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POTENTIAL OF ABIOTIC STRESS RESISTANCE IN PLANTS INDUCED BY MELATONIN

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Abstract—Biotechnology is a perfect way to improve crop production by enhancing its capacity to be resistant to abiotic stress. Abiotic stresses have a detrimental effect on crop plants which contribute to plant efficiency and productivity declines. All of the abiotic stresses induce an enhanced development of reactive oxygen species (ROS). Specific abiotic stresses hinder the growth of plants by various pathways but both because ROS rates rise and conflict with homeostasis of ROS. Melatonin can improve the economy by improving crop production and raising the possibility of abiotic stress management. It shows the different roles of melatonin in a plant system, which can be helpful in enhancing environmentally friendly crop development and maintaining nutritional security that can impact social life. Another crucially significant factor is the development of melatonin-rich food crops such as rice, fruits and vegetables by mixing conventional and modern breeding approaches. This method is an improvement in plant tolerance to biotic and abiotic stress that can lead to improved crop yields, and the nutritional added benefit of foods for solving food safety problems.

Keywords— *Abiotic stress, Melatonin, Drought stress, Reactive Oxygen Species (ROS), Tolerance.*

6.1 Introduction

Agricultural biotechnology is a field of agricultural science involving the use of scientific tools and methods, including molecular markers, tissue culture, molecular diagnostics, vaccines, and genetic engineering to modify living organisms: animals, plants, and microorganisms. Various strategies in biotechnology are considered to improve the quality and harvest yield. Biotechnology is a great way to increase the productivity of crops by enhancing their ability to withstand abiotic stresses [1].

There are several types of abiotic stress. Among them are salinity, high temperatures, mineral deficiency, lethality, and low water accessibility are serious threats to the harvest survival which can influence the harvest yield [1]. Abiotic stresses negatively impact crop plants and lead to reduction of quality of plants and their productivity. The abiotic stress expansion due to climate change and increase pressure of populace, the conventional procedures of overcoming abiotic stress are not prepared to face the impact [1]. A recent meta-analysis study shows an increase of 2.0 to 4.9°C by 2100 in global average temperature. Plus, increasing land contamination with heavy metals also limits crop productivity and causes serious problems to human health. These stresses also affect biochemical, physiological, and growth of harvest plants [1]. Many abiotic stresses affect the metabolism, transport, synthesis, concentration, and storage of sugars [2].

The average loss of yields caused by abiotic stress is so much higher compared to biotic stress [1]. Based on the inclusion of models for climate change and crop yields, further productivity losses for major crops, including wheat, maize and rice, have been expected, with significant impacts on food sustainability [3]. Abiotic stresses have become a significant obstacle in our mission to provide secure food supply as these may reduce the potential yields by 70% in cultivates. A 2007 FAO has reported that only 3.5% of the global land area is clear from some environmental constraint [2].

The planet expects climate change in the future, and degradation of the ozone layer. This is associated with a global temperature change that may increase the problem of abiotic stress on crops and increase the imperative to prepare varieties that are stress tolerant. In addition, the demand is rising to expand the harvest area to areas which are not suitable for the production of important harvests. Hence the preparation of stress-tolerant plants is becoming a major aim of agricultural biotechnology. This work aims to study the potential of abiotic stress resistance in plants induced by melatonin.

Types of Abiotic Stresses

There are several types of abiotic stress which plants are always exposed to (**Figure 6.1**). Drought is the most popular abiotic stress that affects the growth and advancement of plants through shifts in metabolism and expression of genes. In drought and high salinity conditions, plant growth has decreased and showed a drop in their net photosynthetic rates and chlorophyll content. Drought stress causes a drop in photosynthesis by ruining the mechanism of light harvesting and its utilization. It negatively affects the photosynthetic pigments metabolism, which inhibits the function of RuBisCo and disrupts the photosynthetic apparatus [4].

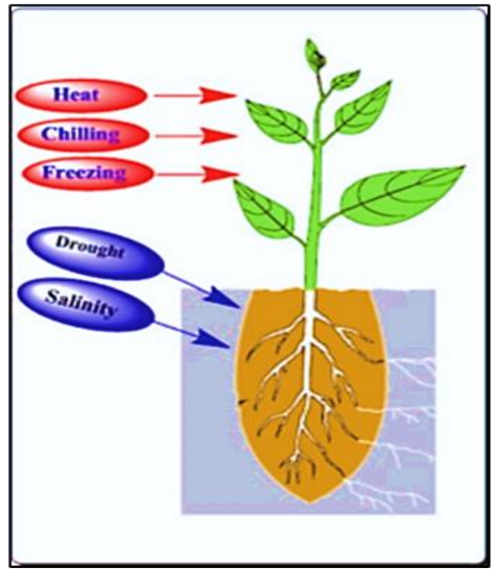

Figure 6.1: Type of environmental stress [1].

Chloroplast structure disruption also affect the photosynthetic efficiency of growing plants under conditions of drought negatively. Drought has a negative impact on intercellular CO_2 levels, which encourages the production of photosynthetic electron transport components to reduce, leading to increased ROS (reactive oxygen species) production, which causes photosynthetic apparatus to disrupt. The photosynthetic apparatus disruption caused by drought leads to a decrease in stomatal conductance, photosynthetic rate, PSII photochemical efficiency, transpiration rate, and photosynthetic electron transport rate. Stress from the drought reduces plant water potential and relative water quality. Additionally, decreasing water capacity triggers a decrease in the absorption of various essential minerals such as, potassium, phosphorus, and nitrogen. The conditions of water deficit have a detrimental effect on the transporters of nitrogen and on the nitrogen metabolism. It is induced by the down-regulation of genes, such as NRT (nitrate transporter), NR (nitrate reductase), AMT (ammonium transporter), GS (glutamine synthetase), GOGAT (glutamate synthase) and NiR (nitrite reductase) under stress from drought. Decreased nutrient absorption is often followed by decreased translocation efficiency to particular sites in plants growing under conditions of water deficit. In addition, decreasing root growth in low-water soils also has a negative effect on nutrient uptake capacity.

Water tension is also causing seed germination inhibition and root vitality. Changes in precipitation patterns and a rise in evapotranspiration caused by global warming have enhanced the frequency and intensity of drought stress. **Figure 6.2** shows the consequences of drought stress.

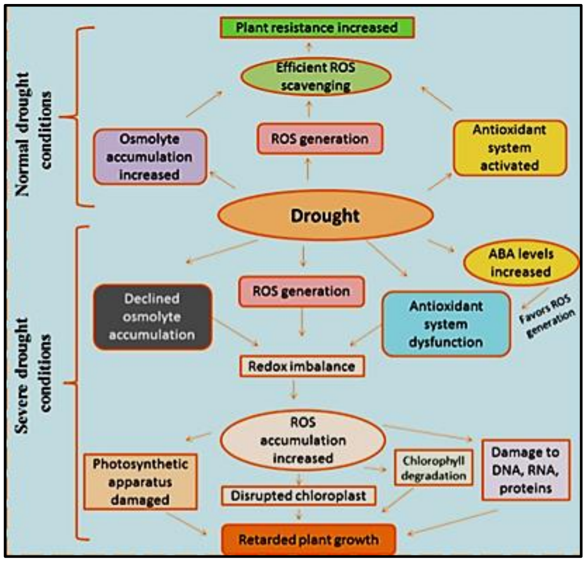

Figure 6.2: The consequences of drought stress [15].

Another big limiting factor for plant growth and production is the intense radiations and high temperatures under tropical climates. High temperatures can cause twigs and leaves to be scorched along with visible sunburn symptoms, growth inhibition, leaves senescence and fruit and leaves discoloration. High temperatures will lessen the potential of the seeds to germinate and lead to establishment of stands [15].

Many plants have different abilities to endure low and freezing temperatures. Typically, tropical plants are practically incapable of surviving the chilling conditions. Plants may also withstand a chilling temperature range of −5 °C to −30 °C that depends on the plant. Plants in colder areas typically tolerate much lower temperatures than this. It is known that plants should be equipped to endure colder or freezing stress in case they undergo a period of chilly acclimatization at a temperature that is low yet non-chilling. For example, wheat plants that grew at normal warm temperatures are dead because of chilling at −5 °C. Somehow, they survive the chilling temperature down to −20 °C after a time of cold acclimation when the plant develops at temperatures underneath 10 °C [1].

Cold stress also reduces grain yield; it influences the quality of crops too [5]. Low temperature exposure causes physiological and biochemical changes in plants, triggering a lack of vigour and lower growth rate. The key sources of chilling lesions are cell membrane structures. Cold changes the structure of the cells, cell membranes and composition of the cell wall.

Among the most important global problems that severely affect the productivity of crops is soil salinity. Salinity reduces plant development and growth due to water stress, cytotoxicity due to excessive absorption of ions such as sodium (Na+) and chloride (almost Cl-), and nutrition imbalance. Additionally, salinity is usually accompanied by oxidative stress due to the reactive oxygen species (ROS) generation.

The plant cannot move. Its immobility caused them to be exposed to more inevitable abiotic stresses. Thus, they need advanced protection from the stress factors by means of intrinsic mechanisms including high levels of antioxidants that are produced endogenously like melatonin [4].

Role of Melatonin

Plants can resolve environmental stress by triggering molecular networks, including signal transduction, stress detection, development of metabolites, and unique stress-related gene expressions. The initial role of Melatonin was possibly that of being a free radical scavenger. Melatonin has probably developed in bacteria; both in α-proteobacteria and in photosynthetic cyanobacteria have been tested. The other functions of Melatonin, including their various receptors, later evolved in evolution. In today's animals, melatonin functions through receptor-mediated means in sleep control, enhancement of immunity circadian rhythm modulation, as a multifunctional oncostatic agent while retaining its ability to lessen oxidative stress via processes that are partly receptor-independent. In plants, melatonin continues to work in reducing the germination and growth of oxidative seeds, enhancing stress tolerance, stimulating the immune system and modulating circadian rhythms; a single melatonin receptor has been identified in land plants where it regulates stomatal leaf closure [4].

Melatonin's most commonly cited functions are associated with abiotic stresses such as heat, high temperature, pollution and chemical stress. Melatonin (N-acetyl-5-methoxytryptamine) is a multifunctional molecule. It can protect plants from the adverse effects of drought stress by increasing the efficiency of ROS scavenging. This helps to preserve the photosynthetic system and to reduce the drought-induced oxidative stress. Melatonin controls processes of plants at a molecular stage, which results in a greater tolerance to stress from drought. Studies have mainly focused on the melatonin ability to reduce the effects of abiotic stresses such as heavy metals, drought resistance, high salinity conditions and temperature fluctuations [6].

6.2 Biotechnology on Abiotic Stress Resistance

6.2.1 Biosynthesis of Melatonin

In plants, there are 4 enzymatic steps in melatonin biosynthesis. The first enzyme is the tryptophan decarboxylase (TDC). The enzyme catalyzes tryptophan to be converted into tryptamine. TDC was cloned into a few species of plants. They include rice, pepper, catharanthus roseus, and tobacco. **Figure 6.3** shows the Biosynthetic pathway of melatonin in plants and in animals.

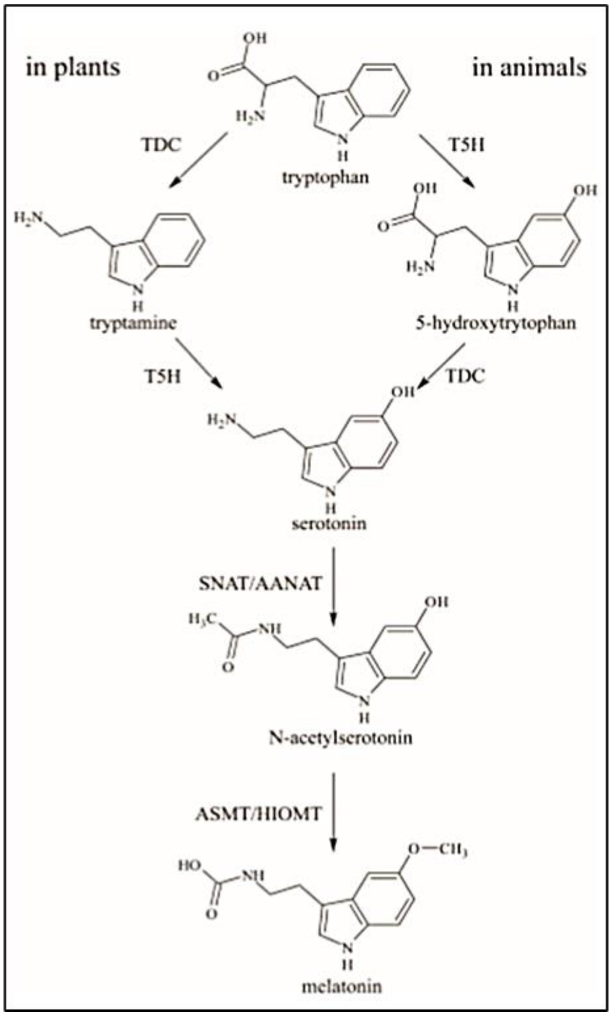

Figure 6.3: Biosynthetic pathway of melatonin in plants and in animals [7].

TDC acts as a bottleneck for the control of biosynthesis of serotonin (precursor to melatonin), because the expression of TDC is very small or negligible. Catalysis of the cytochrome P450 enzyme tryptamine 5-hydroxylase (T5H) is the second step in melatonin biosynthesis. It hydroxylates tryptamine's role in C-5 to form serotonin. T5H was isolated by map-based cloning in mutants of the rice sekiguchi lesion (sl). T5H is expressed constitutively in stable rice plants (Oryza sativa).

The last two enzymes on the biosynthetic pathway for melatonin, which are N-aceylserotonin methyltransferase (ASMT) and N-acetyltransferase arylalkylamine (AANAT). There is no discovery on AANAT homologous genes in higher plants tothis day. Even so, AANAT has been cloned in the Chlamydomonas reinhardtii, a unicellular green alga. N-acetyltransferase (SNAT) genes have been cloned for rice serotonin that encodes an enzyme catalyzing the conversion of serotonin to N-acetylserotonin. Last but not least, ASMT, which is also known as HIOMT (hydroxyindole-O-methyltransferase), was purified in rice by heterologous overexpression of the Escherichia coli [8]. It is a rate-limiting enzyme of melatonin biosynthesis. Subcellular localization shows that SNAT protein is placed in chloroplasts, whereas ASMT is found in the cytoplasm [9].

Evidence from latest research prove that acaffeic acid O-methyltransferase (COMT), which is a multifunctional enzyme, can catalyze the last step of melatonin biosynthesis too [10][4]. Melatonin biosynthesis in plants needs COMT or ASMT activity [10] [4].

6.2.2 Genetic Modification Changes Stress Tolerance in Plants

Overexpression of the melatonin biosynthetic genes increases melatonin levels in transgenic plants. The transgenic plants indicate enhanced tolerance to abiotic stresses [7]. TDC is the first biosynthetic gene that has been overexpressed in rice. Senescence of leaves in transgenic plants that are overexpressed with TDC is slower. Pepper fruit that is infected with fungal causes an increase of TDC gene expression, showing how responsive is melatonin towards pathogen attack. Transgenic rice expressing serotonin N-acetyltransferase gene (SNA / AANAT) gives high levels of melatonin and increases synthesis of chlorophyll during low temperature stress, indicating that melatonin is involved in the resistance to chilling.

Dark conditions and high temperatures by elevating the last two enzyme activities in melatonin synthesis can increase melatonin rates. That implies a protective melatonin function against high temperatures. The homologous ovine genes AANAT and HIOMT overexpressed by transgenic Micro-Tomato plants show loss of apical dominance and increased tolerance for drought.

Transgenic plants of Nicotiana sylvestris expressing a HIOMT gene and an AANAT gene have enhanced production of melatonin. Melatonin gives a shield against DNA damage induced by UVB when exposed to ultraviolet (UV)-B radiation.

6.2.3 Exogenous Treatment on Melatonin on Plants

Melatonin that is applied exogenously can also enhance plant ability to withstand environmental stresses. Since melatonin is beneficial and safe to both animals and humans, exogenous pre-treatment may be a successful cultivation strategy to protect plants from this pathogenic infection. Recent work indicates that chemical priming can guarantee crop stress management since plants can be primed to enhance their tolerance to different abiotic stresses by chemical agents. Chemical priming provides the possibility of increasing plant resistance to these abiotic stresses by effectively priming the pre-existing defensive pathways without genetic alterations.

Exogenous melatonin may increase heat resistance for kiwifruit and cold resistance for cucumbers since there are improvements in antioxidant protection. Exogenous melatonin protective effect has been identified during chilling stress. A tropical plant named Mung bean is extremely susceptible to frostbite. Seedlings aged three-day were exposed for 2 days to 5 °C and then placed back to optimum temperature (25 °C). Melatonin-primed seedlings showed a 20 per cent improvement in the length of root and less disorganized cell ultrastructure. Related effects of melatonin under osmotic stress were also observed in cucumbers [11]. Mung beans that are treated with Melatonin also had an increased accumulation of total proline and phenolic compounds. Besides, melatonin-treated cucumber seeds showed an improved rate of germination during chilling stress too.

Apoptosis in cultured carrot suspension cells caused by low temperature is attenuated by pre-treatment with melatonin. Melatonin therapy has almost completely alleviated degradation of carrot cell plasma membranes and the shrinkage caused by cold stress. This indicates melatonin is useful in dealing with severe conditions by preserving function of the membrane.

Different findings were gathered with the commonly used turfgrass, bermudagrass (Cynodon dactylon), which was strongly covered by exogenous melatonin compared to untreated plants against situations of salt, drought, and cold stress [12]. **Figure 6.4** shows improved abiotic stress resistance in bermudagrass treated with melatonin.

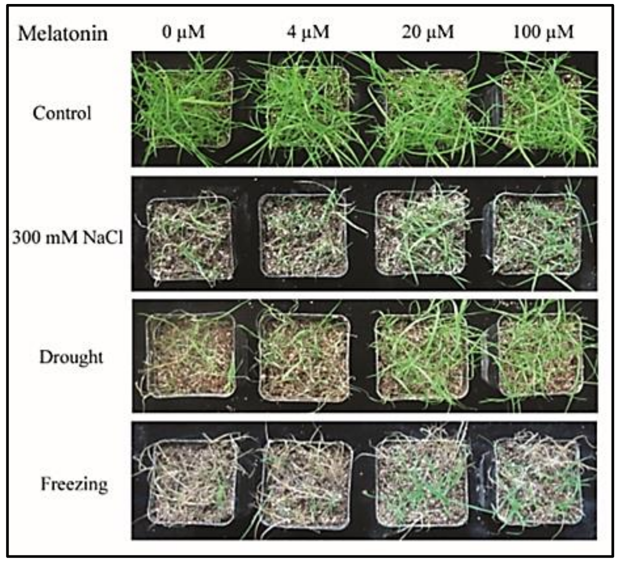

Figure 6.4: Improved abiotic stress resistance in bermudagrass treated with melatonin [12].

6.2.4 Mechanisms of Melatonin-Mediated Stress Tolerance

All of the abiotic stresses are causing increased ROS production. Different abiotic stresses prevent plant growth through different mechanisms, but all because ROS levels rise and interfere with ROS homeostasis [7]. Although ROS is obviously essential for growth and acts as secondary signal transduction messenger huge amounts of ROS are not good for cells and organisms since it causes complex and successful mechanisms to neutralize them. Moreover, high levels of ROS can lead to lipid peroxidation in cellular membranes, protein denaturation, DNA damage, pigment breakdown, impaired enzyme activity and carbohydrate oxidation.

Studies on the interaction of melatonin with stress signalling mechanisms have discovered a complex relationship with ROS (**Figure 6.5**). Evidence shows that melatonin can scavenge ROS with high efficiency as it is a broad-spectrum direct antioxidant.

Many studies have established the hypothesis that adding melatonin reduces stress-caused oxidative damage. The melatonin scavenges ROS directly, enhances antioxidants and antioxidative enzyme activity.

Cellular stress reactions are mostly triggered by the combination of extracellular material with a protein in the plasma membrane. This indicates that receptors present on the plant cell membrane are sensing the stresses. The signal is then transmitted downstream, and secondary messengers including ROS and calcium are produced. Melatonin affects gene expression and is involved along the way in the steps of signal transduction. RNA-seq study showed that 14 genes and six stress receptors are involved in calcium-dependent signalling in melatonin response [13]. Interaction of melatonin with a different of ROS will produce cyclic 3-hydroxymelatonin and other melatonin metabolites, e.g., N-acetyl5-methoxykynuramine and N1-acetyl-N2-formyl-5-methoxykynuramine. These metabolites work as radical scavengers. Sometimes, they are even more active than melatonin due to their capacity to neutralize ROS [4].

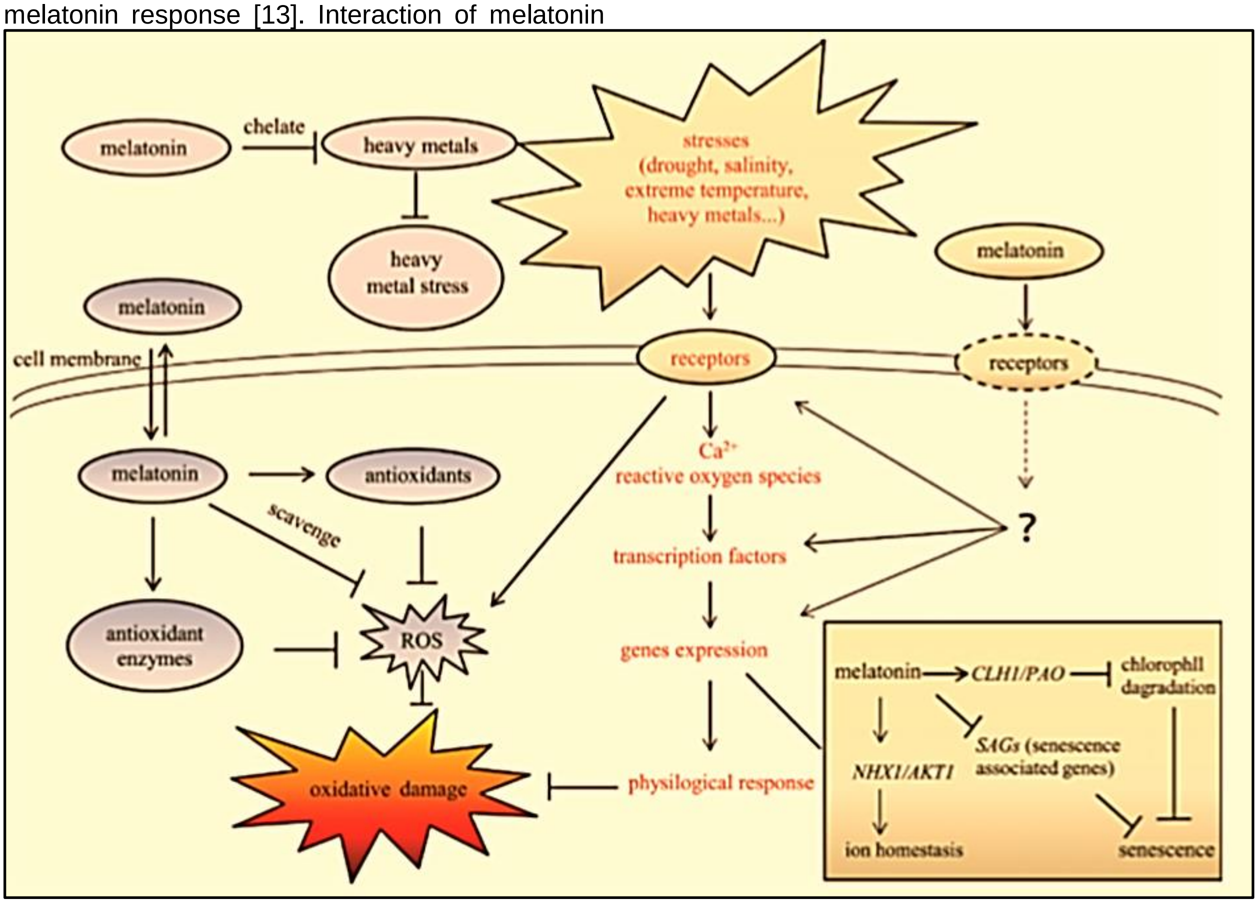

Figure 6.5: Cells responses towards stresses after treatment with exogenous melatonin. Melatonin chelates toxic metals in order to reduce the heavy metal stress. Melatonin can freely cross cell membranes since it is an amphiphilic molecule. Melatonin can scavenge ROS directly. It also elevates the antioxidants levels and the activities of related enzymes to scavenge ROS. Receptor detects stress, followed by a signal transduction cascade [7].

6.3 The Advantages of Melatonin of Abiotic Stress for Plants Compared to Conventional Method

The conventional agricultural methodology is referred to as farming systems which embrace the utilization of artificial chemical fertilizers, pesticides, herbicides and different continual inputs. Conventional agriculture is therefore usually extremely resourceful and energy-intensive, but often highly productive. Generally, conventional farming is different from organic farming or intensive agriculture or horticulture. Conventional method is responded to location-specific conditions by

integrating cultural, behavioural, and physical activities that encourage raw material conservation, promote natural ecosystems, and preserve biodiversity. Organic farming methods also depend on irrigation, biodiversity manures as fertilizers aside from using artificial fertilizers, insecticides, production regulators and feed additives for livestock. Hand trail and biological pest control also has been used in organic farming systems. However, the conventional method is not fully able to control the abiotic stress in plants. Some studies have identified that the melatonin in plants can help the plants to overcome the abiotic stress [14].

The presence of melatonin in plants appears to be quite a ubiquitous occurrence. Since it is yet to be explored metabolic enzymes pathway biosynthetic pathway and biochemical mechanisms, melatonin has further benefited plants and consumers. The application on commercially important crops is one of the impacts of melatonin that used to improve their growth and development. In addition, melatonin has been distinguished in several new ways in which melatonin may have conceivable parts or functions in plants. For example, melatonin has many functions like boosting the retention cycle and consistency of fruits and vegetables and plays a vital role in vascular physical connection during the sculpting cycle and nutrient absorption from roots via modifying root architecture. Another crucially significant element is the manufacturing of food crops rich in melatonin such as grains, fruits, and vegetables through the combination of conventional and modern breeding approaches. This approach is an increment in plant resistance against biotic and abiotic stress that can contribute to increased crop yields, and the nutritional supplement value of products to solve food safety issues [14].

A Improve growth and development

It has been proven that melatonin ubiquitously synthesizes in plant organs. One of the advantages of melatonin in plants is to stimulate growth and preserve plants' credibility underneath unpleasant circumstances without using any conventional method like fertilizer or pesticides. Generally, melatonin regulates the metabolic processes of plants for example improving the development of roots, leaves and explants. It has been known that many plant characteristics, including germination, seedling development and changes in flowering time, grain yields and apoptosis have been altered by melatonin. The soil also has modified the metabolic status and delayed protein depletion in plants, exaggerated pigment content, the chemical process in plants like photosynthetic rates and photosynthetic end products by using melatonin in long term usage compared to control plants. These changes are associated with better protein preservation capability [14].

The drought-induced epigenetic regulation of the leaf can be delayed by lowering oxidation and eliminating the up-regulation of epigenetic regulation-associated genes. This process can be done by the presence of melatonin. Besides, the seed coated with melatonin greatly exaggerated the area of leaf, plant size, plant bud, seedlings of plant, and lipid material of plants. The presence of melatonin in seed could be commercially used for a significant proportion of economically valuable agricultural practice and permaculture crops. The seed industry has the ability to be revolutionized and the crops yield can be enhanced. Due to pre- and post-application of melatonin, the aging and senescence of fruits and vegetables can be delayed. Melatonin has greater potential to play a significant role in enhancing the period lifespan of fruits and vegetables. Melatonin also has been proved to help store the fruit trees, which can both reduce the losses of conventional agricultural commodities after harvest season [14].

B High stress tolerance without disturbing plant production

Melatonin also helps the plant to overcome the stress without disturbing the plant production. Salinity could be a massive environmental issue that restricts plant growth and development which ends up into huge economic losses worldwide. Aside from water deficit caused by salinity due to osmotic pressure, the key to metabolic pathways like photosynthesis, hormone production, energy, and fatty acid metabolism in plant cells also has been disturbs. Various strategies have been adapted for plants to cope with these stressors. The alleviation of the growth inhibition caused by elevated salinity significantly is one of exogenous applications of melatonin which enabled the plants to retain their photosynthetic ability. The negative impact exerted from salinity issue has been regardless of the development phase of the plants, and its implications vary from foliar feeding to plant apoptosis and appear throughout the lifespan. The involvement of melatonin in the biosynthesis and catabolism process can reduce the effect on seed germination and plant growth. The melatonin helps the plants to enhance its tolerance towards sodium and desertification stress. Also, melatonin can up regulate the signalling pathway that was suppressed by sodium stress. This can be highlighted that melatonin helps to increase the production of plants [14].

Due to unstable weather, the presence of melatonin in plants has given another benefit to the farmer to reduce the significant damage to agriculture crops. Melatonin has shown to significantly alleviate cold stress. Cold stress can lead to damages by decreasing the area of the leaves, leaf moisture content, chloroplast pigment content, and the aggregation of ROS causing membrane endothelial dysfunction. The usage of melatonin can increase the activity of inhibitor accelerators resulting in improving plant growth by minimizing cell death. Besides, the extreme temperature can also affect the membrane fluidity and enzyme activities leading to changes in growth and development structures and losses in yield. Under difficult circumstances, the level of melatonin in plants is getting higher due to the genes in plants which are responsible for melatonin biosynthesis. The restricting impact of light and high weather on both light sensitive and thermo-sensitive has the possibility to be reversed by the application of melatonin. It can be highlighted that the presence of melatonin in plants can helps the farmer to overcome any abiotic stress for plants and the production of plants still can be going up.

C Reduce Cost

In the agricultural sector, drought can affect the farmer in many different ways. Drought can affect the plant because the water plays such an important role in plants. The drought can have a big impact on farmers, like economic implications. Economic implications are the hose impacts of drought that cost lives or business money. The farmers may lose their money as the drought kills their crops. The farmer may have to spend lots of cash in order to get the water supply. Also, when the drought strikes, the crops may be damaged. The industries that rely on agriculture like industries that make food products may lose their business due to crop damage. Against drought, melatonin has been proven to protect the plants by overexpressing the genetic traits showing loss of anterior superiority and enhanced drought tolerance [14].

The level of melatonin plays a crucial part in protecting the plants from ozone damage. Plants species can be more vulnerable to radiation exposure due to lower concentration of melatonin compared to ozone tolerance species. With a higher concentration of melatonin, the plants proposed to be protective from UV-B radiation which can cause augmented oxidative damage. That means the plant can still be alive even though the drought has struck the plantation. The farmer will not lose their money and crops will not die due to the drought. It has also been studied that under the bright sunlight, the plants will produce an extremely high concentration of melatonin. The presence of high concentration in melatonin saves the plant from the harsh environment by being pollutant-resistance plants. Melatonin can be used as an environmentally friendly substance in plants that help prevent death even though the soils are higher in concentration of melatonin in plants [14].

Also, the other effect that can make the farmer lose their money is when the plant cannot control the plant disease. Throughout agriculture worldwide, plant diseases have caused a major growth and economic loss. It has helped the general and personal sectors work through different approaches to manage plant diseases, ranging from disease monitoring and analysis to the development of infection-resistant crops. This can cause the high cost to overcome the plant disease. It has been proven that melatonin has several other beneficial roles or benefits in plants. The endogenous exposure of melatonin can improve the resistance against one of the most severe diseases which is fungal disease produced by Diplocarpon Mali. This included the plant transducing oxidative enzyme activity and plant resistance associated enzymes [7].

It has been observed that the implementation of efficient structural protections under which the activation of the tryptophan pathway enriches serotonin under leaves. The serotonin will suppress the growth of fungal hyphae in leaf tissue. Serotonin is the metabolic enzyme pioneer of melatonin. Melatonin can induce the pathogenesis-related genes which may be a defence signalling molecule in plants against pathogens. It can be inferred that the farmer can reduce the cost of purchasing any traditional product such as pesticides, because melatonin can be an effective medical replacement to combat bacterial, viral and parasite diseases in plants. Melatonin may also have a responsibility to protect against bug attacks and could prove to be a reliable way of manipulating or minimizing insect attacks on industrial crop production, as insects cause massive declines and dramatically reduce crop yields [7].

6.4 The Effect of Melatonin in Abiotic Stress for Plant on Today Society

Melatonin (N-acetyl-5-methoxytryptamine) is already recognized as an organism hormone but new to plant biology. Melatonin in plants is of great concern because of its extensive allocation within the natural system and the potential physiological role in plants. Melatonin has many advantages that can affect society with its benefits [7].

As we know, plants are the spunk of life on Earth. Plant diversity established the functioning of all ecosystems. The plants play a role in providing the general support system upon which all life depends. Reforestation, climate control, nutrient conservation and germination are the services that are rendered by the ecosystems. Plants offer several significant benefits including nutrition, drugs, clothing, accommodation and the manufactured goods which make up countless other products. Plants are an invaluable tool for human life and the endangered plant species should be recognized by society all around the world. However, today worldwide plant populations are under threat. It has been estimated that at least 100,000 plants are under danger of extinction. The plant needs to be conserved for the future society. The loss of a plant species can have dramatic effects on the environment as other species like wildlife may lose their sources of food and shelter.

Besides, the plants play a crucial role in soil stabilization and help prohibit erosion. The conservation of plants should be a central component of efforts for biodiversity conservation. Although the situation is serious, efforts across the globe to stop the loss of plant diversity are underway. One of the efforts is using melatonin to conserve the plants. The effect of melatonin can help to ensure the conservation of tree species. The effective tool to ensure the conservation of tree species is by using in vitro cultivars preservation via gene therapy. However, the plant cells and tissues may be subjected to several stresses during the gene therapy process. This contributes to issues during the regrowth of gene therapy materials. By supplementing the preculture and regrowth material with melatonin, the regrowth of frozen shoots can be enhanced. Seed treatment with melatonin can also help to improve the percentage germination of plant seeds. The effect of melatonin can ensure the conservation of plant or tree species is achieved for the future generation.

Next, melatonin can be used in the medical field as well. By incorporating its farming ability against scientifically free radicals, such as reactivating oxygen and nitrogen organisms, it can impact society. It is shown that melatonin can act as an antioxidant that presents no pro-oxidative effects. Thus, the melatonin-intermediate components display beneficial effects and a strong neuron-protective activity with other antioxidants such as ascorbic acid and glutathione. The effect of melatonin along with its beneficial properties on the photoperiodical (metabolic) rhythms explains why it is sometimes taken as a nutritional supplement. Melatonin, stored in plants, is ingested from the gastrointestinal system and introduced into the blood system in human food. It also passes the blood-brain and placenta boundaries and is primarily absorbed into the nucleus and mitochondria. It can be used as herbal remedies, where it is classically used in human sleeping disorders as a sleep transceiver, as a non-depressant, or in combating jet lag. Melatonin can be classified as an antioxidant linked to human health. It can significantly affect society with its benefits.

The agricultural sector is one of the remarkable aspects of economic growth. Changes in purchasing habits such as the sluggish growth in production of farm products also alter society. The decline or rise of the economy of industrial products depends on productivity growth in the agriculture sector. Globally, productivity growth has been higher in the farm sector than in other sectors. Agriculture has played a significant part in the process of development of a country. When development occurs, agriculture must be able to produce a lot of natural resources to sustain the increasing non-agricultural labour force since food is more essential for life. The economy may decline if the productivity of agriculture is not effective. The agricultural society or industrial society is the most affected by the economic decline.

As the study has been identified, melatonin gives benefits to the farmers in agriculture by increasing productivity. When productivity increases, the industrial society will less worry because the amount of food demanded by the population will increase and the income also increases. It is because the consumers who buy the goods at prices that are well above production cost can give incentives to the farmer to increase productivity. This is shown that the effect of melatonin in plants can increase the agricultural economy.

Also, the transgenic plants with the elevation of concentrations of melatonin are the successful example to enhance crops yield. The development of genetically modified crops is expected to increase in the future, and melatonin biosynthesis has been modified in these plants to be used as a method to stimulate immunity to biotic and abiotic stresses. This method would enable the society to increase crop yields automatically. In the future, the foodstuffs with higher concentrations of melatonin will probably be developed by incorporating traditional and modern growing methodologies. Melatonin is also a potential mechanism for controlling diseases and insects. This could lead to the use of melatonin on a commercial scale.

It seems that melatonin can demonstrate to be a significant compound for controlling field crops in particular and can be effective in growing crop yields. It is also helping to address the food security issues around the world with the higher nutraceutical value

CONCLUSION

Melatonin has been identified to be present in plant species. It is an important molecule, which can be handled with various abiotic and biotic stresses. Melatonin in post-harvest processing serves as an antioxidant and improves the post-harvest fruit and vegetable cycle. Exogenous melatonin applications are often considered to mitigate the reactive oxygen species and cell damage caused by abiotic stresses. In addition, the modification of stimulus-specific genes and the regulation of pathogenesis-related protein and antioxidant enzyme genes under abiotic stress make it a more versatile molecule. Besides that, the role of melatonin in plants can give a lot of advantages to the agricultural industry, especially farmers. It has been highlighted that melatonin can increase the economy by enhancing the production of the crops and reduce the risk to control abiotic stress. Furthermore, various strategies for inducing exogenous melatonin activity to sustain a plant system were discussed. The diverse functions of melatonin in a plant system are illustrated, which may be useful in improving the environmentally sustainable crop production and ensuring food protection that may affect social life.

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