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Current Advances in Medicinal Plants, Plant Physiology, Eco-Agricultural Sciences and Modern Applications for Coping the Plant Stresses

Muhammad Wasim Qasim[1*], Mukhtar Hassan[2], Aleeza Rafique[3], Muafia Baigum[4], Zunaira Naeem[3], Muhammad Rashid[5], Saleha Ashfaq[5], Tahira Akram[6], Muhammad Sajjad[3]

[1]Department of Botany, Paras Community College, University of Agriculture Faisalabad, Pakistan
[2]Department of Botany, University of Poonch Rawalakot Azad Kashmir, Pakistan
[3]Department of Botany, University of Agriculture Faisalabad, Pakistan
[4]Department of Biochemistry, University of Agriculture Faisalabad, Pakistan
[5]Department of Biology, University of Haripur, Pakistan
[6]Department of Botany, Government College University, Faisalabad, Pakistan

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***Corresponding author:** Muhammad Wasim Qasim
Department of Botany, Paras Community College, University of Agriculture Faisalabad, Pakistan

Abstract

Natural products are valuable source of pharmacological substances, and traditional herbal medicine is the source of many modern drugs used in pharmacotherapy. Many plant species belonging to the Asteraceae and Lamiaceae families are used as medicines for various ailments. The Satureja species has analgesic, antibacterial, antiviral, antioxidant, antiproliferative, anti-inflammatory, and vasodilatory qualities. Many kinds of modern drugs, such as aspirin, are derived indirectly from medicinal herbs. Many food crops have medicinal qualities, such as garlic. Among the many naturally occurring phenolic compounds found in herbal plants is ferulic acid (FA). The most harmful environmental stress that is thought to reduce agricultural productivity more than any other is drought. Drought stress, for example, inhibits plant growth because water is necessary for cell turgor, which is the force that a confined liquid applies to cell walls to induce cells to enlarge. All stages of a plant's life cycle, including seed germination, seedling development, vegetative growth, and blooming, are significantly impacted by salinity. Energy transfers, plant maturity, fruiting, and seed formation are all significantly influenced by phosphorus.

Keywords: Natural products, pharmacotherapy, ailments, antiproliferative, anti-inflammatory.

INTRODUCTION

The earliest kind of medication is made from medicinal plants, which have been used in traditional medicine in many countries for thousands of years. Human communities have collectively acquired empirical knowledge about their beneficial effects over many generations [1]. Natural products are a valuable source of pharmacological substances, and traditional herbal medicine is the source of many modern drugs used in pharmacotherapy [2]. Many plant species belonging to the Asteraceae and Lamiaceae families are used as medicines for various ailments. The Satureja species has analgesic, antibacterial, antiviral, antioxidant, antiproliferative, vasodilatory qualities. Crassocephalum crepidioides. Conversely, S. Moore was utilised to treat epilepsy, hepatotoxicity, indigestion, tumours, and sleeping sickness. Both the plant families Asteraceae and Lamiaceae offer methods for treating cardiovascular disease, despite differences in their historical significance and botanical characteristics. Due to their potent diuretic properties, the seeds of *Gundelia tournefortti* L. (Asteraceae) are frequently used to make pickles. Asteraceae plant *Achillea millefolium* L. has also demonstrated diuretic effects in a group of hypertensive adults. It is commonly found across Brazil and is widely utilised in traditional, particularly for renal and heart diseases. It sped up erythropoiesis of erythrocytes, decreased viscosity of whole blood, and enhanced peripheral circulation [3, 4].

People have been searching for drugs to treat various ailments and reduce pain for as long as they can remember. The therapeutic qualities of certain medicinal plants were discovered, recorded, and passed down to succeeding generations in every age, every century since the emergence of humans and sophisticated civilizations [5, 6]. The advantages of one civilization were transferred to another, which improved the previous qualities and found new ones up to the present. Today's sophisticated and advanced methods of processing and using medicinal herbs are a result of people's ongoing and unwavering interest in them. Numerous rituals and faiths demonstrate the importance of medicinal plants in the development of human civilization. Many kinds of modern drugs, such as aspirin, are derived indirectly from medicinal herbs. Many food crops have medicinal qualities, such as garlic. Studying medicinal plants has two advantages; it helps in understand plant toxicity and protects people and animals from naturally occurring poisons [7, 8].

Plants produce secondary metabolites, which are beneficial. This explains the recent spike in interest in the study of natural product chemistry. Potential driving forces behind this interest include the need for new treatments, the striking variety of chemical structures and biological activities found in naturally occurring secondary metabolites, the potential utility of novel bioactive natural compounds as biochemical probes, the development of sensitive and novel methods for identifying naturally occurring biologically active compounds, improvements in supplying complex natural products, and enhanced methods for isolating, purifying, and structurally characterising these active constituents [7, 8].

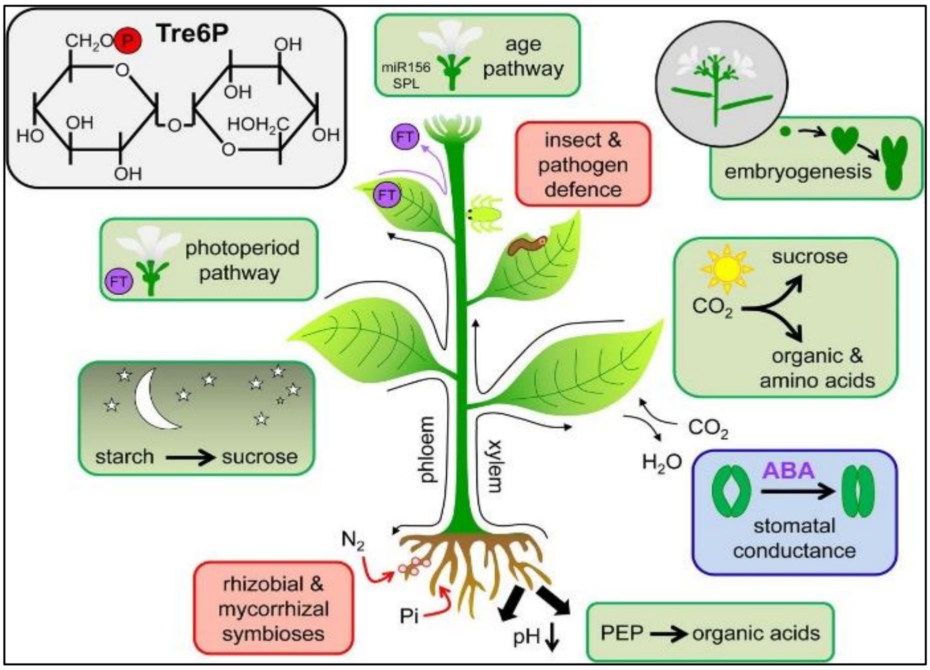

Fig-1: Different compounds and their occurrence in plants with their mechanism

Advances in medicinal plants and plant physiology

Among the many naturally occurring phenolic compounds found in herbal plants is ferulic acid (FA). Numerous medical benefits, including anti-inflammatory, antioxidant, anti-cancer, and antidiabetic effects, have been demonstrated for FA. Fascinatingly, it exhibits a broad spectrum of antibacterial actions against all pathogens and contains both prooxidant and antioxidant qualities. FA reduces oxidative stress and testicular damage while shielding the male genital system from arsenic-induced toxicity. By regulating the expression of the Nfe2l2, Ppargc1a genes, it also enhanced the quality of the sperm [9–12].

The rhizome of the turmeric plant is the primary source of curcumin, a noteworthy bioactive polyphenolic chemical (*Curcuma longa*). Its anti-inflammatory, anti-oxidant, and anti-cancer qualities have long been recognized. In animal models, curcumin has been demonstrated to prevent multiple sclerosis, ischemic stroke, depression, Alzheimer's disease (AD), and other serious disorders. Curcumin has been linked in several studies to a lower risk of stomach cancer. The chemical composition and biological activity of the essential oils extracted from *Thymus vulgaris* were assessed at four different phases of the biological process. The inhibitory effects of the thyme volatile oils on six gram-positive and nine gram-negative bacterial strains were investigated [13, 14]. The antibacterial activity of the essential oils was determined using the bio-impedance approach, and the detection time the metric used to describe and measure the antibacterial activity of the thyme oils. In a laboratory setting, the insecticidal efficacy of thyme volatile oil, thymol, and carvacrol to assessed against distinct larval stages of lesser meal worms. One or two acetone solutions of the investigated compounds fed to the earlier and later larval stages throughout their upbringing [15, 16].

The insecticidal efficacy of thyme volatile oil and pure monoterpenes against larvae dependent on their dose and age. The development of younger larvae is greatly influenced, although the growth of older larvae is mostly regulated by pure oil components. When 1% thyme oil, thymol, and carvacrol is applied to immature larvae, the corresponding mortality rates were 50.0%, 86.67%, and 85%. The plate counting method is used to examine the inhibitory effect of direct exposure. All the thyme essential oils that is assessed shown a significant amount of bacterial static activity against the identified microbes. Its behavior is also described as hostile towards gram-positive bacteria. The most successful oil at inhibiting the development of the microorganism type under investigation was extracted from thyme flowers. The investigated oils also demonstrated to have intelligent antibacterial action by direct contact, which appeared to be more potent against gram-negative bacteria. While the majority of the strains is found to have been nearly entirely inactivated, a few species were able to restore at least 50% of their metabolic activity upon contact with the inhibitor [13, 14].

The most harmful environmental stress that is thought to reduce agricultural productivity more than any other is drought. A persistent decrease in precipitation and an increase in the demand for evapotranspiration exacerbate the severity of drought. Drought stress, for example, inhibits plant growth because water is necessary for cell turgor, which is the force that a confined liquid applies to cell walls to induce cells to enlarge [8]. Smaller leaves, longer stems and roots, disordered stomatal oscillations, changed water and nutrient interactions with poorer crop production, and inefficient water utilisation are the main consequences of drought on agricultural plants. Due to water constraint brought on by global warming, agricultural regions worldwide are forced to be irrigated with salty water, which increases the salt content of the soil. One of the biggest obstacles to contemporary agriculture is salinity, or the accumulation of excessive salt in the soil, which eventually inhibits and damages plant growth and development and results in plant death [14, 15].

When there is more than 200 mM of NaCl present, most plants are perish. All stages of a plant's life cycle, including seed germination, seedling development, vegetative growth, and blooming, are significantly impacted by salinity. Salinity affects a wide range of horticultural crops, including fruits, vegetables, and spices. Salt stress balances ionic strength, which affects several biochemical, physiological, and metabolic processes in addition to generating osmotic stress, water stress, oxidative stress, nutritional stress, and delayed cell division [17, 18]. Plants evolved complex coping mechanisms to tolerate these abiotic stressors, and the challenges of determining the mechanism behind plant adaptation to abiotic stress tolerance have been addressed with the development of biotechnology and omics techniques. Highly efficient omics methods enable the identification of new genes and the comprehension of their genomic function. Plant genes have seen a variety of transcriptional and translational alterations thanks to the process of making proteins that are unique to the conditions they face [18, 19]. Different species and even genotypes respond to these stresses in quite different ways, and it's possible that plants change their genes to create certain byproducts as a stress response reducing adaptation.

Numerous omics methods, including transcriptomics, proteomics, metabolomics, and genomes, are used in the research of stress-tolerance proteins. The great potential of ZnO nanoparticles as a nano-fungicide against *Magnaporthe grisea*. Through the use of RNA sequencing (RNA-seq), the reaction of fungus to ZnO NPs is assessed. The ZnO NPs first affect the fungal cell membrane, which leads to the generation and build-up of reactive oxygen species, which in turn causes oxidative stress. Consequently, the disruption of the fungal catalytic system leads to the suppression of ROS scavenging. Consequently, oxidative stress ensued, damaging macromolecules and causing ROS to build inside the cell, disrupting intracellular homeostasis and ultimately resulting in fungal cell death [17–20].

NO needs to be produced in a particular tissue under certain circumstances, interact with specific targets, and ultimately interrupt the signaling cascade in order to function as a signal molecule. Under both normal and stress situations, NO is generated endogenously in plants in many cellular and subcellular compartments. The medicinal significance remains unclear despite significant advancements in our understanding of potential sources of NO in plants [21, 22]. The response of iron (Fe)-deficient maize plants to an exogenous NO supply provided the first indication that NO may play a role in plant mineral nutrition. Subsequently, a substantial body of data has been documented for additional important elements, such as nitrogen (N), phosphorus (P), potassium (K), zinc (Zn), and magnesium (Mg), indicating that NO has a role in plant mineral nutrition problems [19–21].

The rate of photosynthesis is impacted in plants that is potassium (K) deficient. Large amounts of nitrogen combined with low K levels have led to declines in the formation of carbohydrates, a reduction in fruiting, an increase in fruit split, a crease in fruit, a drop in plugging, and a decrease in the quantity of protein utilised as building blocks. The K deficiency may lead to a drop in output and poor fruit quality. Low K levels typically have detrimental impacts on fruit output and quality prior to indications of leaf insufficiency. K concentrations of 1.2% or higher yielded the largest production of high-quality fruit, whereas K in the leaf range of 0.5–0.8% has been reported to have lower yield and tiny fruit. Moderately low K concentrations in the tree did not induce any visual deficiency symptoms, although they do cause a general decline in growth and substantially impede production when visual deficiency symptoms start to appear in the leaves [23, 24].

Both NPs and NMs possess favourable and motivating attributes for augmenting plant characteristics and integrating them into agricultural practices. Small size (less than 100 nm), high surface-volume ratio, slow and sustained release potential, diverse nature (i.e., organic, inorganic, and hybrid), shapes, textures, and surface charge diversity, specific interaction, and stability are among the properties of nanoparticles (NPs) that are beneficial and have a high potential for use in agricultural practices. The characteristics of the NPs increase their permeability, promoting cell membrane penetration and facilitating their entry into plants through their roots and leaves [24, 25]. Although they may also give solid structures rigidity and compactness, hollow formations can also boost flexibility and elasticity in non-rigid structures and defend against degradation processes. Because of their varied behaviours, NPs are also a good option for creating nanopesticides, nanoherbicides, and nanosensors for intelligently controlled environments for monitoring plants, soil, and pests—a trend known as agriculture. Nonetheless, a few of the previously listed physical and chemical traits are also connected to possible environmental toxicity, human health risks, and phytotoxicity [25–27].

High-purity and required-size nanoparticles have been produced by physical and chemical techniques, but these procedures are expensive and call for hazardous materials. Therefore, because of their effectiveness, rapidity, and environmental friendliness, biological techniques to nanoparticle synthesis have attracted the attention of many researchers in the modern period. It shows how important these nanoparticles are for reducing the detrimental effects of abiotic stressors on crop plants, which might soon be helpful to the agricultural community. Water deficiencies change several aspects of plants, such as photosynthetic activity, biomass, and ROS generation, at the cellular, physiological, and molecular levels. Overproduction of ROS damages proteins, DNA, and cell membranes. It is essential to control ROS generation and preserve the stability of ROS concentrations. It is commonly known that a variety of CNMs, such as fullerene and its derivatives, greatly enhance a plant's capacity to tolerate abiotic stress. Plants can withstand the harmful effects of osmotic stress when their fullerol concentrations are at their optimal levels. The fullerol is common, the amounts of H2O2 and malondialdehyde (MDA) in maize dropped with PEG treatment [28-30].

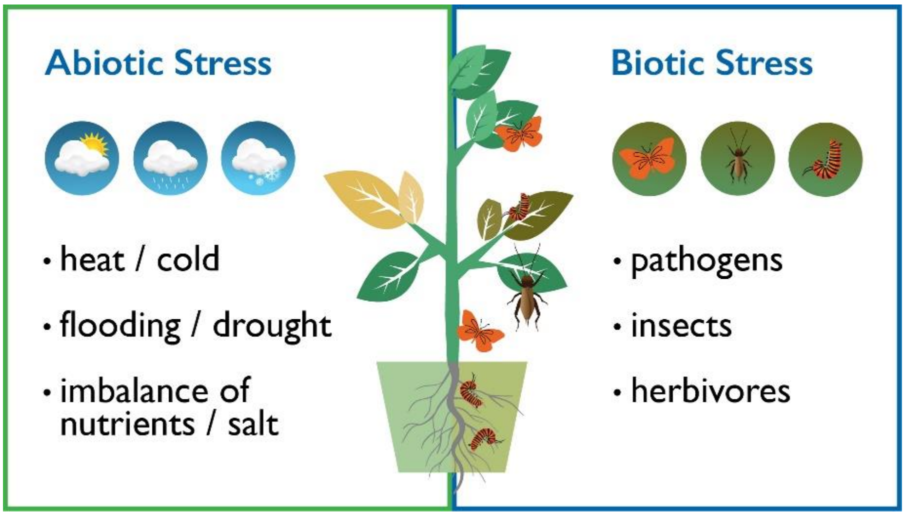

Fig-2: The coping of plant stresses and different modes

Fullerene's ability to scavenge reactive oxygen species (ROS) is attributed to its spherical cage-like structure. ROS are crucial for plants to be able to withstand abiotic stresses, particularly drought. Several studies have illuminated the role of fullerene and its derivatives as effective ROS detoxifiers. The administration of fullerenol topically may aid in mitigation, contingent upon the concentration of nanoparticles employed. Nanoparticles can have both beneficial and detrimental effects on the plant system. At very high doses, a number of nanoparticles can cause biomolecules to oxidise, which can harm or even kill plant cells. However, when present at the right quantities (low nanomolar concentrations), nanoparticles function as crucial regulators of plant growth and development [28–30].

In most agroecosystems, one of the nutrients that most limits crop productivity is nitrogen. In plant biochemistry, nitrogen is involved in many important processes. It is a necessary component of many different cellular components such as cell walls, enzymes, chlorophyll, nucleic acids, and storage proteins. Thus, a lack of nitrogen has a significant impact on agricultural plant growth, development, and output. For the majority of annual crops, the recovery of N applied using chemical fertilisers is less than 50%. The leaching, denitrification, volatilization, integration into soil microorganisms, and soil erosion are the reasons for the limited recovery of N. Root systems are crucial for increasing agricultural plants' effectiveness in absorbing and using N [31, 32]. The phosphorus (P) is the second most valuable mineral nutrient and affects onion output significantly [29]. Since phosphorous is a necessary component of plants and a component of phospholipids, phosphates, and nucleic acid, it has an impact on several physiological and biochemical processes in plants. Energy transfers, plant maturity, fruiting, and seed formation are all significantly influenced by phosphorus [30]. The sources that are kept in the soil may also contribute to either beneficial or bad outcomes. Phosphorus availability in the soil promotes plant growth and development. The phosphorus is recognised as a key component of DNA molecules [31]. Furthermore, P is present in soil in both organic and inorganic forms. Compared to inorganic P, organic P is the more stable type. As a result, if inorganic phosphorus is not fixed by soil, plant highly absorb and use it [32]. P is absorbed by plants at a lower rate than N or potassium [13]. Although a great deal of study has been done on it over the last century, little is still known about how it behaves in the soil and if it is available to crops [31, 32].

In addition to encouraging improved fruit quality, the K fertilizer application method influences how other cations are transported and how nitrogen is used. A lack or excess of K prevented the intake and use of nitrogen (N), but a sufficient supply of K might encourage photosynthesis, boost NR activity, and ultimately raise Malus hupehensis's absorption of nitrogen. During the growth of apple fruits, Ca2+ concentration rose as K fertilisation levels increased. In pear trees, Mg had a clear compensatory impact on K, whereas K had a clear antagonistic effect on Mg, as seen by the Mg transporters increasing under low K and decreasing under medium and high K [33-35]. Under low-K treatment, the K concentrations in the fruits and leaves of pears dramatically decreased. Transcriptome sequencing data suggests that AKT1 and HAK/KUP/KT genes are important for K+ transport in leaves and fruits when K is deficient. Whereas low K during maturity restricted the digestion of carbohydrates, high K levels might change the allocation of nutrients and carbohydrates from leaves to fruits and enhance photosynthesis [11, 16].

CONCLUSION

The reduction in Suc content of leaves and fruit under low K conditions may be attributed to the significantly downregulated expression of Suc synthase (SUS) genes in fruits. Low K is shown to increase genes related to ethylene, cytokinin (CK), jasmonic acid (JA), auxin, and ABA, but it also dramatically downregulated the genes encoding the transporters of auxin, CK, and brassinosteroid in leaves and fruit. The medicinal significance of novel bioactive comprehend the discovery with different bioactivities.

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