010; 38:2.
57. Nourimand M, Mohsenzadeh S, Silva JATD, Physiological responses of fennel seedling to four environmental stresses. Iranian Journal of Science and Technology 2012; 36(1):37-46.
58. Okigbo RN, Eme UE, Ogbogu S. Biodiversity and conservation of medicinal and aromatic plants in Africa. Biotechnology and Molecular Biology. 2008; 3(6):127-134.
59. Ozbek H, Ugras S, Duglar H, Bayram T, Ozturk G, Ozturk A. Hepatoprotective effect of *Foeniculum vulgare* essential oil. Fitoterapia. 2003; 74:317-319.
60. Pareek A. Kumar A. Bioprospecting and genetic transformation of *Bacopa monnieri* L. the source of traditional Indian ayurvedic medicine: A review. Journal of Pharmaceutical and Scientific Innovation. 2014; 3(6):504-506.
61. Parejo I, Viladomat F, Bastida J, Codina C. Development and validation of a high performance liquid chromatographic method for the analysis of antioxidative phenolic compounds in fennel using a narrow pore reversed phase C_{18} column. Anal Chem Acta. 2004; 519:271-280.
62. Pertrovska BB. Historical review of medicinal plants' usage, Pharmacogn. Rev. 2012; 6(11):1-15.
63. Pradhan J, Sahoo SK, Lalotra S, Sarma RS. Positive impact of abiotic stress on medicinal and aromatic plants. International Journal of Plant Sciences (Muzaffarnagar), 12(2):309-313.
64. Prakash P, Gupta N. Therapeutic uses of *Ocimum sanctum* Linn (Tulsi) with a note on eugenol and its pharmacological actions: a short review. Indian J Physiol Pharmacol. 2005; 49(2):125-131.
65. Qian JZ, Wang BC. New research progress in pharmacological activities of hesperidin. Nat Prod Res Dev. 2010; 22:176-180.
66. Rastogi S, Shah S, Kumar R, Vashisth D, Akhtar MD, Kumar A, *Ocimum* metabolomics in response to abiotic stresses: Cold, flood, drought and salinity. PLOS ONE. 2019; 14(2):0210903.
67. Roja G, Rao PS. Anticancer compounds from tissue cultures of medicinal plant. Journal Herbs Spices Med. Plants. 2000; 7:71-102.
68. Ruberto G, Baratta MT, Deans SG, Dorman HJD. Antioxidant and antimicrobial activity of Foeniculum activity and *Crithmum maritimum* essential oils. Planta Medica. 2000; 66:687-693.
69. Russo A, Borrelli F. *Bacopa monnieri*, a reputed nootropic plant: an overview. Phytomedicine 12:305-317.
70. Sasidharan I, Venugopal VV and Menon AN. Essential oil composition of two unique ginger (*Zingiber officinale* Roscoe) cultivars from Sikkim. Natural Product Research. 2012; 26(19):1759-1764.
71. Sewell RDE, Kopaei MR. The history and ups and downs of herbal medicines usage. J Herb Med Pharmacol. 2014; 3(1):1-3.
72. Shariff ZU. Modern herbal therapy for common ailments. Nature Pharmacy Series, Vol.1, Spectrum Books Ltd, U.K. 2001.
73. Sharma M, Ahuja A, Gupta R, Mallubhotla S. Enhanced bacoside production in shoot cultures of *Bacopa monnieri* under the influence of abiotic elicitors. Natural Product Research. 2015; 29(8):745-749.
74. Sharma S, Rasal VP, Patil PA, Joshi RK. *Mentha arvensis* essential oil suppressed airway changes induced by histamine and ovalbumin in experimental animals. Nat Prod Res. 2017; 32(4):468-472.
75. Shinwari ZK. Medicinal plants research in Pakistan. Journal of medicinal plants research. 2010; 4(3):161-176.
76. Singh V, Dayal R, Bartley J. Volatile constituents of *Vitex negundo* leaves. Planta Medica. 1999; 65:580.
77. Surveswaran S, Cai Y, Corke H, Sun M. Systematic evaluation of natural phenolic antioxidants from 133 Indian medicinal plants. Food Chemistry. 2007; 102:938-953.
78. Tasdemir D, Brun R, Franzblau SG, Sezgin Y, Clls I. Evaluation of antiprotozoal and antimycobacterial activities of the resin glycosides and the other metabolites of *Scrophularia cryptophila*. Phytomedicine. 2008; 15:209-215.
79. Tayyab F, Lal SS. Comparative study on supplementation effect of *Momordica charantia* Linn. and *Emblica officinalis* Gaertn. On lipid profile of type II diabetic

patients in Allahabad, Uttar Pradesh, India. Annals of Phytomedicine-An International Journal. 2016; 5(1):40-42.
80. Teshika JD, Zakariyyah AM, Zaynab T, Zengin G, Rengasamy KRR, Pandian SK, *et al*. Traditional modern uses of onion bulb (*Allium cepa* L.): a systematic review. Critical Reviews in Food Science and Nutrition, 2018; DOI: 10.1080/10408398.2018.1449074.
81. Thomson M, Ali M. Garlic (*Allium sativum*): A review of its potential use as an anti-cancer agent. Current Cancer Drug Targets. 2003; 3(1):67-81.
82. Tuteja N, Abscisic acid and abiotic stress signaling. Plant signaling & behavior. 2007; 2(3):135-138.
83. Verma, Sheetal, Singh SP. Current and future status of herbal medicines. Veterinary World, 2008; 1(11):347-350.
84. Vishwanathan AS, Basavaraju R. A review on *Vitex negundo* L A medicinally important plant. EJBS. 2010; 3(1):30-42.
85. Wang DH, Du F, Liu HY, Liang ZS. Drought stress increases iridoid glycosides biosynthesis in the roots of *Scrophularia ningpoensis* seedlings. Journal of Medicinal Plants Research. 2010; 4(24):2691-2699.
86. Weathers PJ, Towler MJ. The flavonoids casticin and artemetin are poorly extracted and are unstable in an *Artemisia annua* tea infusion. Planta Med. 2012; 78(10):1024-1026.
87. Xu Z, Zhou G, Shimizu H. Plant responses to drought and rewatering. Plant signaling and behavior. 2010; 5(6):649-654.
88. Zhao BT, Kim TI, Kim YH, Kang JS, Min BS, Son JK, *et al*. A comparative study of *Mentha arvensis* L. and *Mentha haplocalyx* Briq. by HPLC. Natural Product Research. 2018; 32(2):239-242.