IMPROVEMENT OF DROUGHT AND SALINITY TOLERANCE OF CORIANDER (*Coriandrum sativum* L.) THROUGH APPLICATION OF MELATONIN

A Thesis
By
KAZI AN NAHIAN
Student No: 2205100

MASTER OF SCIENCE
IN
CROP PHYSIOLOGY AND ECOLOGY

DEPARTMENT OF CROP PHYSIOLOGY AND ECOLOGY

HAJEE MOHAMMAD DANESH SCIENCE AND TECHNOLOGY UNIVERSITY

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DEPARTMENT OF CROP PHYSIOLOGY AND ECOLOGY
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DEDICATED
TO
BELOVED PARENTS

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ABSTRACT

Coriander (*Coriandrum sativum* L.) is one of the most important condiments for culinary purposes.Addressing this issue, there were two experiments were carried out at Hajee Mohammad Danesh Science and Technology University in the Department of Crop Physiology and Ecology from 2023 to 2024 followed by completely randomized design (CRD) with three replications. During the experimental period germination traits, seedling growth, photosynthetic pigments, proline contents and water relations were measured to understand the role of melatonin in mitigating the ill effects of drought and salinity stress of coriander (BARI Coriander 2).

The experiment 1 was related to drought stress and the treatments were T_1 = Control condition (Tap water + 0 µM MT), T_2 = Moderate drought stress (-2 bars) + 0 µM MT, T_3 = Moderate drought stress (-2 bars) + 50 µM MT, T_4 = Moderate drought stress (-2 bars) + 100 µM MT, T_5 = Moderate drought stress (-2 bars) + 150 µM MT, T_6 = Higher drought stress (-4 bars) + 0 µM MT, T_7 = Higher drought stress (-4 bars) + 50 µM MT, T_8 = Higher drought stress (-4 bars) + 100 µM MT and T_9 = Higher drought stress (-4 bars) + 150 µM MT. From the results of Experiment 1, it was observed that drought stress plots (T_2-T_9) showed lower performance in respect of germination, seedling growth and photosynthetic traits compared to control condition (T_1). However, the pots treated with MT showed the better results in compared to the no MT-treated pots in artificially created drought conditions. The plants treated with 100 µM MT (T_4) revealed that the highest germination traits (Germination percentage, 97%; Mean Germination Time, 14.31 days and Germination rate index, 37.46; Co-efficient velocity of germination,9.15 and Timson germination rate index 17.14); Photosynthetic pigments (chlorophyll a 6.05 mg g^{-1} FW; chlorophyll b 1.90 mg g^{-1} FW, total chlorophyll 7.95 mg g^{-1} FW, and total carotenoids 2.46 mg g^{-1} FW) and growth attributes (shoot length ,9.29 cm; root length, 10.04 cm ; seedling dry weight, 0.037 mg) traits. Whereas, the lowest germination (Germination percentage, 56%; Mean Germination Time, 13.18 days and Germination rate index,21.71;co efficient velocity of germination 7.04; Timson germination rate index,10.35); Photosynthetic pigments (chlorophyll a ,3.10 mg g^{-1} FW; chlorophyll b, 1.13 mg g^{-1} FW, Total chlorophyll ,4.23 mg g^{-1} FW, and Total carotenoids, 0.85 mg g^{-1} FW) and growth parameters (shoot length ,7.30 cm; root length, 6.89 cm ; seedling dry weight, 0.016 mg) traits were observed at T_9 treatment. On the other hand, highest level of proline was observed in drought stress plots compared to the control (T_1) condition. Among all the treatments (T_2-T_9) under drought condition, the lowest level of proline observed T_4.

The experiment 2 was related to salinity stress and the treatments were T_1 = Control condition (Tap water + 0 µM MT), T_2 = Moderate salinity stress (6 dS m^{-1}) + 0 µM MT, T_3 = Moderate salinity stress (6 dS m^{-1}) + 50 µM MT, T_4 = Moderate salinity stress (6 dS m^{-1}) + 100 µM MT, T_5 = Moderate salinity stress (6 dS m^{-1}) + 150 µM MT , T_6 = Higher salinity stress (12 dS m^{-1}) + 0 µM MT, T_7 = Higher salinity stress (12 dS m^{-1}) + 50 µM MT, T_8 = Higher salinity stress (12 dS m^{-1}) + 100 µM MT and T_9 = Higher salinity stress (12 dS m^{-1}) + 150 µM MT. From the results of Experiment 2, it was observed that salinity stress plots (T_2-T_9) showed lower performance in respect of germination, seedling growth and photosynthetic traits compared to control condition (T_1). Overall, Germination and Germination contributing parameters such as (Germination percentage, 88.66%; Mean Germination Time 15.29 days, Germination rate index ,36.33: Co-efficient velocity of germination ,7.30; Timson germination rate index ,15.09. Photosynthetic pigments (chlorophyll a 6.31 mg g^{-1} FW; chlorophyll b 2.54 mg g^{-1} FW, Total chlorophyll 8.85 mg g^{-1} FW, and Total carotenoids 7.67 mg g^{-1} FW) and growth traits (shoot length ,13.88 cm; root length, 9.01 cm; seedling dry weight, 0.037 mg) traits. Whereas, the lowest germination traits (Germination percentage, 76%; Mean Germination Time, 13.73 days and Germination rate index,18.86; Co-efficient velocity of germination 7.01;Timson germination rate index,9.54); photosynthetic pigments (Chlorophyll a ,3.60 mg g^{-1} FW; Chlorophyll b, 1.30 mg g^{-1} FW, Total chlorophyll ,4.90 mg g^{-1} FW, and Total carotenoids, 3.80 mg g^{-1} FW) and growth parameters (Shoot length ,6.20cm ; root length, 6.84cm) traits were observed at T_9 treatment. Among all the treatments (T_2-T_9) under salinity condition, the lowest level of proline observed T_4. Overall, from the results of two experiments, it was observed that coriander plants suffered a lot both in drought and saline conditions. However, the application of exogenous MT at different doses considerably improved the germination, growth and physiological traits. Among the all treatments the best result was observed at 100 µM MT application in both water deficit (T_4 = Moderate drought stress (-2 bars) + 100 µM MT) and saline (T_4 = Moderate salinity stress (6 dS m^{-1}) + 100 µM MT) conditions. Therefore, the experiments concluded that melatonin @ 100 µMT could be a suitable dose to improve the drought and salinity tolerance of coriander plants.

key words: Coriander, drought, germination, melatonin, salinity, seedling growth

ACRONYMS AND ABBREVIATION

BARI	: Bangladesh Agricultural Research Institute
cm	: Centimeter
C_a	: Chlorophyll a
C_b	: Chlorophyll b
C_{a+b}	: Total chlorophyll
CRD	: Completely Randomized Design
CV	: Co-efficient of Variation
DAS	: Days after sowing
°C	: Degree Celsius
DW	: Dry Weight
e.g.	: For example
FW	: Fresh Weight
g	: Gram
>	: Greater than
HSTU	: Hajee Mohammad Danesh Science and Technology University
Kg	: Kilogram
<	: Less than
≤	: Less than or equal to
K	: Potassium
L	: Liter
m	: Meter
m^2	: Meter square
µ mole	: Micro mole
µmole g^{-1}	: Micro mole per gram
µg	: Micro-gram
µg/g^{-1}	: Micro-gram per gram
mg g^{-1}	: Milligram per gram
ml	: Milliliter
mm	: Millimeter
mmol	: Millimole
M	: Molar
viz.	: Namely

no.	: Number
%	: Percent
pH	: Potential of Hydrogen
P	: Probability value
S	: Salinity
SRDI	: Soil Resource Development Institute
Syn.	: Synonym
TGI	: Timson Germination Index
t ha^{-1}	: Ton Per hectare

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CHAPTER 1

INTRODUCTION

Coriander (*Coriandrum sativum* L.) is a medicinal plant that belongs to the Apiaceae (Umbelliferae) family, which has food, pharmaceutical, and cosmetic potentialities (Khan *et al.*2022). It is an annual, herbaceous plant that originated from the Mediterranean and Middle Eastern regions and grows up to 25–60 cm in height. It has thin, spindle-shaped roots, erect stalk, alternate leaves and small, pinkish-white flowers. The plant is cultivated for its aromatic leaves and seeds (Burdock and Carabin *et al.*2009). Coriander is one of the important and earliest seed spice crops known to mankind (Meena *et al.*2014), which can be dated back to the history of the Queen of Sheba who visited King Solomon mentioned in the Holy Bible. The aromas and flavors have for many years attracted the attention of man is due to the presence of a pleasant aromatic odor or essential oil rich in linalool found in the stem, leaves and fruits of coriander. Flowers are white, having slightly brinjal-like shades while fruit are round (Mengesha *et al.*2013; Kassahun *et al.*2018). Coriander has been known since very ancient times Coriander is considered to have originated in the Mediterranean area and transferred eastward to Asia. This study was conducted to investigate the various characteristics of coriander, clarify its distribution in Asia and analyze the dissemination pathway from the origin to Asia. In Indian Subcontinent, both leaves and seeds are utilized commonly utilized, but roots are not utilized, while in China and Thailand leaves and roots are main parts of utilization. Local varieties in India and Bangladesh have big ellipsoidal seeds, while those in China and Thailand have small globular ones. In Thailand, varieties with big globular seeds are also cultivated, but they are imported from foreign countries. Although European varieties require long-day lengths for flowering, both Indian and Thai varieties flower under rather short-day lengths in the early part of the dry season (November to February). Chinese and Indian coriander may have moved independently from their origin and developed their Coriander in Thailand is considered to have been transferred not from India but from China. (Sharma *et al*.2012). The origin of coriander is uncertain, with the area suggested by most authors being the Near East (Diederichsen, 1996; Arif *et al.* 2014). The author Mengesha (2010) for example suggested a much wider origin for coriander which includes central Asia, the Near East and Abyssinia. The others mention central Asia and Mediterranean countries (Vaidya *et al.*2000; Meena *et al.*2014). The dried fruits are widely employed as a condiment, especially for flavoring sauces, meat products and bakery and confectionery items. Also, coriander fruits are a source of essential oils and fatty oils. Water deficit stress is one of the most important factors limiting the growth and survival of plants in arid and semi-arid regions of the world. Water is a major component of fresh produce and significantly affects the weight and quality of plants. Also, water deficit may cause significant changes in the yield and composition of essential oils in aromatic and medicine plants. So that was reported that water deficit increased essential oil percentage in coriander but decreased essential oil yield. Iran with an average annual rainfall of 240 mm is included among arid and semi-arid regions of the world. The million hectares of cultivated region, only five million are under irrigation because of intense water limitations. However, Iran is one of the world's commercial coriander producers. Coriander has been cultivated for many years in different parts of Iran. Therefore, development of drought-tolerant cultivars with high essential oil yield is important in coriander. This research was conducted in order to evaluate the effect of drought stress on morphological, physiological and phytochemical characteristics of endemic coriander (Amiripour *et al.*2021; Gholizadeh *et al.*2019).

Fresh juice of coriander is extremely advantageous in curing many deficiencies related to vitamins and iron. One to two teaspoons of its juice, added to refreshing buttermilk, is incredibly beneficial in curing many diseases. Fresh leaves can be eaten as such because of various health benefits however; if it is not harvested freshly seeds mature and ripen in late summer developing a delicate aroma which is then used as a dried spice. Moreover, this plant is used to cure diseases like digestive tract disorders, respiratory tract disorders, and urinary tract infections. Coriander has been reported to possess many pharmacological activities like antioxidant (Darughe *et al.*2012), anti-diabetic (Eidi *et al.*2012), anti-mutagenic (Cortes *et al.*2004), anti-lipidemic (Sunil *et al.*2012), anti-spasmodic (Alison *et al.*1999).

In Bangladesh coriander is generally grown in the Rabi season (October to February) which produces 30-50 t ha^{-1} green plants with higher return (100-200 Taka kg^{-1} fresh green plants) of the farmers. Annual production of coriander in Bangladesh is about 1,838 kg ha^{-1} which cover about 2,985 hectares of land in 2018-19(BBS 2019). But the demand of coriander as green leaves as well as dried seed is higher in Bangladesh and it's increasing day by day.

Coriander is a sensitive herbaceous medicinal plant which showed poor growth and development with reduced leaf area under various abiotic stress conditions such as drought and saline conditions (Khan *et al.*2022, Drunasky and Struve *et al.*2005). Therefore, it's a need to improve the stress tolerance mechanisms of coriander plants in Bangladesh. Since drought stress in most cases results in a decrease in plant development, there is a dire need to find a solution to tackle this adverse impact (Yoosefzadeh Najafabadi *et al*.2018; Hesami *et al*.2020; Jafari and Shahsavar, *et al.*2020). It is well-documented that plant growth regulators play a pivotal role in regulating stress signaling and biochemical and physiological pathways (Hasanuzzaman *et al*.2020). In Bangladesh, there are 2.5 M ha of low-lying coastal lands of which about 1.51 M ha (53%) are affected by salinity (Haque *et al*. 2006; Iftekhar and Islam *et al*.2004). Cropping intensity in saline areas of Bangladesh is relatively low (62 to 144%) compared to the national average (159%) of normal growing conditions (Karim *et al*.1990). Salinity stress exerts a negative influence on plant production and reduces its yield (Ghane *et al*.2011; Parida and Das *et al.*2005). The establishment stage of the plant consists of three parts: germination, emergence, and early seedling growth which are particularly sensitive to substrate salinity (Islam *et al.*2022, Song *et al.*2008, Gulzar *et al.*2003, Jamil *et al.*2005). Salinity decreased germination percentage, root length, callus size, coleoptile length, and seedling growth (Alom *et al.* 2016, Agnihotri *et al*.2006; Bera *et al*.2006). Rapid and uniform seed germination under saline conditions increases early seedling establishment and finally, the yield (Bradford *et al*.1995).Salt induces osmotic stress by declining soil water potentials and water availability, which leads to dehydration at the cellular level; and is strongly linked to the production of reactive oxygen species (ROS) like (superoxide (O_2^-), hydrogen peroxide (H_2O_2) and hydroxyl radicals (OH) damaging the DNA, RNA, and proteins (Younesi *et al.*2013; Stefan *et al*.2013; Kang *et al.*2014).

Scientists stated that with the increasing water stress germination percentage, plant height, 1000 seed weight, seed moisture content, water use efficiency, fresh leaves production, seed and oil yields of coriander significantly decreased (Thakur and Thakuret *et al.*2018, Bajya *et al.*2017; Ghamarnia and Daichin *et al.*2013). Drought stress reduced chlorophyll (Chl) content, but enhanced total soluble sugar (TSS), superoxide dismutase (SOD) and peroxidase (POX) activities of coriander leaves (Jannat *et al.* 2023, Afshari *et al.*2022). The yield and physiology of coriander plants are adversely affected by different levels of salinity (Fredj *et al.*2013; Mishra *et al.*2017; Al-Garni *et al.*2019). Salinity stress generally diminishes vegetation, productivity, and metabolic activities of coriander but abscisic acid (ABA) levels and soluble sugars are elevated (Hassanein *et al.* 2022).

Melatonin is a molecule with multiple functions which has direct tasks in improving the performance of the mitochondrial electron transport chain, scavenging free radicals, protecting antioxidant enzymes from oxidative damage, and increasing antioxidant enzyme activities (Han *et al.* 2017; Ahmad *et al.*2020).The positive effect of melatonin on ameliorating the adverse impact of abiotic stresses has been previously studied in different plants such as maize (*Zea mays*) (Huang *et al.*2019), cucumber (*Cucumis sativus*) (Zhang *et al*.2014), moldavian balm (*Dracocephalum moldavica L.)* (Kabiri *et al*.2018), apple (*Malus domestica*) (Li *et al*.2015), wheat (*Triticum aestivum)* (Ke *et al*. 2018), cotton (*Gossypium hirsutum L*.) (Hu *et al*.2020), mutant barley (Li *et al.*2016), maize (Sun *et al.*2020), rapeseed cultivar (Khan *et al*.2019), tomato cultivar “Qianxi” (Zhou *et al*.2020) soybean (*Glycine max L*.) (Wei *et al*. 2015), and baby Mustard (*Brassica juncea var. gemmifera)* (Di *et al.*2022).However, alleviation of drought stress by melatonin foliar treatment on two flax varieties under sandy soil was assessed by (Sadak and Bakry *et al.*2020).The combine effect of biochar and melatonin was evaluated for improving salinity tolerance in borage plants by modulating osmotic adjustment, antioxidants, and ion homeostasis (Farouk and AL-Huqail *et al*.2022). Melatonin was widely used to ameliorate the adverse impact of salinity stress in different crop plants such as rice (Liu *et al*.2020), wheat (Zhang *et al.*2022), maize (Ren *et al.*2020), cotton (Jiang *et al*.2021, Zhang *et al*.2021), cucumber (Liu *et al.*2022), Phaseolus vulgaris bean (Azizi *et al*.2022), strawberry (Zahedi *et al*.2020) and fenugreek (Mohamadi Esboei *et al*.2022).

Some researchers studied the alleviation of water stress in coriander plants by foliar application of boron and silicon (Abdallah *et al.*2022, Afshari *et al.*2022). Besides, Hassanein *et al*, (2022) stated salt-stressed coriander (*Coriandrum sativum L.*) responses to potassium silicate, humic acid and gamma irradiation pretreatments. No study has yet explored the role of exogenous melatonin in improving drought and salinity tolerance in coriander, particularly in Bangladesh. This study aims to fill that gap by investigating melatonin's potential to enhance coriander's stress resilience

The objectives of the investigations were -

1.To assess the seed germination traits of coriander under various level of drought and saline conditions.

2.To observe the influence of seedling growth attributes of coriander under artificially imposed drought and saline environment.

3.To assess the physiological traits of coriander under drought and salinity stresses.

CHAPTER 2

REVIEW OF LITERATURE

Review of literature is a comprehensive summary of previous research on a topic. Considering the importance of drought and salinity tolerance of *Coriandrum sativum,* a number of studies have been reviewed to understand the influence of drought and salinity on germination and growth traits of *Coriandrum sativum*, which are summarized in this chapter.

2.1 Coriander: an amazing spice and culinary herb

Hernández-Almanza *et al.* (2024) coriander (*Coriandrum sativum* L) has been used in culinary as a spice or seasoning as well as an ingredient in perfume and cosmetics in many regions of the world. Nevertheless, despite its multiple applications, for many people still in the 21st century, the coriander has many unbeknownst pharmacological properties**.**

Sánchez-Navarro *et al.* (2024) found that an experiment was carried out in two representative soils from Murcia (SE Spain), one slightly saline (LS) and the other saline (S), where an oat–vetch green manure was intercalated between a spinach cycle and a coriander cycle; the latter being subjected to three different irrigation doses (deficient, optimum and surplus). Rapid response indicators (ECext, cations and anions in the soil solution, etc.) were monitored, as well as the material balances, in particular C and salts. Green manure and crop residues increased soil OC by 12.5% and reduced Na^+ and $NO3^-$ concentrations. Total biomass production was also affected by salinity, both in oat–vetch, 35.9 and 31. 9 tm ha^{-1} in LS and S, respectively, and in the coriander crop, where the irrigation dose was decisive, obtaining around 29 tm ha^{-1} with the optimum and surplus doses and significantly lower amounts with the deficit dose: 20.4 tm ha^{-1} in LSD and 14.0 in SD. Therefore, it is necessary to adjust the irrigation doses, since deficit irrigation significantly reduces production and the surplus does not lead to an increase with respect to the optimum, while also causing ions to leach to depth horizons, as is the case for $NO3^-$, Cl^- and Na^+, with the consequent risk of contaminating the water table.

Mazrou *et al.* (2023) reported that melatonin (MT) has been used to enhance plant growth under various abiotic stresses, although its impact on overcoming drought stress in aromatic plants, including geranium, has not yet been investigated. In the current investigation, MT at 100 µM was applied at 100% (well-watered) or 50% (drought stress) field capacity to verify the role of MT in geranium under drought stress. Drought stress markedly reduced growth parameters, herb yield, and total chlorophyll content; however, MT alleviated these effects. The herb yield of the stressed plants was reduced by 59.91% compared to the unstressed plants, while this reduction was only 14.38% when MT was applied. In contrast, drought enhanced the essential oil percentage in geranium leaves. Despite the reduction in oil yield caused by drought, MT application mitigated this reduction and improved both oil yield and oil components. Moreover, the MT treatment enhanced the accumulation of total phenols, glutathione, and proline and improved the activity of ascorbate peroxidase, catalase, and glutathione reductase, resulting in the alleviation of drought-induced oxidative damage. Consequently, MT reduced both hydrogen peroxide and malondialdehyde accumulation by 71.11 and 48.30%, respectively, under drought, thereby maintaining the cellular structures' integrity. The results enrich awareness regarding the potential benefits of the external application of MT and its roles that can help researchers for improving aromatic plants' performance and productivity under drought stress.

Amiripour et al. (2021) found that this study investigated the effect of Si and salinity on growth, chlorophyll and water content, and the antioxidant capacity of coriander (*Coriandrum sativum* L.) leaves as factorial in a randomized complete block design (RCBD). Foliar application of 50, 100, and 200 mg/L Si and 50, 100, and 200 mM NaCl were applied on 4 leaf plants. The results revealed reduced growth by representing lower shoot and root dry weight through progressing the salinity. 100 and 200 mg/L Si represented a greater role in alleviating the salinity stress on growth properties. Salinity significantly reduced chlorophyll and relative water content (RWC), but they were improved by Si spraying. Total phenol content (TPC) and total flavonoid content (TFC) significantly increased up to 100 mM NaCl and then decreased at 200 mM NaCl. Salinity led to increases in catalase (CAT) and superoxide dismutase (SOD) activity, but higher Si concentrations reduced them 100 mg/L Si and 100 mM NaCl were the best treatment for obtaining the optimum essential oil (EO) percentage and yield. Finally, 100 mg/L Si can be suggested to promote plant growth and yield by changing physiochemical characteristics under medium or severe salinity.

Daničić *et al.* (2021) investigated in the present study, coriander plants were cultivated in half-strength Hoagland nutrient solution containing 0.2,0.6 and 1.2 g NaCl L^{-1} to assess the effect of low concentrations of NaCl on biomass production and mineral nutrients accumulation (Ca, K, Mg, Na, P). The presence of 0.2, 0.6 and 1.2 g NaCl L^{-1} slightly stimulated biomass production. The concentration of Na increased in coriander tissues (up to 4 times relative to control). However, the concentration of K and Ca in leaves of plants treated with 1.2 g NaCl L^{-1} was decreased with respect to control. Based on the findings, even though the biomass of coriander, under applied NaCl concentrations, was slightly increased, the chemical composition of its vegetative organs was severely disrupted by the present salt which is very important for the quality of coriander as a popular herb or spice plant.

Devi *et al.* (2020) stated that coriander (*Coriandrum sativum* L.) is an annual herb that belongs to the family Apiaceae (Umbelliferae) and is commonly known as dhanya. For centuries, the coriander plants and their parts, primarily their leaves and ripe seeds, have been used in folk medicines in addition to culinary uses. This plant is her-baceous and aromatic and is cultivated in several countries, including India, Italy, the Netherlands, Europe, China, and Bangladesh. The coriander plant is rich in essential oils, vitamins (vitamins C and K), minerals (calcium, phosphorous, potassium, thiamine, and niacin), and other micronutrients. The plants are extensively used in the preparation of food items. *C. sativum* essential oil and extracts possess various potential pharmacological properties and has been found to possess carminative, diuretic, stomachic, aphrodisiac, anti-inflammatory, antibacterial, antifungal, and anticancer activities.The present study aims to discuss the botany, traditional uses, medicinal, and industrial applications of coriander extracts and essential oils.

Kern *et al.* (2020) found that Sensitive skin is a common condition that concerns many people in the world. This syndrome is defined by the occurrence of unpleasant sensations such as stinging and burning in response to stimuli that normally should not provoke such sensations. The main hypothesis attributed to the occurrence of sensitive skin is the disruption of the epidermal barrier and greater penetration of substances such as irritants. In keratinocytes, the NF-κB pathway, which plays an important role in orchestrating inflammatory responses, is then activated. Regulation of this activation is a key issue in controlling inflammation. Due to the wide variety of sensory symptoms, neurosensory dysfunction also represents a mechanism to be considered. Some of the cutaneous nerve endings express TRPA1, a sensor of skin barrier insult, which is involved in a variety of physiological or cellular processes including nociception, itch and neurogenic inflammation. Regulation of such sensor activation is also an issue to consider to control neurosensory dysfunction. Coriander seed oil is a 100% virgin oil of coriander seeds and boasts a unique composition of fatty acids. The soothing effect of coriander seed oil on sensitive skin was investigated by studying its capacity to regulate NF-κB and TRPA1 activation. Coriander seed oil allowed the regulation of NF-κB activation induced by TNF-α in an in vitro model of inflammation in keratinocytes. It also regulated the activation of TRPA1 induced by allyl isothiocyanate in an in vitro model of keratinocytes-neurons co-culture. These results are in favour of the soothing effect of coriander seed oil.

Ashraf *et al.* (2020) found that Coriander, an annual herb of the Apiaceae family, falls among one of the most traditionally used herbs in cooking as a nutritional supplement or taste enhancer. Coriander leaves contain antioxidants that inhibit unwanted oxidation processes. Although all parts of this plant have good medicinal importance, coriander seed oil has a special place in folk medicine and has been successfully used to treat anxiety, depression, and Alzheimer's disease. For the extraction of coriander seed oil, techniques like cold pressing and Soxhlet extraction with a variety of extraction solvents were used. Generally, the techniques based on organic solvents offer higher recovery rates, but they may add incorrigible chemical contaminants and compromise the essential oil nutrients. In this context, supercritical fluids and cold press-type extractions were found to be clean, benign, and eco-friendly approaches, but the former needs a relatively very high capital investment so is rarely used for the extraction of coriander seed oil. This chapter covers different extraction techniques for coriander seed oil with the main focus on cold press extraction. It will also provide a bioactive profile of coriander seed oil and its functionality and different medicinal applications.

Vojodi Mehrabani *et al*. (2018) studided the effect of salinity on some morphological and physiological traits of (*Coriandrum sativum* L.). The factors were arranged as factorial based on randomized complete block design with five NaCl levels (0, 50, 100, 150 and 200 mM NaCl) and local ecotypes (Tabriz, Malayer) with three replications. The results revealed that there was interaction of salinity levels with ecotypes in terms of proline content and relative water content. The highest amounts of proline content (77 μg^{-1} FWt) were recorded for the Tabriz clone under 200 mM NaCl. The greatest relative water content was obtained by Tabriz clone × NaCl 0 and Malayer × NaCl 0 and 50-mM combinations. The highest dry weight of leaves, K+/Na^+ ratio and K+ belonged to the non-salinity condition. The highest amounts of Na^+ accumulation, MDA and H2O2 level and ion leakage were attained with 200 mM NaCl level. Soluble sugar content was affected by both salinity and ecotype. The highest content of soluble sugars was achieved by the Malayer ecotype. With increasing salinity levels, the content of soluble sugars increased and the highest amount of soluble sugars content was recorded at 200 mm.

Silva *et al.* (2017) investigated that foodborne illness represents a major economic burden worldwide and a serious public health threat, with around 48 million people affected and 3,000 deaths each year only in the USA. One of the possible strategies to reduce foodborne infections is the development of effective preservation strategies capable of eradicating microbial contamination of foods. Over the last few years, new challenges for the food industry have arisen such as the increase of antimicrobial resistance of foodborne pathogens to common preservatives and consumer's demand for naturally based products. In order to overcome this, new approaches using natural or bio-based products as food preservatives need to be investigated. Coriander (*Coriandrum sativum* L.) is a well-known herb widely used as a spice, or in folk medicine, and in the pharmacy and food industries. Coriander seed oil is the world's second most relevant essential oil, exhibiting antimicrobial activity against Gram-positive and Gram-negative bacteria, some yeasts, dermatophytes and filamentous fungi. This review highlights coriander oil antimicrobial activity and possible mechanisms of action in microbial cells and discusses the ability of coriander oil usage as a food preservative, pointing out possible paths for the successful evolution of these strategies towards successful development of a food preservation strategy using coriander oil.

da Silva Sá *et al.* (2016) studied that evaluate the emergence, growth and Phyto mass accumulation of coriander cultivars under saline stress. Two coriander cultivars (C1⁻ 'Verdão SF 177' and C2⁻ 'Português Pacífico') were evaluated under five levels of irrigation water salinity (0.6 control); 1.2; 1.8, 2.4 and 3.0 dS m-1), arranged in a 2 x 5 factorial scheme, in a randomized block design, with four replicates and five plants per replicate. Coriander plants were cultivated on trays of 36 cells with capacity for 0.1 dm3 of substrate, until 20 days after sowing, and evaluated for emergence, growth, Phyto mass accumulation and tolerance to salinity. The increase in irrigation water salinity reduced emergence percentage, growth and Phyto mass accumulation of coriander plants. The results observed in the salinity tolerance index confirmed the results observed for emergence, growth and Phyto mass accumulation, with linear reductions in the tolerance as irrigation water salinity increased.

Okkaoğlu *et al.* (2015) conducted that this study was carried out to investigate the effect of five different salt levels (0,25,50,75,100 m Mol) on some agronomical traits and essential oil content of three coriander cultivars. The results indicated that growth and yield parameters and technological properties of coriander cultivars were affected by salt stress. The highest essential oil rate was obtained from the Kudret-K cultivar with a 75 m Mol salt level.

Neto *et al.* (2014) studied that as a result, shoot dry mass and plant height were reduced by both medium and high-salinity. In roots, although salinity decreased the dry mass, it was more pronounced in plants in high-salinity water irrigated.

Mahendra *et al*. (2011) stated that the essential oil obtained from its fruits at amounts ranging from approximately 0.5 to 2.5% is used both in flavors and in the manufacture of perfumes and soaps. The plant is grown widely all over the world for seed, as a spice, or for essential oil production. It is one of the earliest spices used by mankind. It has been used as a flavoring agent in food products, perfumes and cosmetics. It is used for various purposes such as for flavoring sweets, beverages, tobacco products and baked goods and as a basic ingredient for curry powder. It has been used as an analgesic, carminative, digestive, anti-rheumatic and antispasmodic agent.

Maroufi *et al.* (2010) found that today, public desire for community has increased the use of medicinal plants are the reasons become more wealthy societies, changes in the culture of nutrition, show the destructive effects of chemical drugs, increased use of trust in communities and industrial plants and environmental pollution; so that the use of plants is important in most developed countries as a norm for health. The medicinal and aromatic plants have been an integral part of our daily life for thousands of years. There are cave paintings in which medicinal and aromatic herbs are depicted. To this day, modern research continues to discover the health benefits of plants while illustrating the importance of preserving our ecosystem. The medicinal and aromatic plants are an accessible, affordable and culturally appropriate source of primary health care for more than 80% of the world's population. Coriander is important among the plants due to the essential oil is used in the pharmaceutical industry, cosmetics and health and food productions. Therefore, the objective of this article is to show the use of coriander in daily life people that it has been used centuries ago in the human nutrition. Keywords: Human nutrition, coriander, medicinal plants.

2.2 Effect of drought stress on coriander and other crops

Bistgani *et al.* (2024) reported that drought poses a significant challenge, restricting the productivity of medicinal and aromatic plants. The strain induced by drought can impede vital processes like respiration and photosynthesis, affecting various aspects of plants' growth and metabolism. In response to this adversity, medicinal plants employ mechanisms such as morphological and structural adjustments, modulation of drought-resistant genes, and augmented synthesis of secondary metabolites and osmotic regulatory substances to alleviate the stress. Extreme water scarcity can lead to leaf wilting and may ultimately result in plant death. The cultivation and management of medicinal plants under stress conditions often differ from those of other crops. This is because the main goal of medicinal plants is not only to increase the yield of the above-ground parts but also to enhance the production of active ingredients such as essential oils. To elucidate these mechanisms of drought resistance in medicinal and aromatic plants, the current review provides a summary of recent literature encompassing studies on the morphology, physiology, and biochemistry of medicinal and aromatic plants under drought conditions. Abdallah *et al*. (2022) found that this study was undertaken during the 2020 and 2021 seasons. Field experiments were conducted at the Experimental Farm of South Tahrir Research Station in the El-Bustan area, El-Beheira Governorate, Agricultural Research Center, Egypt. The influence of different irrigation levels and boron foliar spray on the vegetative growth, yield and essential oil of the coriander plant (*Coriandrum sativum* L.) grown in sandy soil was investigated. The treatments comprised four-drip irrigation levels (60, 80, 100 and 120%) of crop evapotranspiration (ETc) and four boron rates (0, 50, 100 and 150 ppm) in a split-plot design with three replicates. The results revealed that both irrigation and boron foliar application significantly affected growth characteristics, yield and essential oil content of coriander plant. Maximum mean values of growth characteristics and fruit yield were achieved with the highest amount of irrigation water (120% ETc) which showed non-significant differences with the lower irrigation level (100% ETc). The least mean values of growth characteristics and yield parameters were obtained at an irrigation level of (60% ETc) in untreated boron application. The results showed that essential oil yield increased at moderate water stress (80% ETc) with boron foliar application at 150 ppm thereby improving fruit quality. The highest values of crop coefficient (Kc) of coriander were obtained in April with a mean value of 0.64 at the experimental site. The mean values of water consumptive use were 1201 m3/feddan during the growing season. Therefore, spraying boron at 150 ppm could serve as a promising approach under moderate water stress (80%) conditions to maximize coriander yield and quality in sandy soils.

Chowdhury *et al*. (2021) found that the increasing human population and changing climate, which has given rise to frequent drought spells, pose a serious threat to global food security, while identification of high-yielding drought-tolerant genotypes remains a proficient approach to cope with these challenges. To offer a methodology for the evaluation of the drought-tolerant wheat genotypes based on the pheno-physiological traits, a field experiment was executed, entailing four wheat genotypes viz. BARI Gom 26, BAW 1158, BAW 1167, and BAW 1169 and two water conditions viz. control treatment (three times irrigation at 20, 50, and 70 DAS, i.e., 100% field capacity) and stressed treatment (no irrigation during the entire growing season). The results revealed that drought stress drastically reduced the days to booting, heading, anthesis and physiological maturity, relative water content (RWC), chlorophyll content, canopy temperature depression (CTD), and photo-assimilates-spike dry matter (SDM), grains spike^{-1} and grain yield of all wheat genotypes. In addition, the genotypes BAW 1167 and BARI Gom 26 remained more prone to adverse effects of drought as compared to BAW 1169 and BAW 1158. Furthermore, DS induced biosynthesis of compatible solutes such as proline, especially in BAW 1169, which enabled plants to defend against oxidative stress. It was inferred that BAW 1169 remained superior by exhibiting the best adaptation as indicated by the maximum relative values of RWC, total chlorophyll, CTD, proline content, SDM, grains spike^{-1}, and grain yield of wheat. Thus, based on our findings, BAW 1169 may be recommended for general adoption and utilization in future wheat breeding programs aimed at developing potent drought-tolerant wheat genotypes to ensure food security on a sustainable basis.

Vinila *et al*. (2020) carried out an experiment to screen the coriander germplasm for drought tolerance at various Locations in Horticultural College and Research Institute, TNAU, Coimbatore. Preliminary screening was done with 240 accessions and 50 accessions were selected based on yield performance along with check CO (Cr) 4 and were raised in the main field in a Randomized Block Design in three replications. The crop was grown purely under rain-fed conditions. Biochemical parameters were measured during crop growth. A considerable reduction was noticed in biochemical components such as soluble protein contents and NRase activity. In contrast, proline content was significantly increased under water deficit. The expression of characters under water deficit revealed the tolerant nature of coriander accessions. ACC 18, followed by ACC 87 is thus grouped as drought tolerant accessions and ACC 145, ACC 202, ACC 201, and ACC 230 as drought susceptible accessions.

Thakur and Thakur *et al.* (2018) conducted an experiment that plant growth is seriously affected by abiotic stresses and drought is one of the most important limiting factors. Drought stress during the early reproductive growth stage usually reduces the seed yield and seed quality. To assess the effect of drought stress on seed yield and seed quality of coriander, the experiment was conducted in a greenhouse in plastic pots at Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan (H.P.) during the Rabi season of 2012–13. Coriander cv. Solan Selection was used as a test crop. There were four treatments of Water stress i.e. T_1-Control, T_2-25%, T_3-50%, and T_4-75% Water deficit was imposed at the flower forming phase for 15 days. The treatments were arranged in a design CRD (Completely Randomized Design) with four replications. Data were recorded and results indicated a significant reduction in plant height stress index, dry matter index, biological yield, number of seeds per plant, harvest index (HI) and yield stability ratio and also observed per cent reduction in 1000 seed weight, seed moisture content and germination percentage. On other hand there where per cent increase in solute leakage, mean germination time.

Bajya *et al.* (2017) stated that eight coriander varieties viz. Rcr-20, Rcr-41, Rcr-435, Rcr-436, Rcr-446, Rcr-475, Rcr-684 and Rcr-728 were conducted at the research farm of S.K.N. College of Agriculture, Jobner (Rajasthan) during Rabi, 2016 in randomized block design with three replications on loamy sand soil under control condition plot were irrigated at regular interval while in drought condition plots were maintained under rainfed condition. Yield and yield contributing parameters were recorded at maturity stages and after harvesting. The Coriander varieties Rcr-20 and Rcr-446 behaved as drought tolerance varieties and maintained higher seed yield along with the number of umbels per plant, seeds per umbel, test weight, seed yield, biological yield, and harvest index under drought conditions. The coriander varieties Rcr-435 and Rcr-728 were maintained under higher seed yield along with the number of umbels per plant, seeds per umbel, test weight, seed yield, biological yield, and harvest index under control conditions.

Moosavi *et al*. (2014) studied the effect of drought stress at different growth reproductive stages and N fertilizer rates on some morphological and quantitative traits and water use efficiency (WUE) of fennel (Foenicolum vulgare Mill), an experiment was conducted as a split-plot based on a Randomized Complete Block Design with three replications, at Research Field of Islamic Azad University of Birjand Branch in 2010. The main plot included irrigation at three levels (irrigation stop at the start of flowering, and seed-filling stages, and optimum irrigation) and the sub-plot was N fertilizer at four rates (0, 60, 120 and 180 kg N/ha). Results showed that irrigation stop at the start of flowering and seed-filling stages decreased plant height by 16.2 and 5.2%, fruit yield by 69.7 and 52.6%, essential oil yield by 72.9 and 31.4%, and WUE for essential oil production by 69.1 and 4.5%, respectively as compared to optimum irrigation treatment. Moreover, the increase in rate of nitrogen application from 0 to 120 kg N/ha significantly increased plant height, stem diameter, branch number of main stem and fruit yield, 5.8, 12, 15.5 and 24.3%, respectively. However, the highest yield and WUE for essential oil production was observed in 60 kg N/ha application treatment. In general, according to the results of the current study, optimum irrigation with 60 kg N/ha application treatment can be recommended to achieve a high essential oil yield of fennel in Birjand, Iran.

Jamali *et al.* revealed that (2013) field experiment was carried out by split factorial design with 3 replications. The factors studied included two levels of irrigation, irrigation after 30 mm evaporation from the evaporation pan (without drought stress condition), and irrigation after 70 mm evaporation from the evaporation pan (drought stress condition), nitrogen levels were N_0, N_{60}, N_{90}, N_{120} kg/ha and phosphorus levels were P_0, P_{80}, P_{100}, P_{120} kg/ha. The results showed that irrigation, nitrogen and phosphorus fertilizers had significant effect on seed weight, weight per plant, 1000 seed weight and plant height. Means comparison showed that the highest plant height and weight per plant was obtained from irrigation after 30 mm evaporation from the evaporation pan and application of 120 kg/ha nitrogen and 120 kg/ha phosphorus. The highest seed weight and 1000 seed weight were obtained from irrigation after 30 mm evaporation from the evaporation pan and application of 90 kg/ha nitrogen and 100 kg/ha phosphorus. A field experiment was carried out by split factorial design with 3 replications. The factors studied included two levels of irrigation, irrigation after 30 mm evaporation from the evaporation pan (without drought stress condition), and irrigation after 70 mm evaporation from the evaporation pan (drought stress condition), nitrogen levels were N_0, N_{60}, N_{90}, N_{120} kg/ha and phosphorus levels were P_0, P_{80}, P_{100}, P_{120} kg/ha. The results showed that irrigation, nitrogen and phosphorus fertilizers had significant effect on seed weight, weight per plant, 1000 seed weight and plant height. Means comparison showed that the highest plant height and weight per plant was obtained from irrigation after 30 mm evaporation from evaporation pan and application of 120 kg/ha nitrogen and 120 kg/ha phosphorus. The highest seed weight and 1000 seed weight were obtained from irrigation after 30 mm evaporation from the evaporation pan and application of 90 kg/ha nitrogen and 100 kg/ha phosphorus.

Bashtanova *et al.* (2012) reported that drought resistance of crops is one of the great challenges for the world's agricultural systems. Although the concept of 'drought hardening' has been known for many years, very little has been done on pre-harvest treatment that can help leafy vegetable crops resist drought stress on a retailer's shelf. Our hypothesis was that for pot grown vegetables a saline treatment could be found that would reduce transpiration pre and post-harvest, but not harvestable yield

Farahani *et al.* (2009) found that drought stress is especially important in countries where crop agriculture is essentially rain-fed. Drought stress causes an increase in solute concentration in the environment, leading to an osmotic flow of water out of plant cells. This in turn causes the solute concentration inside plant cells to increase, thus lowering water potential and disrupting membranes along with essential processes like photosynthesis. These drought-stressed plants consequently exhibit poor growth and yield. In worst-case scenarios, the plants completely die. Certain plants have devised mechanisms to survive under low water conditions. These mechanisms have been classified as tolerance, avoidance or escape. Also, medicinal and aromatic plants have been an integral part of our daily life for thousands of years. There are cave paintings in which medicinal and aromatic herbs are depicted. To this day, modern research continues to discover the health benefits of plants while illustrating the importance of preserving our ecosystem. This review may give applicable advice to commercial farmers and medicinal and aromatic plant researchers for the management and proper use of water in medicinal and aromatic plant farming under drought conditions and increase the quantity and quality characteristics of medicinal and aromatic plants in arid and semi-arid areas.

2.3 Effect of salinity stress on coriander and other crops

Bistgani *et al.* (2024) reported that drought poses a significant challenge, restricting the productivity of medicinal and aromatic plants. The strain induced by drought can impede vital processes like respiration and photosynthesis, affecting various aspects of plants' growth and metabolism. In response to this adversity, medicinal plants employ mechanisms such as morphological and structural adjustments, modulation of drought-resistant genes, and augmented synthesis of secondary metabolites and osmotic regulatory substances to alleviate the stress. Extreme water scarcity can lead to leaf wilting and may ultimately result in plant death. The cultivation and management of medicinal plants under stress conditions often differ from those of other crops. This is because the main goal of medicinal plants is not only to increase the yield of the above-ground parts but also to enhance the production of active ingredients such as essential oils. To elucidate these mechanisms of drought resistance in medicinal and aromatic plants, the current review provides a summary of recent literature encompassing studies on the morphology, physiology, and biochemistry of medicinal and aromatic plants under drought conditions

Ahmed *et al.* (2024) found that salt stress causes deleterious impacts on the germination, growth, and productivity of various crop plants. Screening new cultivars regarding salt stress tolerance could enhance the growth and productivity of sorghum. In this regard, an experiment was conducted at the laboratory of the Department of Agronomy, Hajee Mohamad Danesh Science and Technology University (HSTU), Bangladesh, in October 2018 to find out salt tolerance based on seed germination and seedling growth traits. The experiment consisted of seven sorghum varieties, viz. Adan Gab, Karmici, Debuday, ESP/S01, Green Jambuplus, Jambo, and Elmi Jama, and three levels of salt stress, viz. 0, 100, and 200 mM NaCl induced salt stress, laid out a completely randomized design (CRD) with three replications. The seeds of the seven sorghum varieties were placed in plastic trays (20 cm x 10 cm) on a sand bed irrigated with tap water (control) and NaCl (100 and 200 mM salinity levels) solutions. Data were collected on germination character and seedling growth at parameters. The collected data were analyzed statistically and means were adjudged by DMRT at 1 and 5% level of probability. The results of the experiment revealed that salinity stress significantly reduced the germination percentage (GP) and germination rate (GR) of sorghum in all sorghum varieties, and the variety Debuday showed the highest values of GP and GR, while Karmici showed the lowest values under 100 and 200 NaCl stress. Moreover, the root and shoot lengths, fresh weights, and dry weights gradually decreased with salinity levels, and the minimum reduction was recorded in Debuday, whereas the maximum reduction was in the Karmici variety. Higher Na and lower K accumulation of the Debuday genotype can be treated as salt tolerant. Contrary, the salt tolerance index (STI) based on the root and shoot dry weight in the Debuday variety exhibited the highest values, and the Karmici variety exhibited the minimum values under salt stresses. The inhibition of GP and GR, and lengths and biomass weight of root and shoot, were at the minimum level, while, on the contrary, the values declined superficially in the Karmici variety. Therefore, it can be concluded that the variety Debuday is indorsed as a salt-tolerant sorghum variety, and Karmici is a more susceptible one, based on the seed germination and seedling growth properties.

Saddiq *et al.* (2021) carried out of an experiment determined the effects of salinity on five spring and five winter wheat genotypes seedlings. We evaluated the salt stress on root and shoot growth attributes, i.e., root length (RL), shoot length (SL), the relative growth rate of root length (RGR-RL), and shoot length (RGR-SL). The ionic content of the leaves was also measured. Physiological traits were also assessed, including stomatal conductance (gs), chlorophyll content index (CCI), and light-adapted leaf chlorophyll fluorescence, the quantum yield of photosystem II (Fv′/Fm′) and instantaneous chlorophyll fluorescence (Ft). Physiological and growth performance under salt stress (0,100, and 200 mol/L) were explored at the seedling stage. The analysis showed that spring wheat accumulated low Na^+ and high K^+ in leaf blades compared with winter wheat. Among the genotypes, Sakha 8, S-24, W4909, and W4910 performed better and had improved physiological attributes (gs, Fv′/Fm′, and Ft) and seedling growth traits (RL, SL, RGR-SL, and RGR-RL), which were strongly linked with proper Na^+ and K^+ discrimination in leaves and the CCI in leaves. The identified genotypes could represent valuable resources for genetic improvement programs to provide a greater understanding of plant tolerance to salt stress.

Konuşkan *et al.* (2017) reported that maize is known as a salt-sensitive species. The salt tolerance level identification in the large genetic resources and breeding populations is an important research topic for solving the salinity problem. The effects of NaCl stress on germination and seedling growth of fifteen maize genotypes were investigated in this study. Electrical conductivity (EC) values of the NaCl were settled 0 (distilled water), 4, 6, 8, 10 and 12 dS m^{-1}. This investigation was performed as factorial arrangement of completely randomized design with four replications. Analysis of variance (ANOVA) showed that genotypes, salinity levels and interaction between genotype x salinity were significant for all the investigated treatments emergence index (EI), root dry weight (RDW), shoot dry weight (SDW), root length (RL), shoot length (SL), and salt tolerance indexes (STI). Results also revealed that the highest reduction in the emergence index (59.7%) was obtained in the highest level (12 dS m-1) of salinity. The results further revealed that the cultivars named DKC 6589, PR31G98, and PR31A34 were the most tolerant genotypes than the others under NaCI stress. Maize is a very important cereal all over the world and is generally cultivated in irrigated agricultural areas. Salinity affects adversely maize productivity in these areas. Maize is known as a salt-sensitive species. The salt tolerance level identification in the large genetic resources and breeding populations is an important research topic for solving the salinity problem. The effects of NaCl stress on germination and seedling growth of fifteen maize genotypes were investigated in this study. Electrical conductivity (EC) values of the NaCl were settled at 0 (distilled water), 4, 6, 8, 10 and 12 dS m^{-1}. This investigation was performed as a factorial arrangement of completely randomized design with four replications. Analysis of variance (ANOVA) showed that genotypes, salinity levels and interaction between genotype x salinity were significant for all the investigated treatments emergence index (EI), root dry weight (RDW), shoot dry weight (SDW), root length (RL), shoot length (SL), and salt tolerance indexes (STI). Results also revealed that the highest reduction in the emergence index (59.7%) was obtained in the highest level (12 dS m^{-1}) of salinity. The results further revealed that the cultivars named DKC 6589, PR31G98, and PR31A34 were the most tolerant genotypes than the others under NaCI stress.

Ewase *et al.* (2013) carried out of experiment to study the effect of salinity stress on seed germination and plant growth of Coriander (*Coriandrum sativum* L.) by the selection method. For this purpose, four treatments of different concentrations of NaCl were used, namely: 0, 1000, 2000, 3000, and 4000 ppm of NaCl. The following parameters: seed germination, root number and length, plant strength, number of leaves, plant length, shoot tip necrosis, and the percentage of survivals were recorded. The Obtained results showed that all growth parameters were reduced by increasing the NaCl concentration except for the percentage of shoot tip necrosis which was increased with a significant difference among all treatments. Coriander plants were found to resist salinity up to the concentration of 3000 ppm NaCl only.

Neffati et al. (2010) reported that the influence of salt stress on vegetative growth, essential oil content, and composition of Tunisian coriander (Coriandrum sativum L.) grown in hydroponic culture was investigated. The volatile constituents of stems and leaves were isolated by hydro-distillation and analyzed by GC and GC/MS. Seedlings were treated with different levels of salt stress (25 mM, 50 mM and 75 mM NaCl). Results showed that the stem and leaf biomasses were not affected under 25 mM NaCl, compared to the control, although it decreased significantly at 50 mM and 75 mM. Essential oil content was 1762.64 μ/g DW (0.18%) and 1255.77 μ/g DW (0.12%) in stems and leaves, respectively. At low and moderate stress, a significant difference in the essential oil content was developed between stems, with a significant decrease, and leaves, with an increase up to 43%. Under high salinity, the oil content of both organs decreased significantly. The major volatile compound of stems and leaves was (E)-2-decenal with 24% and 52%, respectively. Other important components were decanalled, (E)-2-dodecenal, dodecanal, (E)-2-undecenal, (E)-2-tridecenal and (E)-2-undecanal. Further, the content of these compounds was affected differently by the treatment level and by the organ type.

Uddin et al. (2005) carried out a pot experiment at the Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh, to evaluate salinity tolerance of mustard/rapeseed cultivars viz., BINAsarisha-5, BINAsarisha-6 and Safal during October 2003 to January 2004. Salinity levels were 4, 6, 8 and 10 dSrm with a control (0.43 dSm). Plant height, leaf area, total dry matter, number of siliquae per plant, number of seeds per siliqua, 1000 seed weight and harvest index were decreased with the increase of salinity compared to control. Na+ content in leaves increased but K+ content decreased with the increase of salinity. BINAsarisha-6 showed the highest number of siliquae, seed yield per plant, harvest index, higher Na+ and medium K+ content in leaves and BINAsarisha-5 showed the highest number of seeds per siliqua, 1000 seed weight, lower Na+ and higher K+ content in leaves under the salinity levels. On the other hand, Safal showed the lowest number of seeds per siliqua, seed yield, higher Na + and the lowest K+ content in leaves. BINAsarisha-6 and B1NAsarisha-5 were found to be tolerant and Safal was less tolerant to imposed salinity.

Cicek *et al.*(2002) investigated the effect of salinity with different osmotic potentials on shoot length, total fresh and dry weight, amounts of organic (proline) and inorganic (K^+ and Na^+) substance of leaf tissue, the Na^+ /K^+ ratio, and leaf area, relative water content (RWC) and leaf osmolality in two maize (*Zea mays* L,var. intendata, C.6127 and DK.623) cultivars which are grown as a second yield in the Southeastern Anatolia Region (SAR) of Turkey, were investigated. Plants were grown for 30 days in the controlled growth room. Salinized culture solutions at different osmotic potentials (0, -0.1, -0.3 and -0.5 MPa) prepared by adding varying amounts of NaCl and $CaCl_2$ to the main culture solution were applied to plants from the beginning of the germination. As a result, the shoot length, total fresh and dry weight and leaf area decreased, amounts of proline Na^+, Na^+ /K^+ ratio and the leaf osmolality increased, but amounts of K^+ did not change significantly with increasing stress, and salt stress caused a similar decrease in leaf relative water content in both maize cultivars.

Islam *et al.* (2001) found that Varieties Rai-5, Shambal and Daulat of *Brassica juncea* and varieties BARI Sarisa-7 and BARI Sarisa-8 of *Brassica napus* were tested for yield and component characters under different levels of soil salinity. The variations due to salinity levels, varieties and variety-salinity (interaction) were significant for different characters. The variable degrees of increase and decrease of regression coefficient estimates (curve estimation) indicated the performance as influenced by different salinity levels. The performance of the variety Barisarisa-7 in plant height and days to first flowering is the best followed by BARI Sarisa-8 and Daulat. Barisarisa-8 showed the best performance in days to maturity followed by BARI Sarisa-7 and Shambal. Shambal followed by Daulat and BARI Sarisa-7 was performed in case of the number of siliquae per plant. Daulat performed better than others in case of seed per plant and seed yield per plant followed by Rai-5. Considering all the characters the most tolerance ability was found in Daulat under *B. juncea* and BARI Sarisa-7 under *B. napus* which were followed by BARI Sarisa-8 of *B. napus* against different levels of salinity.

2.4 Ameliorating of various stresses using melatonin

Admasie *et al.* (2023) investigated that excess salinity is one of the most important abiotic stresses that negatively affects plant growth and development. Like many other leguminous crops, dry bean (*Phaseolus vulgaris* L.), is classified as a salt-sensitive plant. Researches related to the use of selenium to reduce salinity stress have been increasing in recent years. However, no study has been found in the world literature that shows the effects of this element on reducing salinity stress in dry beans. The main purpose of this study was to determine whether the negative effects of salinity stress on growth, yield, and organic compounds of dry beans could be reduced by foliar selenium applications. Three different foliar application dosages of selenium (0, 5 and 20 ppm) under four different irrigation water salinity levels (control-0.6, low-1.6, moderate-3.0 and high-4.8 dS/m) were tested in the study. It has been shown that the foliar application of selenium, which is suggested to be used to reduce salinity stress in many plants, did not show, in general, a statistically positive trend for almost all growth, yield, and quality parameters in dry beans. Compared to the control salinity treatment, it was revealed that the application of 20 ppm selenium did not affect the salinity threshold value at a significant level, but this application had a very low positive effect on the slope value, which expresses the decrease in yield after the threshold salinity. In general, it was concluded that foliar application of selenium under studied concentrations had a minor effect than expected in improving the tolerance of salinity stress in dry bean. Hussain *et al.* (2023) found that salt stress has a significant impact on agricultural output, affecting seed germination and seedling growth. The uncontrolled production of oxidative species (ROS) induces a range of biochemical, physiological, and metabolic changes, resulting in reduced crop yields. Under such circumstances, seed priming may be a feasible and practicable approach for achieving rapid, uniform emergence, vigorous seedlings, and higher crop yields. The present study was therefore executed to explore the efficacious effects of various seed priming agents, such as hydro-priming (HP), CaCl2 @ 2% (CaP), and melatonin @1000 M (MP) to cope with salt stress in salt-affected fields. A non-priming control treatment (WP) was also included in the trial to allow for a fair comparison of the treatments. Three promising maize genotypes, SB-9617 (V1), YH-1898 (V2), and NCEV-1530-9 were investigated with these priming treatments (V3). The study results depicted that all seed priming methods significantly attenuated the adverse effects of salt stress. However, seed priming with melatonin (MP), on the other hand, improved development and adaptability in maize seedlings under salt-stress conditions. In our findings, melatonin priming (MP) significantly produced the higher total soluble sugar (34.6%), total phenolics contents (61.1%), proline contents (45.1 %), and total soluble protein contents (34.8 %), combined with enhanced antioxidant enzyme activity viz., SOD (32.5%), POD (18.2%) and CAT (17.1%) than un-primed (WP). The improved organic osmolytes coupled with activated enzymatic defense system in melatonin priming (MP) caused a significant reduction of malondialdehyde (MDA) levels (35.1%), H_2O_2 concentration (31.3%) and electrolyte leakage (16.9%) via improving the ROS scavenging activity (15.6%), membrane stability (22.7%) and relative water contents (29.3%) relative to un-primed treatment (WP). The melatonin-primed plants also exhibited the highest crop growth and leaf area indices without causing substantial damage to the chlorophyll contents, resulting in increased radiation interception (PAR) and its usage efficiency with improved yield. Interestingly, SB- 9617 (V2) was proved the outperforming maize genotype in maintaining better crop growth and yield with improved physiological and biochemical characteristics under salt-affected field conditions. The current findings may serve as a chunk of scientific information for the researchers to disclose further the unexplored aspects of the salt tolerance mechanism in maize crops to achieve sustainability in crop yield in salt-affected soils.

Luo *et al.* (2023) investigated that drought stress imposes a serious threat to crop productivity and nutritional security. Drought adaptation mechanisms involve complex regulatory network comprising of various sensory and signaling molecules. In this context, melatonin has emerged as a potential signaling molecule playing a crucial role in imparting stress tolerance in plants. Melatonin pretreatment regulates various plant physiological processes such as osmoregulation, germination, photosynthesis, senescence, primary/secondary metabolism, and hormonal cross-talk under water deficit conditions. Melatonin-mediated regulation of the ascorbate-glutathione (AsA–GSH) cycle plays a crucial role in scavenging reactive oxygen species generated in the cells during drought. Here, in this review, the current knowledge on the role of melatonin to ameliorate adverse effects of drought by modulating morphological, physiological, and redox regulatory processes is discussed. The role of melatonin in improving the water absorption capacity of roots by regulating aquaporin channels and hormonal cross-talk involved in drought stress mitigation are also discussed. Overall, melatonin is a versatile bio-molecule involved in growth promotion and yield enhancement under drought stress that makes it a suitable candidate for eco-friendly crop production to ensure food security.

Zhao *et al.* (2023) reported that global warming in this century increases incidences of various abiotic stresses, restricting plant growth and productivity and posing a severe threat to global food production and security. Different phytohormones are produced by plants to mitigate the adverse effects of these stresses. One such phytohormone is melatonin (MEL), which, being a potential bio-stimulator, helps to govern a wide array of functions in horticultural crops. Recent advancements have determined the role of MEL in plants' responses to abiotic stresses. MEL enhances physiological functions such as seed germination, growth and development, seedling growth, root system architecture, and photosynthetic efficiency. The potential function of MEL in stressful environments is to regulate the enzymatic and non-enzymatic antioxidant activity, thus playing a role in the substantial scavenging of reactive oxygen species (ROS). Additionally, MEL, as a plant growth regulator and bio-stimulator, aids in promoting plant tolerance to abiotic stress, mainly through improvements in nutrient uptake, osmolyte production, and cellular membrane stability. This review, therefore, focuses on the possible functions of MEL in the induction of different abiotic stresses in horticultural crops. Therefore, this review would help readers learn more about MEL in altered environments and provide new suggestions on how this knowledge could be used to develop stress tolerance.

Hu *et al.* (2021) studied the effects of abscisic acid (ABA) and melatonin (MT) on cotton drought tolerance and to explore their combined effects. ABA or MT spraying promoted the water status and antioxidant capacity of drought-stressed leaves, which was conducive to scavenging ROS, finally increasing lint yield. However, the mitigation mechanisms of ABA and MT on drought were not identical, which were mainly manifested as: (1) ABA increased the relative water content (RWC) of drought-stressed leaves via, reducing water loss, but MT increased it via, promoting water uptake efficiency; (2) for the enzymatic antioxidant system, ABA and MT might modulate different kinds of superoxide dismutase to catalyze the reduction of O2− under drought; and (3) for ascorbic acid (AsA)-glutathione (GSH) cycle, MT increased the glutathione reductase activity in drought-stressed leaves, but ABA did not. ABA + MT spraying led to higher leaf RWC and total antioxidant capacity than single hormone under drought, leading to a lower H2O2 level. For the enzymatic antioxidant system, single hormone treatment affected Cu/ZnSOD or MnSOD expression, but ABA + MT upregulated both genes in drought-stressed leaves Hormones combined application also had higher CAT expression than single hormone. For the AsA-GSH cycle, ABA + MT had higher dehydroascorbic acid reductase activity than a single hormone, resulting in higher AsA content. Moreover, hormones combined application caused higher ascorbate peroxidase activity than single hormone, suggesting that their combination synergistically improved the ability of AsA to eliminate ROS. All these confirmed that ABA plus MT had synergistic effects on improving crop drought resistance.

Rehaman *et al.* (2021) conducted with abiotic stress adversely affects plant growth and metabolism and as such reduces plant productivity. Recognized as a major contributor to the production of reactive oxygen species (ROS), it hinders the growth of plants through the induction of oxidative stress. Bio stimulants such as melatonin have a multifunctional role, acting as a defense strategy in minimizing the effects of oxidative stress. Melatonin plays an important role in plant processes ranging from seed germination to senescence, besides performing the function of a bio stimulant in improving the plant's productivity. In addition to its important role in the signaling cascade, melatonin acts as an antioxidant that helps in scavenging ROS, generated as part of different stresses among plants. The current study was undertaken to elaborate on the synthesis and regulation of melatonin in plants, besides emphasizing its function under various abiotic stresses namely, salt, temperature, herbicides, heavy metals, and drought. Additionally, a special consideration was put on the crosstalk of melatonin with phytohormones to overcome plant abiotic stress.

Bahcesular *et al.* (2020) reported that melatonin has been reported to exhibit significant functions in plant growth and development in response to stress conditions. Along with the present study, the effects of melatonin priming on plant growth and development, essential oil, phenolic acids and antioxidant activities of basil (*Ocimum basilicum* L.) under salinity were examined. In this context, the seeds were firstly primed with 1 and 10 μM melatonin and subsequently, plants were exposed to salinity stress from 100 mM NaCl. The results showed that salinity decreased all growth parameters except leaf number and melatonin treatments were effective in all parameters under stress groups but depending on the dose applied. According to GC–MS/FID results, of the major compounds, eugenol and methly eugenol exhibited decreases whereas linalool increased under salinity. Furthermore, rosmarinic acid, cichoric acid and caffeic acid were identified as major phenolics with HPLC analyses. Under salinity, rosmarinic acid was not detected, cichoric and caffeic acids were decreased while 10 μM melatonin treatments increased all phenolic acids. Salt stress and melatonin applications except salinity with 10 μM melatonin decreased DPPH antioxidant activity, total phenolics and total flavonoids. The salinity with 10 μM melatonin addition favoured for total phenolics and flavonoids.

Sharma *et al.* (2019) reported that rough stress adversely effects physiological and biochemical processes of plants, leading to a reduction in plant productivity. Plants try to protect themselves via activation of their internal defense system, but severe drought causes dysfunction of this defense system. The imbalance between generation and scavenging of reactive oxygen species (ROS) leads to oxidative stress. Melatonin, a multifunctional molecule, has the potential to protect plants from the adverse effects of drought stress by enhancing the ROS scavenging efficiency. It helps in the protection of photosynthetic apparatus and the reduction of drought-induced oxidative stress. Melatonin regulates plant processes at a molecular level, which results in providing better resistance against drought stress.

In this review, the authors have discussed various physiological and molecular aspects regulated by melatonin in plants under drought conditions, along with their underlying mechanisms

Cui *et al*. (2017) reported that melatonin plays an important role in abiotic stress in plants, but its role in wheat drought tolerance is less known. To verify its role, wheat seedlings (*Triticum aestivum* L. 'Yan 995') at 60% and 40% of field capacity were treated with 500 μM melatonin in this study. Melatonin treatment significantly enhanced the drought tolerance of wheat seedlings, as demonstrated by decreased membrane damage, more intact grana lamella of chloroplast, higher photosynthetic rate, and maximum efficiency of photosystem II, as well as higher cell turgor and water holding capacity in melatonin-treated seedlings. Besides, melatonin markedly decreased the content of hydrogen peroxide and superoxide anion in melatonin-treated seedlings, which is attributed to the increased total antioxidant capacity, GSH and AsA contents, as well as enzyme activity including ascorbate peroxidase (APX), monodehydroascorbate reductase (MDHAR), dehydroascorbate reductase (DHAR), glutathione peroxidase (GPX), and glutathione transferase (GST). The GSH-AsA-related genes including *APX, MDHAR,* and *DHAR* were commonly upregulated by melatonin and correlated to the antioxidant enzyme activity as well as the content of GSH and AsA, indicating that the increase of GSH and AsA was attributed to the expression of these genes. Our result confirmed the mitigation potential of melatonin in drought stress and certain mechanisms of melatonin-induced GSH and AsA accumulation, which could deepen our understanding of melatonin-induced drought tolerance in wheat.

Erini *et al.* (2017) carried out a research in order to evaluate the effect of drought and salinity on (*Citrus aurantium* L.) plant physiological characteristics, total phenolic, flavonoid and ascorbic acid contents, and volatile organic compounds. (*C. aurantium*) plants were exposed to different levels of drought and salinity for an experimental period of 60 days. Moderate water deficit (MWD) and 100 mM NaCl increased significantly leaf total phenolic, flavonoid and ascorbic acid contents. Both drought and salinity promoted the accumulation of essential oil in leaves, while MWD and 100 mM NaCl resulted in the highest concentrations of essential oil. The main compounds of the essential oil were linalool, linalyl acetate, neryl acetate, geranyl acetate and α-terpineol. MWD and severe water deficit (SWD) reduced the concentration of hydrocarbon monoterpenes and promoted the accumulation of oxygenated compounds, while treatment with 50 and 100 Mm NaCl, promoted the accumulation of hydrocarbon monoterpenes and reduced oxygenated monoterpene concentrations in *C. aurantium*.

Al-Shammari et al. (2017) reported that the effect of nano-silica and melatonin (75µM) individually or in combination in foliar applications on the morphophysiological, biochemical and yield properties of pea plants under salinity stress conditions was evaluated. Salt stress caused a remarkable decrease in the growth and yield characteristics; for example, the plant dry weight, plant height, number of flowers plant^{-1}, number of pods plant^{-1}, weight of 100 green seeds and protein concentration in the pea plants during both seasons were decreased compared with the control. Similarly, their physio-biochemical characteristics were negatively affected; chlorophyll a, chlorophyll b and the relative water content (RWC) were significantly reduced in the stressed pea plants. However, malondialdehyde (MDA), hydrogen peroxide, electrolyte leakage (EL%), superoxide and the antioxidant components (catalase (CAT), superoxide dismutase (SOD), peroxidase (POX) and total phenolic compounds) were significantly increased when the plants were under salt stress compared with the control plants. On the other hand, the foliar application of nano silica and melatonin individually or in combination enhanced the physio-biochemical characteristics, morphological characteristics and yield of the stressed pea plants. The best treatment was the combination treatment (nano-silica + melatonin), which caused significant increases in the plant dry weight, plant height, number of flowers and pods plant^{-1}, weight of 100 green seeds, protein concentration, chlorophyll concentrations and RWC in the stressed pea plants. Additionally, the combination treatment significantly decreased the EL%, MDA, $O2^{-}$ and H_2O_2 and adjusted the upregulation of the antioxidant enzymes, proline and total phenolic compounds in the stressed plants compared with the stressed untreated pea plants. Generally, it can be suggested that the co-application of nano-silica (50 mLL−1) + melatonin (75 µM) plays a positive role in alleviating the adverse impacts of salinity on pea plants by modifying the plant metabolism and regulating the antioxidant defense system as well as scavenging reactive oxygen species.

Sadak *et al.* (2016) found that mitigation of salinity adverse effects of on wheat by grain priming with melatonin. International Journal of ChemTech Research, 9(2), 85-97A pot experiment was conducted during (2013/2014 & 2014/2015) at the National Research Centre, Dokki, Giza, Egypt, to study the effect of soaking wheat grains with melatonin (ME) (100µM and 500µM) on growth, photosynthetic pigments, IAA, yield quantity and quality in fever of nutritional and antioxidant compounds in the yielded grains of wheat plants irrigated with diluted seawater at 3.85 dS/m and 7.69 dS/m. Salinity stress caused marked decreases in wheat plant growth parameters (shoot height, number of leaves/plant, fresh and dry weights of shoot) with significant decreases in photosynthetic pigments and indole acetic acid (IAA) contents. Yield and yield attributes, carbohydrates, protein, nitrogen, phosphorous and potassium contents were decreased in response to different salinity levels. Meanwhile flavonoids and phenolic contents increased by salinity stress. Antioxidant activity at 50 and 100µg/l showed significant increases in response to salinity stress. On the other hand, ME treatments proved to be effective in enhancing growth parameters, photosynthetic pigments and IAA contents of salinity-stressed plants. Melatonin treatments at different levels caused significant increases in yield and yield attributes, carbohydrate, protein, nitrogen, phosphorous, potassium, flavonoids, phenolic contents, and antioxidant activity of the yielded seeds either in non-stressed and salinity stressed plants relative to their corresponding controls. Generally, 500 µM ME was the most pronounced and effective treatment in alleviating the deleterious effect of salinity stress on wheat plants.

Hasan *et al.* (2015) Identified of physiological markers related to salt tolerance during various vegetative and reproductive stages is crucial for evaluating wheat genotypes and improving their salt tolerance. Two salt-tolerant (Shatabdi and BAW 1135) and two salt-sensitive (BARI Gom 26 and BAW 1122) wheat genotypes of Bangladesh were grown in three salinity levels (control, 6 dS m^{-1}, and 12 dS m^{-1}) to observe the sensitivity of some physiological traits. Salt-tolerant wheat genotypes maintained lower levels of leaf Na, higher levels of leaf K, and greater K/Na ratios in saline conditions than the sensitive ones. Due to salt stress, flag leaf proline content was increased in salt-tolerant wheat genotypes whereas the proline level was decreased in the sensitive one compared to the control. Salt-sensitive genotypes showed a greater increment in SPAD (relative chlorophyll content) value at moderate salt stress but a greater reduction in SPAD values at high salt stress than tolerant ones. Salt-sensitive genotypes were affected more in their straw yield and finally grain yield plants^{-1} under saline conditions than salt-tolerant genotypes. There was a highly significant negative correlation between grain yield and Na content and also a highly significant negative correlation between grain yield and K: Na content of the wheat genotypes under saline environments. Stress susceptibility index (SSI) was also observed by us based on grain yield plant^{-1} the order of tolerance was BAW 1135 > Shatabdi > BARI Gom 26 > BAW 1122 at moderate salinity level and BAW 1135 > Shatabdi > BAW 1122> BARI Gom 26 at high saline conditions.

Mazrou *et al*. (2003) found that as a type of abiotic stress, drought limits plant growth and productivity. The increased demand for the valuable essential oil extracted from geranium (*Pelargonium graveolens* L.) is mainly regulated by plant growth, which is adversely affected by drought. Melatonin (MT) has been used to enhance plant growth under various abiotic stresses, although its impact on overcoming drought stress in aromatic plants, including geranium, has not yet been investigated. In the current investigation, MT at 100 µM was applied at 100% (well-watered) or 50% (drought stress) field capacity to verify the role of MT in geranium under drought stress. Drought stress markedly reduced growth parameters, herb yield, and total chlorophyll content; however, MT alleviated these effects. The herb yield of the stressed plants was reduced by 59.91% compared to the unstressed plants, while this reduction was only 14.38% when MT was applied. In contrast, drought enhanced the essential oil percentage in geranium leaves. Despite the reduction in oil yield caused by drought, MT application mitigated this reduction and improved both oil yield and oil components. Moreover, the MT treatment enhanced the accumulation of total phenols, glutathione, and proline and improved the activity of ascorbate peroxidase, catalase, and glutathione reductase, resulting in the alleviation of drought induced oxidative damage. Consequently, MT reduced both hydrogen peroxide and malondialdehyde accumulation by 71.11 and 48.30%, respectively, under drought, thereby maintaining the cellular structures' integrity. Overall, this is the first report that reveals the ability of MT application to improve geranium oil yield and resistance to drought by enhancing the antioxidant defense system. The results enrich awareness regarding the potential benefits of the external application of MT and its roles that can help researchers to improve aromatic plants' performance and productivity under drought stress.

CHAPTER 3

MATERIALS AND METHODS

The present investigation comprised two distinct experiments drought and salinity to assess germination traits, shoot length, root length and seedling dry weight, physio-biochemical traits, estimation of proline. The Chapter deals with the materials and methods that were used in carrying out the experiment.

3.1 Experimental site

The two experiments were conducted side by side at the Research laboratory of the Department of Crop Physiology and Ecology at Hajee Mohammad Danesh Science and Technology University, Dinajpur, Bangladesh. The exact location of the study was 25°1′51.9″ N latitude and 88° 39′17.1″ E longitude and the elevation was 37.58 meter from the sea level.

3.1.2 Experimental period

The main experiments were performed during the Rabi season within the fiscal year (December 2023 to January 2024). The technical program and methodology of the study are given below.

3.1.3 Germplasm collection

Seeds of BARI Dhonia-2 were collected from Spices Research Center, Bogura.

3.1.4 Melatonin (MT) collection and solution preparation

Melatonin is soluble in organic solvents such as Ethanol and dimethylformamide (DMF). Melatonin was purchased from Sigma-Aldrich (CAS NO 73-31-4) company. For the preparation of melatonin solution at 50,100 and 150 µM concentration, exactly 11.614, 23.228, and 34.642 mg of melatonin were added per liter of solution, respectively. For dissolving the chemical ,0.04 ml of 99.99% ethanol was used for 1mg of MT. The melatonin solution was then properly mixed with water to obtain desired concentration (Cipolla-Neto 2018).

3.1.5 Experimental design and treatments:

The experiments were carried out following a completely randomized design (CRD) with three replications. There were nine sets of treatments in each experiment-

Experiment I: Improvement of drought tolerance of coriander (*Coriandrum sativum* L.) through application of melatonin

T_1 = Control condition (Tap water + 0 µM MT)

T_2 = Moderate drought stress (-2 bars) + 0 µM MT

T_3 = Moderate drought stress (-2 bars) + 50 µM MT

T_4 = Moderate drought stress (-2 bars) + 100 µM MT

T_5 = Moderate drought stress (-2 bars) + 150 µM MT

T_6 = Higher drought stress (-4 bars) + 0 µM MT

T_7 = Higher drought stress (-4 bars) + 50 µM MT

T_8 = Higher drought stress (-4 bars) + 100 µM MT

T_9 = Higher drought stress (-4 bars) + 150 µM MT

Experiment II: Improvement of salinity tolerance of coriander (*Coriandrum sativum* L.) through application of melatonin

T_1 = Control condition (Tap water + 0 µM MT)

T_2 = Moderate salinity stress (6 dS m^{-1}) + 0 µM MT

T_3 = Moderate salinity stress (6 dS m^{-1}) + 50 µM MT

T_4 = Moderate salinity stress (6 dS m^{-1}) + 100 µM MT

T_5 = Moderate salinity stress (6 dS m^{-1}) + 150 µM MT

T_6 = Higher salinity stress (12 dS m^{-1}) + 0 µM MT

T_7 = Higher salinity stress (12 dS m^{-1}) + 50 µM MT

T_8 = Higher salinity stress (12 dS m^{-1}) + 100 µM MT

T_9 = Higher salinity stress (12 dS m^{-1}) + 150 µM MT

In both experiments, tap water with no application of melatonin (0 µM MT) will be the normal growth condition of plants considered as the Control treatment (T_1). Drought stress (-2 and -4 bar water potential) was induced using PEG 6000 (Michel *et al.*, 1983). Saline solutions (6 and 12 dS m^{-1}) was prepared by dissolving calculated amount of NaCl along with tap water. MT (melatonin) was applied as priming of seed before sowing and foliar spray was done at fully expanded two leaf stages in respective treatments. The uniform and healthy seeds were taken and the seeds were surface sterilized with 2% sodium hypochlorite for two minutes and washed thrice with distilled water followed by the seeds were primed in different concentrations of melatonin (50, 100 and 150 µM MT) for 6 hours before sowing of the seed (Anitha *et al.,* 2023).

3.1.6 Seed sowing and seedling evaluation:

Twenty-five seeds of coriander were sown in plastic pots (15 cm in diameter and 6 cm in depth) containing soil and compost mixture (1:1 ratio). The pH and nutrient contents of the soil sample are presented in (Table 1**)** tested in the Soil Resource Development institute (SRDI). A recommended compost use is about 1/4 to 1/2 cup of trico compost (Kazi company). The normal environmental temperature and humidity were ranges from 5.33ºC to 30.55ºC and 85% to 95%, respectively. The plastic pots were irrigated daily with the required amount of respective PEG and saline solution. After evaluating germination traits seedlings was thinned out and five healthy plants were allowed growing up to 30 days for physio-biochemical observation.

Table 1: pH and nutrient status of the soil and compost used in this study

Sample	pH	Organic Carbon (%)	Organic Matter (%)	Total Nitrogen (%)	Phosphorous (µgm/gm) soil	Potassium (meq/100gm) soil	Sulfur (µgm/gm) soil	C: N
Soil	6.60	0.80	5.38	0.07	17.45	0.36	10.41	11.43:1.00
Compost	7.53	7.66	13.21	0.66	328.82	2.52	123.49	11.60:1.00

3.2 Data collection:

3.2.1 Germination traits

Germination was counted at 24-hour intervals and continued up to the 15 th day. A seed was considered germinated as the radicle come out and will attain >2 mm long.

3.2.2 Germination rate (%)

Germination percentage was calculated following Abdel-Haleem and EI-Shainey (2015) as Germination percentage = (Germinated seeds/Total number of seeds) × 100

3.2.3 Mean germination time (MGT)

Mean time to germination (MGT) was measured as the rate and time spread of germination (Soltani *et al*., 2015). Mean germination time was calculated following Al-Mudaris (1998). Mean germination time (MGT) = $\Sigma Fx/\Sigma F$; where F is the number of seeds germinated on day x.

3.2.4 Germination rate index (GRI)

The germination rate index was calculated using the following formula (Al-Mudaris, 1998)

Germination rate index (GRI) = $G1/1+G2/2+.... +Gi/i$

Where, G1 = Germination percentage on day 1, G2 = Germination percentage at day 2; and so on.

3.2.5 Co-efficient of velocity of germination (CVG)

Co-efficient of germination was calculated using the following formulae (Copeland 1976).

Co-efficient of germination = [100 (A1 + A2 + ---------+ An)/A1 T1 + A2 T2 + ---------AnTn]

Where, A = Number of seeds germinated, T = Time (days) corresponding to A, n = No of days to final count.

3.2.6 Timson germination index (TGI)

Many, including the Timson germination index, have been reported as a good indicator of seed germination rate (Al-Mudaris,1998). This index is calculated as the sum of percent germination of seeds at 2-day intervals by the total germination period (Khan & Ungar, 1996). Timson's germination index was calculated using the formula reported by Ajmal Khan and Ungar (1998). Timson germination index (TGI) = $\Sigma G/T$

Where, G = Percentage of seed germinated per day, T = Germination period

3.2.7 Shoot length, root length and seedling dry weight

On the 15th day after placement for germination, all other seedlings were removed from each Petri dish keeping 10 healthy seedlings and allowed to grow for up to 20 days by adding the required amount of respective solution daily. At 20 days after placement for germination, five seedlings from each Petri dish were sampled. The shoot and root length of individual seedlings was recorded manually with scale.

Then the seedlings were dried at 70°C for 72 hours in an electric oven (Model− E28# 03−54639, Binder, Germany) and weight was recorded with an electrical balance.

3.2.8 Physio-biochemical traits

Data on physio-biochemical properties (e.g. photosynthetic pigments, proline content, and soluble sugar content) was recorded at the vegetative stage.

3.2.9 Estimation of Photosynthetic pigments

Photosynthetic pigments chlorophyll a (C_a), chlorophyll b (C_b), total chlorophyll (C_{a+b}) and total carotenoids (C_{x+c}) of the fresh leaf were determined after 5-7 days of melatonin application by following Lichtenthaler (1987) method. Exactly 2.5g of the fresh leaf was taken into a brown colored bottle and 25ml of acetone (80%, v/v) was poured into it. Then the bottle was kept in a dark place for 48 hours for the extraction of pigments into the solution. After that, the solution was taken into a cuvette and the absorbance reading was recorded at 663.2 nm, 646.8 nm and 663.2 nm ,470 nm for determination of Chlorophyll *a*, Chlorophyll *b*, Total Chlorophyll *a+b* and Total Carotenoids *x+c*. According to Lichtenthaler (1987) using the formulate:

$$C_a = 12.25A_{663.2} - 2.79A_{646.8}$$

$$C_b = 21.50A_{646.8} - 5.10A_{663.2}$$

$$C_{a+b} = 7.15A_{663.2} + 18.71A_{646.8}$$

$$C_{x+c} = (1000A_{470} - 1.82C_a - 85.02C_b)/198$$

3.2.10 Estimation of proline

The activity level of proline was determined by following methods described by Bates et al (1973). Exactly ,0.5 g of fresh and fully expanded young leaf was taken and homogenized with 3% sulfosalicylic acid (10 ml) and filtered. From the filtrate,2 ml was taken in a test tube and another 2ml of acid -ninhydrin and 2ml of glacial acetic acid was added to it. The mixture was heated at 100^0 C temperature for 1 hour and the chemical reaction was ended in the ice bath. Then 4ml of toluene was mixed with reaction mixture and extracted. Afterwards, the toluene, which contained the chromophore was aspirated carefully from the aqueous solution and allowed to warm at room temperature. Finally, the absorbance reading was taken at 520 nm using toluene as a blank. The formula used for proline estimation is given below-

The youngest fully expanded leaf of 0.5g of fresh weight was taken for proline estimation. According to Bates (1973) as fresh weight basis:

µmoles proline / g of fresh plant material = {(µg proline / ml × ml toluene) / 115.5 µg / µmoles} / (g sample/5)

3.3 Data analyses

For both experiment all the collected data were statistically analyzed to find out the level of significant using statistix 10 program (https://www.statistix.com/free-trial/).The mean differences were compared by Tukey's HSD Test at $p \leq 0.05$ % level. Relative changes in stress condition over control for all studied parameters were measured using the formula as Relative change = [(Treatment – Control) /Control] × 100. (Ahmad *et al.* 2008; Zhao *et al.* 2020; Singh *et al.*2023).

CHAPTER 4

RESULTS AND DISCUSSION

The results and main findings of the current investigation are presented in several tables and figures. An adequate discussion of the results and possible interpretations, whenever possible, is provided in this chapter.

4.1 Experiment I: Improvement of drought tolerance of coriander (*Coriandrum sativum* L.) through application of melatonin

4.1.1 Germination traits

4.1.1.1 Germination rate (%)

The effects of melatonin on the germination traits of coriander under drought-stress conditions were significant (Table 2). The result of the present research revealed that the highest GP (97.33%) was found in T_1 treatment (control condition) which was statistically similar to T_4, T_5, T_3 and T_8 (95.00, 85.33, 82.00 and 81.11%, respectively). The lowest germination (T_9:76.00%) was found in higher drought stress conditions with 150 µM MT treatments (T_9) followed by moderate drought stress with no melatonin treatment (T_2:76.33%). In case of relative change in germination percentage, it was observed that the GP reduced with the increment of drought stress compared to the control condition. However, due to the application of melatonin to drought stress, it was observed that the reduction of germination percentage was less (-2.39 to -15.75% in moderate drought and -16 to -21.91% in higher drought conditions) compared to drought stress pots without melatonin (-21.57 and -42.46% in T_2 and T_6 treatments, respectively).

Ye *et al.* (2016) reported that the influences of foliar-sprayed melatonin (100 µmol/L) on maize (*Zea mays* L.) seedlings growth during drought stress were investigated in this study. The results suggest that melatonin could be considered as a potential plant growth regulator for the improvement of crop drought tolerance in crop production. Muhammad *et al.* (2023) found that Melatonin-priming significantly ($P < 0.05$) increased seed germination, root length, shoot length, fresh seedling weight, proline content, total soluble protein content, sugar content, chlorophyll content. Additionally, similar the results obtained confirm that priming seeds with melatonin under low germinability conditions relieves stress and improves both germination and seedling growth (García-Cánovas, 2024, Anitha,2019). In addition, Ahmad *et al.* (2019) Foliar application of 100 µM and soil drench of 50 µM melatonin was the most effective treatment concentrations under drought stress.

4.1.1.2 Mean Germination Time (MGT)

Melatonin's effect on mean germination time (MGT) under drought stress is presented in **(**Table 2**)**, The result of the present research revealed that highest MGT (T_1:14.31 days) found in T_1 treatment (control condition). which was statistically similar to the values of T_8, T_3, and T_5 (13.84,13.30, and 13.84 days, respectively). After moderate drought stress with no melatonin treatment (T_2:13.23 days), the lowest Mean Germination (T_9:13.18 days) occurred in severe drought stress conditions including 150 µM MT treatments (T_9). In case of relative change in mean Germination Time it was observed that the MGT increase with the increment of drought stress compared to control condition. However, due to application of melatonin in drought stress pots it was observed that the increase of mean germination time was less (+3.98 to +4.25 in moderate drought, respectively) compared to drought stress pots without melatonin (-0.570 and -0.97, T_2 and T_6 respectively)

Liu *et al.* (2023) observed that 16 µM exogenous MT can effectively improve the mean germination time, germination potential, and vigor index of melon seeds under combined stress, and increase radicle length and fresh weight. Additionally, similar result was observed by several studied state that the results showed that the exogenous administration of 100 µM of melatonin significantly improved the germination rate, mean germination time, germination index, and vigor index of seeds, increased the root: shoot ratio and increased the size of the aboveground and underground biomass (Zeng *et al.*,2022, Okunlola *et al*. 2023, He *et al.*2023, Zhang et al.2013). In addition, Okunlola *et al.* (2023) found that pointed to beneficial effects of foliar application of melatonin in facilitating and improving drought tolerance of *Capsicum* via increased osmolyte accumulation, pigments, and total concentration of inorganic ions under drought conditions. Thakur *et al.* (2018) they also found that the water stress condition not only affects seed germination but also increases mean germination time in crop plants. These results agree with the present findings.

4.1.1.3 Germination rate index (GRI)

Under drought stress conditions, melatonin had a significant impact on the coriander plant's germination rate index characteristics **(**Table 2**)**. The results of the present investigation showed that the T_1 treatment (control condition) had the greatest GRI (T_1:37.46), which was statistically similar to the GRI of T_4, T_8, T_5, and T_9 (36.25, 32.38, 30.90, and 28.09, respectively). The lowest GRI (T_6:21.71) was found in higher drought stress condition plus 50 µM MT treatments (T_3 :27.19) followed moderate drought stress with no melatonin treatment (T_2:25.50). It was found that when drought stress increased, the mean Germination rate index (GRI) reduced in comparison to the control condition. However, it was found that the application of melatonin in these pots decreased the percentage of germination (-3.21 to -27.39 in moderate drought and -24.99and - 42.03 % in greater drought conditions) in comparison to drought stress pots without melatonin (-31.90 and -42.03 %, in T_2 and T_6, respectively).

According to Kamatchi *et al.* (2023) observed that the study evidenced that melatonin pretreatment could effectively enhance seed germination under PEG-induced drought stress in tomato, which, therefore, can be recommended for further research. Shaheen *et al.* (2024) stated that conversely, seed priming with various melatonin levels significantly enhanced the germination rate index in both wheat cultivars under control and drought environments. Yu *et al.* (2022) found that the results show that 100 μM melatonin seed-soaking treatment under high temperature conditions effectively improves the germination potential, the germination index, and the vigor index of rice seeds; increases the length of the shoot and the root; improves the activity of the antioxidant enzymes; and significantly reduces the malondialdehyde content. Oliveira-Spolaor *et al.* (2022) reported that Melatonin (ML) these results demonstrated that ML mitigated negative effects produced by drought on germination and growth of soybean seedlings, and acted as a drought tolerance inducer, improving yield under stress condition.Li *et al.* (2019) revealed that the results revealed that 10 μM melatonin could aggravate the adverse effects of drought stress on germination percentage, germination index, and germination potential of two wheat varieties (JM22 and HG35). However, 300 µM melatonin could obviously alleviate the negative effect of water stress on germination and increase radicle length, radicle number and plumule length of germinated seeds.

Table 2: **Effect of melatonin on germination traits of Coriander under drought condition**

Treatments	GP		MGT		GRI		CVG		TGI	
	%	RC (%)	days	RC (%)	value	RC (%)	Value	RC (%)	Value	RC (%)
T_1	97.33 a	-	14.31	-	37.46 a	-	9.15 a	-	17.14 a	-
T_2	76.33 c	-21.57	13.23	-0.570	25.50 cd	-31.90	7.08 b	-22.54	12.89 ab	-24.82
T_3	82.00 ac	-15.75	13.30	+4.43	27.19 bd	-27.39	7.04 b	-23.02	13.98 ab	-18.46
T_4	95.00 ab	-2.39	13.88	+3.98	36.25 ab	-3.21	7.20 b	-21.71	16.15 a	-5.81
T_5	85.33 ac	-12.32	13.84	+3.98	30.90 ad	-17.49	7.16 b	-21.27	14.22ab	-17.05
T_6	56.00d	-42.46	12.74	-4.30	21.71 d	-42.03	7.44 b	-18.61	10.35 b	-39.63
T_7	77.66 bc	-20.20	13.18	-0.97	28.71 ad	-23.35	7.26 b	-20.58	13.87 ab	-19.09
T_8	81.11 ac	-16.66	13.84	+4.25	32.38 ac	-13.54	7.17 b	-21.63	13.64 ab	-20.41
T_9	76.00 c	-21.91	13.18	-0.999	28.09 ad	-24.99	6.80 b	-25.60	13.24 ab	-22.76
CV (%)	7.67		4.39		11.27		3.80		11.39	
P-value	<0.001		0.1130		0.0004		<0.001		<0.001	
SE value (±)	5.0580		0.4870		2.7436		0.2286		1.2970	

Here, T_1 = Control condition (Tap water + 0 µM MT), T_2 = Moderate drought stress (-2 bars) + 0 µM MT, T_3 = Moderate drought stress (-2 bars) + 50 µM MT, T_4 = Moderate drought stress (-2 bars) + 100 µM MT, T_5 = Moderate drought stress (-2 bars) + 150 µM MT, T_6 = Higher drought stress (-4 bars) + 0 µM MT, T_7 = Higher drought stress (-4 bars) + 50 µM MT, T_8 = Higher drought stress (-4 bars) + 100 µM MT, T_9 = Higher drought stress (-4 bars) + 150 µM MT , GP = Germination percentage, MGT = Mean germination time, GRI =Growth rate index, CVG = Co-efficient velocity of germination, TGI = Timson germination index

4.1.1.4 Co-efficient velocity of germination (CVG)

Melatonin under drought stress conditions had significant effects on coriander CVG traits (Table 1). According to the results of the present investigation, the CVG (T_1:9.15) for the T_1 treatment (control condition) was the highest and was statistically comparable to the values of 7.20, 7.17, 7.16, and 7.04 for the T_5, T_8, T_4, and T_3 treatments. The lowest CVG (T_9:6.80) was observed in the settings with severe drought stress and 150 µM MT treatments (T_9). Moderate drought stress and no melatonin treatment (T_2:7.08) followed.

When comparing the relative change in mean Co-efficient velocity of germination to the control condition, it was shown that the CVG decreased as drought stress increased. However, compared to drought stress pots without melatonin (-18.61 and -23.02 % in T_6 and T_2, respectively), it was found that the application of melatonin in these pots reduced the germination percentage by less (-21.27 to -21.71 % in moderate drought and -21.63 to -25.60 % in higher drought conditions).

Kamatchi *et al.* (2023) stated the results showed that the germination parameters were significantly reduced in stress control; however, notable improvements were observed in melatonin pre-treated seeds. Pretreatment with 100 µM melatonin led to an increase in germination percentage (61%), germination index (150.5), Co-efficient velocity of germination (1010.1) under drought stress. Rajavel *et al.* (2009) found that the present investigation offered a scope for evaluating the seeds through different osmopriming treatments in response to seed and seedling physiology. High significance and reliability were observed in germination (%), Co-efficient of Velocity of Germination (CVG), Vigour Index (VI), shoot and root characters. Anitha *et al.* (2022) observed that among the melatonin treatments, seeds treated with @ 100 µM concentration recorded the highest germination percentage (99.67 %), promptness index (98.80), Germination rate index (1631.68) under PEG induced drought stress condition. Bai *et al.* (2020) found additionally, there was an increase in GRI and CVG, representing faster germination in a shorter time. It is essential that CVG only focus on the time required to attain the final germination percentage.

4.1.2.3 Timson germination index (TGI)

According to drought stress, melatonin has significant effects on coriander's TGI characteristics **(**Table 2). The result of the present research revealed that highest TGI (T_1:17.14) found in T_1 treatment (control condition) which was statistically similar withT_4, T_5, T_3 and T_8 and (16.15,14.22 ,13.98,13.64 and respectively). The lowest TGI (T_9:13.24) was found in higher drought stress condition plus 150 µM MT treatments (T_9) followed moderate drought stress with no melatonin treatment (T_2: 12.89). However, due to application of melatonin in drought stress pots it was observed that the reduction of CVG percentage was less (-5.81, -17.05 in moderate drought and -20.41, -22.76 in higher drought conditions) compared to drought stress pots without melatonin (-18.46 and -19.09, in T_2 and T_6 respectively).

According to, El-Beltagi *et al.* (2022) found that Under 15 and 25 days of drought stress, the MGT, GE, GRI, FGP, TGI, CVG, SVI-I, SVI-II, and RMC were significantly reduced ($p \leq 0.05$. These parameters decrease as the drought level increases in the growth medium. Comparable results from the previous studies show the same decline in agronomic characteristics under water-deficit conditions in carrot, maize, and common vegetables. Taken together, our results demonstrate that AsA and α-toc have the capability to mitigate adverse effects of drought conditions on oat plants by improving gemmation rate and Timson germination index, leaf relative water contents, photosynthetic pigments, and the antioxidant defense system.

4.1.2 Seedling growth traits

4.1.2.2 Shoot length

Melatonin during drought stress has significant impacts on coriander shoot length outcome (Table 3). The current study's results showed that the T_1 treatment (control condition) had the longest shoot length (T_1:9.29 cm). In terms of statistics, this figure was similar to those of T_8, T_4, and T_5 (8.13, 8.41, and 8.70 cm, respectively). After moderate drought stress without melatonin treatment (T_2:7.30 cm), the lowest shoot length (T_9:8.08 cm) was seen under conditions of increasing drought stress, including 150 µM MT treatments (T_9). Shoot length declined as drought stress increased, according to the study, however the percentage of shoot length that decreased in drought stress pots with melatonin treatment was lower than in pots without it (-17.46 and -18.39 %, T_6 and T_2, respectively).

According to Naghizadeh *et al.* (2019) found the obtained results suggested that foliar application of 100 µM melatonin also alleviated oxidative burst and malondialdehyde production in Moldavian balm plant under moderate and severe drought stress probably through regulation of secondary metabolism and the enzymes activity of phenylalanine ammonia-lyase and polyphenol oxidase. Li *et al.* (2022) the Additionally, similar result was observed by several studied state that the seed soaking treatment using melatonin at a concentration of 100 µM under drought stress effectively promoted the germination rate and improved the biomass of rice seed shoots and roots &, that tomato is an important vegetable that is highly sensitive to drought (DR) stress which impairs the development of tomato seedlings Conversely, ME (100 µM) pretreatment and of DR by restoring chlorophyll content chlorophyll content, root architecture, gas exchange parameters of tomato (Li *et al.*2022 Altaf *et al*. 2022) . In addition, (Liu Ling *et al.* 2019) reported that his experiment explored the role of exogenous melatonin (MT) in enhancing the resistance of tobacco seedlings to drought stress. It was found that MT application significantly increased total root length, shoot length.

4.1.2.3 Root length

Melatonin significantly affects root length traits of coriander under drought stress condition. The result of the present research revealed that highest root length (T_1:10.04) found in T_1 treatment (control condition) which was statistically similar with T_8, $T_5$and T_4 and (8.81, 9.20, and 9.29 respectively). The lowest root length (T_9:7.66) was found in higher drought stress condition plus 150 µM MT treatments (T_9) followed moderate drought stress with no melatonin treatment (T_2:6.89). The study found that root length decreased with increased drought stress, but melatonin application reduced this reduction percentage in drought stress pots. However, due to application of melatonin in drought stress pots it was observed that the reduction of root length percentage was less (-7.40, -8.33 in moderate drought and -12.25, -23.63 in higher drought conditions) compared to drought stress pots without melatonin (-31.30 and -31.80, in T_2 and T_6, respectively).

Liang *et al.* (20190 found that however, irrigation with melatonin mitigated the drought-induced impairment in a dose-dependent manner, with the greatest efficiency provided by 100 µM. Melatonin promoted the development of the root system architecture. Zhu *et al.* (2023) found indicated that exogenous melatonin could improve the drought resistance and yield of cotton by promoting root growth and delaying root senescence. Korkmaz *et al.* (2022) stated that results suggested that melatonin application significantly increases the root and shoot growth of the test rootstocks. Besides that, the highest root length was noted from a Flying dragon, while the Carrizo citrange had the highest shoot height.

4.1.2.3 Seedling dry weight

The study found that melatonin had minimal impact on the stress-drought water balance (SDW) parameters of drought-stressed coriander. The T_1 treatment had the highest SDW (T_1:0.037 g plant^{-1}), similar to other treatments (T_3, T_4, T_9, and T_5). The lowest SDW (T_9:0.032 g plant^{-1}) was observed in severe drought stress conditions, including 150 µM MT treatments (T_9). In case of relative change in mean shoot length it was observed that the SDW reduced with the increment of drought stress compared to control condition. However, due to application of melatonin in drought stress pots it was observed that the reduction of SDW percentage was less (-8.10, -27.02 in moderate drought and -48.64, -54.05 in higher drought conditions) compared to drought stress pots without melatonin (-56.75 and -70.27, T_2 and T_6 respectively).

Ahmad *et al.* (2021) conducted that the results showed that drought stress negatively affected the growth behavior of maize seedlings, such as reduced biomass accumulation, decreased photosynthetic pigments, and enhanced the malondialdehyde and reactive oxygen species (ROS)

Table 3: Effect of melatonin on seedling growth traits of Coriander under drought condition

Treatments	Shoot length		Root length		SDW	
	cm	RC (%)	cm	RC (%)	g plant^{-1}	RC (%)
T_1	9.29 a	-	10.04 a	-	0.037	-
T_2	7.30 d	-21.407	6.896 c	-31.30	0.016	-56.75
T_3	7.58 cd	-18.396	7.306 c	-27.22	0.034	-8.10
T_4	8.70 abc	-6.421	9.29 ab	-7.40	0.034	-8.10
T_5	8.41 ab	-9.468	9.20 ab	-8.33	0.027	-27.02
T_6	7.67 cd	-17.464	6.84 c	-31.80	0.011	-70.27
T_7	7.74 bcd	-16.675	7.32 c	-27.09	0.017	-54.05
T_8	8.13 bcd	-12.552	8.81 b	-12.25	0.019	-48.64
T_9	8.08 bcd	-13.0181	7.66 c	-23.63	0.032	-13.51
CV (%)	4.16		4.69		51.34	
P-value	<0.001		<0.001		0.2042	
SE value (±)	0.2751		0.2209		0.0122	

Here, T_1 = Control condition (Tap water + 0 µM MT), T_2 = Moderate drought stress (-2 bars) + 0 µM MT, T_3 = Moderate drought stress (-2 bars) + 50 µM MT, T_4 = Moderate drought stress (-2 bars) + 100 µM MT, T_5 = Moderate drought stress (-2 bars) + 150 µM MT, T_6 = Higher drought stress (-4 bars) + 0 µM MT, T_7 = Higher drought stress (-4 bars) + 50 µM MT, T_8 = Higher drought stress (-4 bars) + 100 µM MT, T_9 = Higher drought stress (-4 bars) + 150 µM MT, SDW = Seedling dry weight

Altaf *et al.* (2022) stated that ME (100 µM) pretreatment improved the detrimental-effect of DR (Drought)by restoring seed dry weight, chlorophyll content, root architecture, gas exchange parameters and plant growth attributes compared with DR-group only.Abdallah *et al.* (2022) found that the results revealed that growth and yield parameters progressively increased with increasing irrigation levels. Imran *et al.* (2021) found that 100 µM MT showed the highest shoot length (26.78%), root length (32.7 %), fresh weight (74.1 %) and dry weight (70.5 %) in soybean plants compared with the drought stress control plants. These results agree with the present findings.

4.1.3 Photosynthetic pigments

4.1.3.1 Chlorophyll (C_a)

The study found that melatonin significantly impacted the chlorophyll C_a traits of coriander when it was stressed by drought. The T_1 treatment had the highest C_a (T_1:6.05 mg g^{-1} FW), while the combination of moderate drought stress with 150 µM MT treatments (T_9) produced the lowest C*a* (T_9:3.19), which was followed by moderate drought stress without melatonin treatment (T_2: 3.10).

According to the study, as compared to the control condition, drought stress decreased the proportion of chlorophyll in the pots. In contrast to salinity stress pots without melatonin (-36.74 and -48.05 % in T_6 and T_2, respectively), melatonin treatment decreased C_a percentage less under moderate drought and higher drought conditions.

According to Okunlola *et al.* (2023) drought strongly decreased chlorophyll a, b, and carotenoid content, but increased root biomass, total soluble sugar, and proline concentrations of *Capsicum* compared to well-watered plants. These findings pointed to beneficial effects of foliar application of melatonin in facilitating and improving drought tolerance of *Capsicum* via increased osmolyte accumulation, pigments, and total concentration of inorganic ions under drought conditions. Huang *et al.* (2023) observed that the chlorophyll a, chlorophyll b content increased by 40.51%, and the net photosynthetic rate increased by 1.2 times. Ahmad *et al.* (2022) found that results showed that drought stress significantly inhibited the physiological and biochemical parameters of maize seedlings. However, the application of melatonin with nitrogen remarkably improved the plant growth attributes, chlorophyll C_a and chlorophyll C_b, fluorescence, and gas exchange parameters. Amiri *et al.* (2024) observed that the Almelatonin treatment (especially 100 mM) improved photosynthetic (Chlorophyll a, Chlorophyll b) performance by increase in net photosynthesis (P_N) and transpiration rate (E), reducing chlorophyll degradation but increasing the antioxidant enzyme activities.

4.1.3.2 Chlorophyll (C_b)

Melatonin significantly impacts coriander C_b traits under salinity stress conditions. The highest C_b (T_1:1.95 mg g^{-1} FW) was found at T_1 treatment, similar to T_3, T_8, and T_5. The lowest C_b (T_8:1.50 mg g^{-1} FW) was found in higher drought stress conditions plus 150 µM MT treatments (T_8), followed by moderate drought stress without melatonin treatment (T_2: -1.13 mg g^{-1} FW).

In case of relative change in mean C_b it was observed that the C_b reduced with the increment of drought stress compared to control condition. However, due to application of melatonin in salinity stress pots it was observed that the reduction of C_b percentage was less (+0.01, +0.20 in moderate drought and -0.013,

-0.21 in high drought conditions) compared to drought stress pots without melatonin (-0.264, -0.565, in T_2 and T_6 respectively).

The study found that drought stress led to a reduction in mean C_b percentage compared to the control condition. However, melatonin application in salinity stress pots reduced the reduction of C_b percentage less than drought stress pots without melatonin (-0.264, -0.565 %, in T_2 and T_6 respectively).

According to Sattar *et al.* (2023) found that Under drought stress conditions, grain yield and yield attributes, water content and photosynthetic efficiency of wheat crops were significantly decreased. Application of Si+ ML significantly improved leaf pigments (Chl a, Chl b and Chll a + b), leaf relative water content (RWC), proline, total soluble sugars, and total soluble protein.Liang *et al.* (2019) found that these results demonstrate that supplemental melatonin could effectively ameliorate the repression of biomass accumulation and photosynthetic (Chlorophyll Ca and Chlorophyll Cb) caused by drought and thus enhance the seedlings adaptability to drought stress. Ahmad *et al.* (2019) found that however, foliar application of 100 µM and soil drench of 50 µM melatonin was the most effective treatment concentrations under drought stress. Our current findings hereby confirmed the mitigating potential of melatonin application for drought stress by maintaining plant growth, improving the photosynthetic Chlorophyll (Ca), Chlorophyll (Cb) characteristics and activities of antioxidants enzymes.

4.1.3.3 Total Chlorophyll (C_{a+b})

Melatonin significantly affected the chlorophyll C_{a+b} traits of coriander when it was stressed by drought (Table 3). The current study's findings showed that the T_1 treatment (control condition) had the highest C_{a+b} (T_1:7.95 mg g^{-1} FW), which was statistically equivalent to the values for T_8, T_5, and T_4 (5.80,7.03, and 7.91 mg g^{-1} FW, respectively). The combination of moderate drought stress with 150 µM MT treatments (T_9) produced the lowest C_{a+b} (T_9:5.07 mg g^{-1} FW), which was followed by moderate drought stress without melatonin treatment (T_2:4.23 mgg^{-1} FW). When comparing the relative change in mean C_{a+b} to the control condition, it was found that C_{a+b} decreased as drought stress increased. However, melatonin treatment in drought stress pots was shown to reduce C_{a+b} less than melatonin-free drought stress pots (-41.44, -46.77 % in T_6 and T_2, respectively; -11.56, -41.44 % in moderate drought and -27.03, -36.25 % in greater drought circumstances).

According to Gul *et al.* (2022) reported the findings of the study revealed that the Chl *a, b*, and *a* + *b* contents and the carotenoid content significantly increased with MEL application during severe and mild drought stress. After applying 200 µM MEL, leaf water attributes, comprising relative water content (RWC), leaf water content (LWC), and relative saturation deficit (RSD), increased by 1.9%, 100%, and 71.2%, respectively. Sardar *et al.* (2024) found that foliar application of melatonin helped overcome drought-induced losses and enhanced plant height (23.72%), root length (43.47%), total chlorophyll contents (46%), carotenoids (60%) and yield (34.23%), glycine betaine (GB) (77.7%), whereas reducing the oxidative activities of hydrogen peroxide (H_2O_2) (20%) and leaf water potential (LWP) (33.35%) in broccoli plants.

Table 4: Effect of melatonin on Photosynthetic pigments of coriander under drought condition

Treatments	Chlorophyll (C_a)		Chlorophyll (C_b)		Total Chlorophyll (C_{a+b})		Total Carotenoids (C_{x+c})	
	mg g^{-1} FW	RC (%)	mg g^{-1} FW	RC (%)	mgg^{-1} FW	RC (%)	mg g^{-1} FW	RC (%)
T_1	6.05 a		1.95 ab		7.95 a		2.46 a	
T_2	3.10 c	-48.05	1.13 bc	-0.404	4.23 c	-46.77	1.14 de	-53.52
T_3	4.38 ac	-27.66	1.40 abc	-0.264	5.78 ac	-27.32	1.30 cd	-46.88
T_4	5.61 ab	-7.35	2.30 a	+0.208	7.91 a	-0.54	2.11 b	-14.09
T_5	5.10 ac	-15.77	1.93 ab	+0.015	7.03 ab	-11.56	2.02 b	-17.75
T_6	3.83 bd	-36.74	0.82 c	-0.565	4.65 bc	-41.44	0.85 f	-65.31
T_7	4.38 ac	-27.66	1.71 abc	-0.099	6.09 ac	-23.38	1.12 e	-54.47
T_8	4.30 ac	-28.98	1.50 abc	-0.210	5.80 ac	-27.03	1.36 c	-44.71
T_9	3.19 ab	-47.26	1.87 ab	-0.013	5.07 bc	-36.25	1.21 cde	-50.81
CV (%)	16.98		21.04		14.80		4.03	
P-value	0.0015		0.0016		0.0004		<0.001	
SE value (±)	0.6153		0.2784		0.7320		0.0497	

Here, T_1 = Control condition (Tap water + 0 µM MT), T_2 = Moderate drought stress (-2 bars) + 0 µM MT, T_3 = Moderate drought stress (-2 bars) + 50 µM MT, T_4 = Moderate drought stress (-2 bars) + 100 µM MT, T_5 = Moderate drought stress (-2 bars) + 150 µM MT, T_6 = Higher drought stress (-4 bars) + 0 µM MT, T_7 = Higher drought stress (-4 bars) + 50 µM MT, T_8 = Higher drought stress (-4 bars) + 100 µM MT, T_9 = Higher drought stress (-4 bars) + 150 µM MT ,C_a = Chlorophyll a, C_b = Chlorophyll b, C_{a+b} = Total Chlorophyll and C_{x+c} = Total Carotenoids

4.1.3.4 Total Carotenoids (*C_{x+c}*)

Effect of melatonin traits of coriander under drought stress condition was significant (Table 3). The current study's findings showed that the T_1 treatment (control condition) had the greatest C_{x+c} (2.46 mg g^{-1} FW), which was statistically comparable to the values obtained in T_8, T_3, and T_4 (1.36, 1.30, and 2.11 mg g^{-1} FW, respectively). Moderate drought stress conditions including 150 μM MT treatments (T_9) had the lowest C_{x+c} (1.21 mg g^{-1} FW), followed by moderate drought stress conditions without melatonin treatment (T_2:1.14 mgg-^{1} FW). The relative change in mean C_{x+c} was shown to decrease with increasing drought stress when compared to the control condition. It was discovered that the application of melatonin in these pots decreased the proportion of C_{x+c} (-14.09, -17.75 in moderate drought and -54.47, -50.81 in higher drought circumstances), in contrast to the drought stress pots without melatonin (-46.88, -65.31 T_2 and T_6 respectively).

Additionally, similar result was observed by several studied state that treatment with melatonin (100 μM) significantly mitigated the negative effects of drought stress on the seedling photosynthetic parameters and physiological and biochemical indexes(Luo *et al.* 2023, Imran *et al.*2021).In addition, Yasmeen *et al*. (2022) observed that Melatonin increased plant growth and biomass, photosynthetic pigments, gas exchange characteristics, and enhanced the activities of various enzymatic and non-enzymatic antioxidants and proline content by decreasing oxidative stress. We conclude that foliar application of melatonin offers new possibilities for promoting lentil drought tolerance. Zhao *et al.* (2023) Showed that focuses on a comprehensive study of melatonin-induced physiological and molecular events in horticultural crops, which are important to the development of tolerance and enhancement of productivity in horticultural crops under abiotic stress conditions.

4.1.4 Proline and relative leaf water content

4.1.4.1 Proline content

The study found that melatonin significantly affected the Proline content of leaf coriander under drought stress conditions (Table 5). The result of the present research revealed that highest proline (T_8:0.213) found in T_7 treatment (Higher drought stress) which was statistically similar with T_3, T_4, T_5, and T_3

(0.150,0.170 and 0.150 respectively). The lowest proline (T_1:1.20) was found in control condition (Tap water + 0 µM MT) followed moderate drought stress with no melatonin treatment (T_2: 0.130).

When comparing the relative change in mean proline to the control condition, it was found that proline increased as drought stress increased. In contrast to drought stress pots without melatonin (+8.33 and +38.91%, T_2 and T_6, respectively), it was found that the use of melatonin in these pots increased proline levels (+41.66, +47.25 % in moderate drought and +72, +77 % in greater drought conditions).

According to Jafari *et al.* (2022) observed that revealed treatments of 100 and 50 µM melatonin significantly increased proline levels, and at the highest concentration in lime (Jafari *et al.* 2022, Kabiri *et al.*2018). In addition, El-Bauome *et al.* (2022) the obtained results showed that under drought-stressed conditions, foliar application of proline, methionine, and melatonin significantly ($p \leq 0.05$) enhanced leaf area, leaf chlorophyll content, leaf relative water content (RWC), vitamin C, proline, total soluble sugar, reducing sugar, and non-reducing sugar compared to the untreated plants. These treatments also significantly increased curd height, curd diameter, curd freshness, and dry matter compared to untreated plants Eventually, it can be concluded that the foliar application of proline, methionine, and melatonin can be considered a proper strategy for enhancing the growth performance and productivity of cauliflower grown under drought-stressed conditions.

4.1.4.2 Relative leaf water content (RLWC)

Under drought stress, melatonin has significant effects on coriander's RLWC characteristics (Table 5). The current study's findings showed that the T_1 treatment (Control condition) had the greatest RWLC (T_1:24.15%), which was statistically comparable to the RWLC of T_8, T_4, T_5, and T_3 (21.54, 22.48, and 18.10 %, respectively). The settings with the highest levels of drought stress and 150 µM MT treatments (T_9) had the lowest RWLC (T_9:17.87 %), which was followed by moderate drought stress and no melatonin treatment (T_2:10.62 %). The study found that drought stress led to a reduction in relative leaf water content percentage (RLWC) compared to the control condition. However, melatonin application reduced the reduction of RWLC in drought stress pots by less than without melatonin (-6.92, -10.81 % in moderate drought and -6.57, -25.98 % in higher drought conditions).

Table 5: Effect of melatonin on proline and relative leaf water content of Coriander under drought condition

Treatments	Proline		RLWC	
	µmole g^{-1} FW	RC (%)	%	RC (%)
T_1	1.04 e	-	24.15 a	-
T_2	1.48 d	+41.66	10.62 c	-56.00
T_3	1.44 d	+38.91	18.10 b	-25.06
T_4	1.13 e	+8.33	22.56 a	-6.57
T_5	1.30 de	+25.0	21.54 a	-10.81
T_6	1.85 a	+77.1	7.84 c	-67.54
T_7	1.82 b	+75.21	15.15 b	-37.27
T_8	1.53 cd	+47.25	22.48 a	-6.92
T_9	1.79 bc	+72.10	17.87b	-25.98
CV (%)	6.89		6.22	
P-value	<0.001		<0.001	
SE value (±)	0.8315		0.8954	

Here, T_1 = Control condition (Tap water + 0 µM MT), T_2 = Moderate drought stress (-2 bars) + 0 µM MT, T_3 = Moderate drought stress (-2 bars) + 50 µM MT, T_4 = Moderate drought stress (-2 bars) + 100 µM MT, T_5 = Moderate drought stress (-2 bars) + 150 µM MT, T_6 = Higher drought stress (-4 bars) + 0 µM MT, T_7 = Higher drought stress (-4 bars) + 50 µM MT, T_8 = Higher drought stress (-4 bars) + 100 µM MT, T_9 = Higher drought stress (-4 bars) + 150 µM MT, Proline .RLWC = Relative leaf water content

According to Chen *et al.* (2020) found that proline content may potentially rise as consequence of a reduction in proline oxidase activity during stress. Melatonin in the right, can modify water metabolism to enhance the response of plants to stress by improving proline accumulation. Additionally, similar result was observed by several studied state that observed that revealed treatments of 100 and 50 µM melatonin significantly increased proline levels, and at the highest concentration in lime(Jafari *et al.* 2022, Imran *et al* 2021).Yasmeen *et al.* (2022) stated that the exogenous application of proline enhances growth and other physiological characteristics, upregulates osmo protection, protects the integrity of the plasma lemma, reduces lipid peroxidation, increases photosynthetic pigments, phenolic acids, flavonoids, and amino acids, and enhances stress tolerance, carbon fixation, and leaf nitrogen content.

4.2 Experiment II: Improvement of salinity tolerance of coriander (*Coriandrum sativum* L.) through application of melatonin

4.2.1 Germination traits

4.2.1.1 Germination rate (%)

Melatonin significantly impacts coriander germination under salinity stress conditions (Table 6**)**. The result of the present research revealed that highest GP (88.66%) found in T_1 treatment (control condition) which was statistically similar to T_5, T_4, T_8 and T_3 (84.00%,85.33%,81.11% and 80.00%, respectively). The lowest germination (T_7:76.00%) was found in higher salinity stress condition plus 50 µM MT treatments (T_7) followed moderate salinity stress with no melatonin treatment (T_2: 76.33%).

The GP decreased with an increase in saline stress in comparison to the control condition when the relative change in germination percentage was detected. Conversely, melatonin application in salinity stress pots was found to reduce the germination percentage less than in salinity stress pots without melatonin (-13.19 and -39.85% in T_2 and T_6, respectively; -3.76-5.26 in moderate salinity and -8.52, -13.15 % in higher salinity conditions).

According to Li *et al.* (2019) found that Seed germination was significantly suppressed under a 200 mM NaCl treatment, but pre-treatment with melatonin significantly improved seed germination under salt stress. Liu *et al.* (2024) found that the results showed that MT solution immersion significantly improved the germination indicators of red clover seeds under salt stress. Hussain *et al*. (2024) observed that seed priming with 100µM of melatonin proved to be a good choice to alleviate the adversities of salts at germination and early seedling establishment stage in maize. Wang *et al.* (2022) investigated in Our results revealed that application of MT significantly reduced the negative influence of salt stress on wheat seed germination. Cen *et al.* (2020) stated that the results demonstrated that melatonin application promoted alfalfa seed germination and seedling growth, and reduced oxidative damage under salt stress. Castañares *et al.* (2019) found that Seed germination percentage under salt stress increased with treatments of 10 and 50 $\mu mol \cdot L^{-1}$ melatonin. Seed treatment and plant watering with melatonin at 50 $\mu mol \cdot L^{-1}$ improved growth parameters and plants showed higher chlorophyll content as well as better biochemical parameters than non-treated plants. Results suggest that melatonin can alleviate the effect of salt stress during seed germination and first stages of plant development. Liu *et al.* (2023) found that the effect of MT showed a concentration-dependent manner. 16 μM exogenous MT can effectively improve the germination rate, germination potential, and vigor index of melon seeds under combined stress, and increase radicle length and fresh weight. Seed vigor index was the most sensitive index, and MT treatment increased by 102.22% compared with combined stress.

4.2.1.2 Mean Germination Time (MGT)

Melatonin showed little impact on the coriander's mean germination time traits while it was under salinity stress was insignificant (Table 1). The current study's findings showed that the T_3 treatment (control condition) had the highest MGT (T_3:15.29), which was statistically equivalent to the MGTs of T_3, T_5, T_8, and T_4 (14.66,14.03,14.17,14.37, and 14.66, respectively). The conditions with increased salinity stress and 150 μM MT treatments (T_9) had the lowest MGT (14.03), while moderate salinity stress and no melatonin treatment (T_2: 13.88) had the next lowest MGT.As salt stress increased, the mean germination time (MGT) decreased in comparison to the control condition. However, it was discovered that the application of melatonin in salinity stress pots decreased the increase of mean MGT (-4.08, -8.20 %, in moderate salinity and -5.99, -8.22 %, in higher salinity conditions, respectively), in comparison to salinity stress pots without melatonin (-7.27 and -9.90 %, in T_2 and T_6, respectively).

According to, Akram *et al.* (2020) found that similarly, addition of melatonin cause shortening of the germination time. While the addition of melatonin causes improvement in the said parameter in maize crop during saline stress. Xiao *et al.* (2019) found that together, these results indicate that a 20 μM melatonin treatment optimally promotes cotton seed germination. Compared with the control, germination potential (GP), germination rate (GR), and final fresh weight (FW) increased by 16.67%, 12.30%, and 4.81%, respectively

4.2.1.3 Germination rate index (GRI)

Under salt stress conditions, (Table 6**)** melatonin has a considerable effect on the coriander plant's germination rate index (GRI). The result of the present research revealed that highest GRI (T_1:36.33) found in T_1 treatment (control condition) which was statistically similar with T_5, T_8, and T_4 (28.0,30.43 and 30.66, respectively). The lowest GRI (T_9:27.00) was found in moderate salinity stress condition plus 50 µM MT treatments (T_3) followed moderate salinity stress with no melatonin treatment (T_2: 23.00). The study found that the Germination rate index (GRI) decreased with salinity stress compared to the control condition. However, melatonin application in salinity stress pots reduced GRI percentage less (-15.59 to -29.35 % in moderate salinity and -16.24, -25.67 % in higher salinity conditions) compared to pots without melatonin (-29.35 and -48.07 % in T_2 and T_6 respectively).

Hancı and Fatih *et al.* (2019) studied that Overall, all doses of melatonin increased the maximum germination ratio and germination index values slightly under 300 mM NaCl stress conditions. Wang *et al.* observed that transcriptome results showed that MT affected the activity of antioxidant enzymes, response to stress, and seed germination-related genes in maize seeds under salt stress and regulated the expression of genes related to starch and sucrose metabolism and phytohormone signal transduction pathways**.**

Jiang et al. (2016) found that the results showed seed priming with 0.8 mM melatonin significantly improved germination energy, germination percentage, germination rate index, shoot and root lengths, seedling fresh and dry weights.

Table 6: Effect of melatonin on germination traits of Coriander under salt stress condition

Treatments	GP		MGT		GRI		CVG		TGI	
	%	RC (%)	days	RC (%)	value	RC (%)	value	RC (%)	value	RC (%)
T_1	88.66 a	-	15.29 a	-	36.33 a	-	7.30 a	-	15.09 ab	-
T_2	76.33 c	-13.91	13.88 b	-9.16	23.00 cd	-36.69	6.51 b	-10.72	9.54 e	-36.77
T_3	80.00 ac	-9.77	14.17 b	-7.27	25.66 bc	-29.35	6.94 ab	-4.87	11.51 ce	-23.72
T_4	85.33 ac	- 5.26	14.66 ab	- 4.08	30.66 ab	-15.59	7.13 ab	-2.31	15.60 a	+3.39
T_5	84.00 ab	-3.76	14.03 b	-8.20	28.00 bc	-22.93	6.99 ab	-4.17	13.45 ad	-23.72
T_6	53.33 d	-39.85	13.77 b	-9.90	18.86 d	-48.07	6.89 ab	-5.55	10.48 de	+3.39
T_7	76.00 c	-14.28	13.73 b	-10.15	29.26 bc	-19.45	7.09 ab	-2.87	13.80 ac	-23.72
T_8	81.11 ac	-8.52	14.37 ab	-5.99	30.43 ab	-16.24	7.02 ab	-3.81	13.80 ac	+3.39
T_9	77.00 bc	-13.15	14.03 b	-8.22	27.00 bc	-25.67	7.01 ab	-3.98	12.49 be	-23.72
CV (%)	3.93		2.63		8.70		3.16		8.38	
P-value	<0.001		0.0016		0.0016		0.0359		<0.001	
SE value (±)	2.4999		0.3057		1.9674		0.1801		0.8802	

Here, T_1 = Control condition (Tap water + 0 µM MT), T_2 = Moderate salinity stress (6 dS m^{-1}) + 0 µM MT, T_3 = Moderate salinity stress (6 dS m^{-1}) + 50 µM MT, T_4 = Moderate salinity stress (6 dS m^{-1}) + 100 µM MT, T_5 = Moderate salinity stress (6 dS m^{-1}) + 150 µM MT, T_6 = Higher salinity stress (12 dS m^{-1}) + 0 µM MT, T_7 = Higher salinity stress (12 dS m^{-1}) + 50 µM MT, T_8 = Higher salinity stress (12 dS m^{-1}) + 100 µM MT, T_9 = Higher salinity stress (12 dS m^{-1}) + 150 µM MT, GP = Germination percentage, MGT = Mean germination time, GRI =Growth rate index, CVG = Co-efficient velocity of germination, TGI = Timson germination index

4.2.1.4 Co-efficient velocity of germination (CVG)

Melatonin under salinity stress conditions had significant effects on coriander CVG traits (Table 1). According to the results of the present the investigation, the CVG (T_1:7.30) for the T_1 treatment (control condition) was the highest and was statistically similar to the values for T_3, T_5, T_8, and T_4 (6.94, 6.99, 7.02, and 7.13, respectively). The condition with increased salt stress and 150 µM MT treatments (T_5) had the lowest CVG (T_5:6.99) after moderate stress without melatonin treatment (T_2: 6.51). In case of relative change in mean CVG it was observed that the CVG reduced with the increment of salinity stress compared to the control condition. However, due to the application of melatonin in salinity stress pots, it was observed that the reduction of CVG percentage was less (-2.31, -4.17 % in moderate salinity and -3.81, -3.98 % in higher salinity conditions) compared to salinity stress pots without melatonin (-5.55, -4.87 % in T_6 and T_2 respectively).

According to, Shah, N. A, *et al.* (2023) stated that significant improvement was observed in morpho-physiological attributes including stomatal and epidermal physiology along with agronomic parameters including germination energy (GE), mean emergence time (MET), coefficient of velocity of germination (CVG), germination rate index (GRI) and timson germination index (TGI) time to 50% emergence (T:50) during exposure to salinity stress. Hussain *et al.* (2024) found that in general, low (5 and 100 µMT) concentrations of MT were found most effective in improving seed dormancy-efficient velocity of germination and early seedling growth of halophytes particularly under saline conditions.

4.2.1.5 Timson germination index (TGI)

Under situations of saline stress, melatonin has a substantial effect on coriander TGI characteristics (Table 6). The current study's findings showed that the T_1 treatment (control condition) had the highest TGI (T_1:15.09), which was statistically comparable to T_8, T_5, and T_4 (13.80,13.45, and 15.60, respectively). The condition with increased salt stress and 150 µM MT treatments (T_9) had the lowest TGI (12.49), followed by moderate salt stress and no melatonin treatment (T_2: 9.54). The study found that the mean Timson germination index decreased with salinity stress compared to the control condition. However, melatonin application reduced the reduction of TGI percentage in salinity stress pots by less (-23.72, +3.39 % in moderate salinity and -23.72, +3.39 % in higher salinity conditions) compared to drought stress pots without melatonin.

According to Stephen *et al*. (2018) stated that observations on various germination parameters were recorded at (25±2°C). Priming of chilli seeds for with -0.5 MPa solution of PEG (24 hours), 8× dilution of vermin wash (30 hours) and 5ppm solution of melatonin (30 hours) gave the best results in terms of various germination attributes (Timson germination index). Among various hydro priming durations 30 hours was proved as best treatment. Ismaeil *et al.* (2022) found that the study clearly demonstrated that the deleterious effects of salt stress on seed germination, timson germination index and early seedling growth of wheat cultivars were considerably alleviated by melatonin priming.

4.2.2 Seedling growth traits

4.2.2.1 Shoot length

Melatonin significantly impacted coriander shoot length traits under salinity stress (Table 7)**.** The highest shoot length (T_1:13.88) was found in the T_1 treatment (control condition), and the results were statistically comparable to those of the T_8, T_3, and T_4 treatments (9.80, 12.32, and 13.88, respectively). Following moderate salinity stress without melatonin treatment (T_2:10.27), the lowest shoot length (T_9:9.61) was observed in conditions with increased salinity stress and 150 µM MT treatments (T_9).

When considering the relative change in shoot length, it was found that, in contrast to the control condition, the shoot length increased with an increase in salt stress. Even so, compared to salinity stress pots without melatonin (T_2 and T_6; -11.05 and -55.25 %, respectively), the reduction of shoot length percentage was less in salinity stress pots with melatonin applied (-20.44, +0.21 % in moderate salt and -29.28, -30.63 % in higher salt conditions).

According to Bakyani *et al.* (2022) found that the Increasing salinity decreased leaf chlorophyll and photosynthetic rates, decreased K concentrations and increased Na concentrations in roots and shoots, and increased oxidative marker levels and the activity of protective antioxidant enzymes in leaves.Al *et al.* (2021) stated that the one level of melatonin (1.0 µmol L^{-1}) was applied exogenously, sole, or in combination with the salinity stress. NaCl-induced phytotoxicity significantly ($P < 0.05$) reduced shoot and root dry matter accumulation, chlorophyll contents, relative water contents (RWC), membrane stability index (MSI), and antioxidant enzymatic activities in both cultivars as compared to the control treatment. El-Bauome *et al.* (2022) observed that the results showed that 0.02% Met concentration significantly improved all the growth and yield parameters like shoot length by 25.7%, plant fresh biomass by 66.89%, fruit weight by 67.26%, dry biomass by 37%, and the number of fruits by 82% under 6 dS/m stress condition. Kul et al., (2019) reported that Under salt stress, MEL treatments increase plant growth and photosynthetic activity, improve chlorophyll contents, reduce ROS generation, and thus oxidative damage to plants**.**

Table 7: Effect of melatonin on seedling growth traits of Coriander under salt stress condition

Treatments	Shoot length		Root length		SDW	
	cm	RC (%)	cm	RC (%)	g plant^{-1}	RC (%)
T_1	13.88 ba	-	9.01 a	-	0.037	0
T_2	10.27 bcd	-25.81	7.07 c	-21.47	0.017	-54.05
T_3	12.32 abc	-11.05	8.12 abc	-9.89	0.014	-62.16
T_4	13.88 a	- 0.21	8.81 ab	- 2.255	0.012	-67.56
T_5	11.02 abc	-20.44	8.63 ab	- 4.21	0.012	-67.56
T_6	6.20e	-55.25	6.84 c	-24.03	0.015	-59.45
T_7	7.04 de	-49.17	7.32 bc	-18.78	0.033	-10.81
T_8	9.80 cd	-29.26	8.66 ab	-3.84	0.037	0.00
T_9	9.61cd	-30.63	7.52 abc	-16.56	0.033	-10.81
CV (%)	11.25		6.73		64.53	
P-value	<0.001		0.0003		0.2396	
SE value (±)	0.9560		0.4397		0.0122	

Here, T_1 = Control condition (Tap water + 0 µM MT), T_2 = Moderate salinity stress (6 dS m^{-1}) + 0 µM MT, T_3 = Moderate salinity stress (6 dS m^{-1}) + 50 µM MT, T_4 = Moderate salinity stress (6 dS m^{-1}) + 100 µM MT, T_5 = Moderate salinity stress (6 dS m^{-1}) + 150 µM MT, T_6 = Higher salinity stress (12 dS m^{-1}) + 0 µM MT, T_7 = Higher salinity stress (12 dS m^{-1}) + 50 µM MT, T_8 = Higher salinity stress (12 dS m^{-1}) + 100 µM MT, T_9 = Higher salinity stress (12 dS m^{-1}) + 150 µM MT, SDW=Seedling dry weight

4.2.2.2 Root length

Melatonin significantly affected the root length characteristics of coriander when it was under salt stress (Table 7**).** The current study's outcome showed that the T_1 treatment (control condition) had the maximum root length (T_1:9.01 cm), which was statistically comparable to the values at T_3, T_5, T_4, and T_8 (8.12, 8.63, 8.81, and 8.66 cm, respectively). The conditions with increased salinity stress and 150 µM MT treatments (T_9) resulted in the lowest root length (T_9:7.52 cm), which was followed by moderate salinity stress without melatonin treatment (T_2: 7.02 cm). In case of relative change in mean root length, it was observed that the root length reduced with the increment of salinity stress compared to the control condition. However, due to the application of melatonin in salinity stress pots, it was observed that the reduction of root length percentage was less (-3.84, -4.21 % in moderate salt and -2.255, -16.56 % in higher salt conditions) compared to salt stress pots without melatonin (-16.56, -21.47 %, T_6 and T_2 respectively).

According to Khan *et al.* (2023) reported salt stress negatively affected photosynthetic efficiency, cell viability, plant growth, fruit quality, and impaired root morphology, and stomatal physiology, but induced the accumulation of reactive oxygen species ((H_2O_2 and $O_2{\cdot}^{-}$), malondialdehyde (MDA) content, and electrolyte leakage. Sardar *et al.* (2023) found that the results showed that exogenous melatonin application improved morphological characteristics of broccoli, i.e., plant height, the number of leaves, head weight, head diameter, root length, shoot length, leaf relative water content, the number of florets, shoot fresh weight, root fresh, and dry weight. Jalili *et al.* (2023) found that according to our findings, all of the melatonin concentrations had a positive effect as a growth regulator but looking at the overall data 0.1 µM melatonin was the best candidate for increasing salt tolerance and reducing oxidative stress in alfalfa root. Zhang *et al.* (2020) stated that results showed exogenous MT had increased the endogenous MT content in maize root.

4.2.2.3 Seedling dry weight (SDW)

Melatonin's effect on coriander's SDW traits under salinity stress conditions was insignificant (Table **7**). According to the current study's findings, the T_1 treatment (control condition) had the highest SDW (T_1:0.037). Following moderate salinity stress without melatonin treatment (T_2: 0.017), the lowest SDW (0.012) was reported in conditions with increased salinity stress and 150 µM MT treatments (T_5).

It was found that, when analyzing the relative change in mean shoot length to the control condition, the SDW reduced as drought stress increased. In contrast to salinity stress pots without melatonin (-54.05 and -59.45 %, in T_2 and T_6 respectively), it was found that the application of melatonin in salinity stress pots reduced the SDW percentage by less (-62.16, -67.56 % in moderate salinity and -59.45, -10.81 % in higher salinity conditions).

According to Sardar *et al.* (2023) found the results showed that exogenous melatonin application improved morphological characteristics of broccoli, i.e., plant height, the number of leaves, root length, shoot length, Seedling dry weight, leaf relative water content, the number of florets, shoot fresh weight, root fresh, and seedling dry weight.Park *et al.* (2021) observed that it demonstrated that exogenous melatonin supplementation significantly improved the physiologic and biochemical parameters in salinity-damaged green mustard seedlings. Wang *et al.* (2016) found that the results of plant height, leaf area, fresh weight and dry weight of cucumber plants were highest in 100 µM MT treatments among the five treatments (0, 50, 100, 150 and 200 µM MT). Bahcesular *et al.* (2020) and Konuşkan *et al. (*2017) also found that saline conditions reduced the germination percentage, seedling growth, leaf area and dry weight of basil and maize, respectively.

4.2.3 Photosynthetic pigments:

4.2.3.1 Chlorophyll (*C_a*)

Melatonin under salt stress situations has a substantial impact on coriander's chlorophyll C_a characteristics (Table 8). The current study's findings showed that the treatment with the greatest C_a (T_1:6.31 mg g^{-1} FW) was T_1 (control condition), which was statistically comparable to T_5, T_8, and T_4 (5.66, 5.69, and 6.31 mg g^{-1} FW, respectively). The combination of moderate salinity stress with 150 µM MT treatments (T_7) resulted in the lowest C_a (T_7:5.66 mg g^{-1} FW), which was followed by moderate salinity stress without melatonin treatment (T_2: 3.60 mg g^{-1} FW).

When comparing the relative change in mean Chlorophyll C_a to the control condition, it was found that salinity decreased as salinity stress increased. Salinity stress pots with melatonin applied, however, showed a lower reduction in C_a percentage (-10.30, +0 % in moderate salinity and -7.29, -9.71 % in higher salinity conditions) when compared to salinity stress pots without melatonin (T_6 and T_2; -29.21 and -19.96 %, respectively).

According to Vafadar *et al.* (2021) found these novel findings indicate that the MT-induced effects on photosynthetic parameters and salt-evoked oxidative stress were mediated through calcium/calmodulin ($Ca^{2+/}$CaM) signaling. Ahmad *et al.* (2021) revealed this study unraveled the crucial role of melatonin in salt stress mitigation and thus can be implicated in the management of salinity in maize seedling. Gao *et al.* (2019) observed that the results showed that pretreating with different concentrations of MT promoted the growth of seedlings in response to 150 mM NaCl. These results demonstrate an important role of MT in the relief of salt stress and, therefore, provide a reference for managing salinity in naked oat.

4.2.3.2 Chlorophyll (*C_b*)

The effect of melatonin on C_b traits of coriander under Salinity stress conditions was significant (Table 8). The result of the present research revealed that the highest C_b (T_1:2.54 mg g^{-1} FW) was found at T_1 treatment (control condition) which was statistically similar to T_8, T_5, and T_4 (2.04, 2.06 and 2.08 mg g^{-1} FW, respectively). The lowest C_b (T_9: -31.10 %) was found in moderate salinity stress condition plus 150 µM MT treatments (T_5) followed by moderate salinity stress with no melatonin treatment (T_2: -48.81 %).

In case of relative change in mean C_b it was observed that the C_b reduced with the increment of salinity stress compared to the control condition. However, due to the application of melatonin in salinity stress pots, it was observed that the reduction of C_b percentage was less (-18.11, -18.89 % in moderate salt and -19.68, -31.102 % in high salt conditions) compared to salinity stress pots without melatonin (-36.61, -47.24 %, in T_6 and T_2 respectively).

According to, Ubaidillah *et al.* (2024) reported that this study shows that exogenous melatonin can increase the total chlorophyll content, relative water content, and proline content, reduce the total sodium content, and increase potassium absorption under conditions of salinity stress. Vafadar *et al.* (2021) stated that exogenous MT, as well as $Ca2^{+}$, enhanced tolerance index, membrane stability, leaf area, the content of chlorophyll (Chl) a, Chl b, and carotenoids (Car), Fv/Fm, and stomatal conductance under salinity stress.

Table 8: Effect of melatonin on Photosynthetic pigments of Coriander under salt stress condition

Treatments	Chlorophyll (C_a)		Chlorophyll (C_b)		Total Chlorophyll (C_{a+b})		Total Carotenoids (C_{x+c})	
	mg g-1 FW	RC (%)	mgg-1 FW	RC (%)	mgg-1 FW	RC (%)	mgg-1 FW	RC (%)
T_1	6.31 a	-	2.54 a	-	8.85 a	-	7.67 a	-
T_2	3.60 a	-42.94	1.30 d	-48.81	4.90 de	-35.41	3.80 de	-50.45
T_3	5.05 ab	-19.96	1.34 d	-47.24	6.39 abc	-15.48	6.33 abc	-17.50
T_4	6.31 a	+ 0.00	2.08 b	-18.11	8.39 ab	-8.70	7.34 a	-4.38
T_5	5.66 ab	-10.30	2.06 b	-18.89	7.72 cd	-25.56	6.84 ab	-10.81
T_6	4.46 7ab	-29.21	1.61 c	-36.61	6.10 f	-55.33	3.26 e	-57.44
T_7	5.66 ab	-10.25	1.71 c	-32.67	7.37 cde	-31.47	5.53 bc	-27.96
T_8	5.69 ab	-9.71	2.04 b	-19.68	7.73 bc	-18.11	6.69 ab	-12.76
T_9	5.85 ab	-7.29	1.75 c	-31.102	7.60 ef	-46.00	4.96 cd	-35.30
CV (%)	15.80		4.34		7.65		8.31	
P-value	0.0181		<0.001		<0.001		<0.001	
SE value (±)	0.6964		0.0648		0.4208		0.3965	

Here, T_1 = Control condition (Tap water + 0 µM MT), T_2 = Moderate salinity stress (6 dS m^{-1}) + 0 µM MT, T_3 = Moderate salinity stress (6 dS m^{-1}) + 50 µM MT, T_4 = Moderate salinity stress (6 dS m^{-1}) + 100 µM MT, T_5 = Moderate salinity stress (6 dS m^{-1}) + 150 µM MT, T_6 = Higher salinity stress (12 dS m^{-1}) + 0 µM MT, T_7 = Higher salinity stress (12 dS m^{-1}) + 50 µM MT, T_8 = Higher salinity stress (12 dS m^{-1}) + 100 µM MT, T_9 = Higher salinity stress (12 dS m^{-1}) + 150 µM MT, C_a = Chlorophyll a, C_b = Chlorophyll b, C_{a+b} = Total Chlorophyll, C_{x+c} = Total Carotenoids

4.2.3.3 Total Chlorophyll (C_{a+b})

Under salt stress situations, melatonin had a substantial impact on the C_{a+b} characteristics of coriander (Table 8**)**. The current study's findings showed that the treatment condition T_1 had the greatest C_{a+b} (T_1:8.85 mg g^{-1} FW), which was statistically comparable to the values found at T_5, T_8, and T_4 (7.72, 7.73, and 8.39 mg g^{-1} FW, respectively). The combination of moderate salinity stress with 150 µM MT treatments (T_2) resulted in the lowest C_{a+b} (4.90 mg g^{-1} FW).

When comparing the relative change in mean C_{a+b} to the control condition, it was found that C_{a+b} decreased as drought stress increased.

According to, Ahmad *et al.* (2022) stated that results revealed that exogenous supplementation with melatonin under salinity stress significantly improved both wheat cultivars' growth and physiological attributes (i.e. chlorophyll contents). Muhammad *et al.* (2024) reported that Moreover, melatonin significantly improved leaf water content and reduced water potential, particularly under hydroponic conditions and varied abiotic stresses, highlighting its role in mitigating water stress. The analysis also revealed increases in chlorophyll pigments with soil drenching and foliar spray, and these were considered the effective application methods. Wang *et al.* (2021) found that therefore, our findings suggested exogenous MT significantly ameliorated maize physiological and photosynthetic adaptation (total Chlorophyll) under salinity stress, thereby providing helpful guidance for maize cultivation in areas of high salinity.

4.2.3.4 Total Carotenoids (C_{x+c})

The effect of melatonin on shoot length traits of coriander under salinity stress conditions was significant (Table 8). The result of the present research revealed that the highest C_{x+c} (T_1:7.67 mg g^{-1} FW) was found at T_1 treatment (control condition) which was statistically similar to T_8, T_3 and T_4 (6.69, 6.84 and 7.34 mg g^{-1} FW, respectively). The lowest C_{x+c} (4.96 mg g^{-1} FW) was found in moderate salinity stress condition plus 150 µM MT treatments (T_9) followed by moderate drought stress with no melatonin treatment (T_2: 3.80 mg g^{-1} FW).

The study found that the mean $\underline{C_{x+c}}$ percentage decreased with salinity stress compared to the control condition. However, melatonin application in salinity stress pots reduced the reduction of C_{x+c} percentage less (-4.38, -10.81 % in moderate salinity and -12.76, -35.30 % in higher salinity conditions) compared to salinity stress pots without melatonin (-27.96, - 17.50 % in T_6 and T_2).

Wang *et al.* (2016) found that the results showed that the melatonin-treated plants significantly increased growth mass and antioxidant protection. The application of 50–150 µM melatonin significantly improved the photosynthetic capacity. Bakyani *et al.* (2022) studied that Under severe salinity stress, the MEL90 treatment resulted in increases in chlorophyll & carotenoid contents, gas exchange attributes, leaf antioxidant enzyme activities, and decreases in leaf oxidative markers and Na. Wang *et al.* (2016) found that among the five treatments (0, 50, 100, 150 and 200 µM MT), 100 µM MT resulted in higher photosynthetic pigments on cucumber plants under 200 mM saline stress conditions. Konuşkan *et al.* (2017) also found that the photosynthetic pigments were reduced in saline conditions compared to the control conditions. These results agree with the present findings.

4.2.4 Proline and relative leaf water content

4.2.4.1 Proline content

Melatonin had a considerable impact on the proline content of coriander leaves during salt stress (Table 9). The maximum proline (T_6: 0.75 µmole g^{-1} FW) was found in the T_6 treatment (higher salinity stress) in the current investigation. These values were statistically equivalent to those of the T_7 treatment (T_7:0.69 µmole g^{-1} FW). The control conditions (T_1) had the lowest proline (T_1:0.26 µmole g^{-1} FW). At T_4 treatment (0.30 µmole g^{-1} FW) and T_8 treatment (0.53 µmole g^{-1} FW), 100 µM MT accomplished the lowest proline under both moderate and higher salt conditions. In case of relative change in mean proline, it was observed that the proline increases with the increment of proline compared to the control condition. However, due to the application of melatonin in salinity stress pots, it was observed that the increase of proline was (+43.33 to +19.00 in moderate salt and +169.00 to +105.66 %, in higher salt conditions) compared to salinity stress pots without melatonin (+55.66, +186.66%, in T_2 and T_6 respectively).

According to, El Moukhtari *et al.* (2020) showed that Under high-salt conditions, proline application enhances plant growth with increases in seed germination, biomass, photosynthesis, gas exchange, and grain yield. These positive effects are mainly driven by better nutrient acquisition, water uptake, and biological nitrogen fixation.Wang *et al.* (2024) stated that based on optimal concentration of MT inducing salt tolerance of okra plants, application of 5 mM DPI and 100 µM MT + 5 mM DPI, respectively, significantly increased salt tolerance of okra plants. observed in okra plants with 100 µM MT under salt stress. Madebo *et al.* (2021) found proline levels exhibited higher levels among treated fruits. Azizi et al (2022) observed that melatonin application increased proline and sugar content while decreasing malondialdehyde and H_2O_2 content that were increased by salinity stress.Hussain *et al.* (2021) found that heat tolerance in okra was highly linked highly linked to genotypes 'genetic potential, having more water use efficiency, enzymatic activities, and physio-biochemical attributes under the foliar applications of proline.

Table 9: Effect of melatonin on proline and relative leaf water content of Coriander under salt stress condition

Treatments	Proline		RLWC	
	µmole g^{-1} FW	RC (%)	%	RC (%)
T_1	0.26 g	-	28.82 a	-
T_2	0.40 d	+55.66	23.99 bc	-16.75
T_3	0.35 ef	+34.33	25.78 abc	-10.56
T_4	0.30 g	+19.00	27.89 ab	-3.21
T_5	0.37 de	+43.33	27.66 ab	-4.04
T_6	0.75 a	+98.66	10.62 f	-63.13
T_7	0.69 ab	+87.00	17.87 e	-37.98
T_8	0.53 c	+64.66	22.00 cd	-23.67
T_9	0.69 b	+87.66	19.56 de	-32.13
CV (%)	3.36		6.26	
P-value	<0.001		<0.001	
SE value (±)	1.540		1.1602	

Here, T_1 = Control condition (Tap water + 0 µM MT), T_2 = Moderate salinity stress (6 dS m^{-1}) + 0 µM MT, T_3 = Moderate salinity stress (6 dS m^{-1}) + 50 µM MT, T_4 = Moderate salinity stress (6 dS m^{-1}) + 100 µM MT, T_5 = Moderate salinity stress (6 dS m^{-1}) + 150 µM MT, T_6 = Higher salinity stress (12 dS m^{-1}) + 0 µM MT, T_7 = Higher salinity stress (12 dS m^{-1}) + 50 µM MT, T_8 = Higher salinity stress (12 dS m^{-1}) + 100 µM MT, T_9 = Higher salinity stress (12 dS m^{-1}) + 150 µM MT, RWC = Relative leaf water content

4.2.4.2 Relative leaf water content (RLWC):

The effect of melatonin on the RLWC of coriander under Salinity stress conditions was significant (Table 9). The result of the present research revealed that the highest RLWC (T_1:28.82 %) was found at T_1 treatment (Control condition) which was statistically similar to T_8, T_3, T_4 and T_5 (22.0, 25.78, 27.66 and 27.89 % respectively). The lowest RWLC (T_9:19.56 %) was found in higher salt stress conditions plus 150 µM MT treatments (T_9) followed by moderate salt stress with no melatonin treatment (T_2: 23.99 %). In case of relative change in RWLC percentage, it was observed that the RWLC reduced with the increment of salinity stress compared to the control condition. However, due to the application of melatonin in salt stress pots, it was observed that the reduction of germination percentage was less (-

3.21, -4.04 % in moderate salt and 23.67, -32.13 % in higher salt conditions) compared to salt stress pots without melatonin (T_2 and T_6; -16.75 and -63.13 %, respectively).

Eisa *et al.* (2023) observed that the results obtained, revealed the significant effectiveness of exogenous melatonin treatment at 200 µM concentration under salt stress conditions by enhancing the plant growth traits such as chlorophyll and carotenoids content, relative water content, proline content, peroxidase enzyme activity (POD), and by the decreased electrolyte leakage rate, and Na^+ content, as well as delaying the emergence of flower buds under salinity stres.Shtaya *et al.* (2019) found that Salinity stress decreased relative water content (RWC), whereas chlorophyll content, fresh weight and dry weight were not affected. Hosseini *et al. (*2023) stated that the most effective increase in RWC was observed in 100 µM foliar MT and 100 µM root MT, with the increase in RWC values being 25.78 and 27.89 %, respectively, compared with those in salt treated control plants. These results agree with the present finding.

CHAPTER 5

SUMMARY AND CONCLUSION

Coriander (*Coriandrum sativum L.*) is a medicinal plant that belongs to the Apiaceae (Umbelliferae) family, which has food, pharmaceutical, and cosmetic potentialities. The experiment were conducted at the research field , Department of Crop physiology and Ecology , Hajee Mohammad Danesh Science and Technology University, during November 2023 to February , 2024 to find out the improve the drought experiment 1 and salinity experiment 2 tolerance of coriander through the exogenous application of application of melatonin (MT).Twenty-five seeds of coriander were placed for germination in 15 cm in diameter and 6 cm in depth plastic pots containing a mixture of soil and compost in a 1:1 ratio and irrigated with respective treatments. The plastic pots were irrigated daily with the required amount of respective solution. After evaluating germination traits seedlings was thinned out and five healthy plants were allowed growing up to 30 days for physio-biochemical observation.

Germination percentage, germination rate index, co-efficient of velocity of germination, mean germination time, timson germination index, shoot length, root length, seedling dry weight and healthy seedling number of 30 days seedling were found to be affected due to drought and salt stress. The highest germination percentage was detected at control T_1(97.33%) conditions, whereas the range of germination percentage at different drought level was (76.00-95.00%). Among the treatments in drought stressed pots, the highest GP was found at T_4 (95%), followed by T_3 (82%), T_9 (76%). The maximum mean germination time was detected at control T_1 (14.31 days), followed by T_4 (13.88 days), T_3 (13.30 days), T_9 (13.18 days). The highest co-efficient of velocity of germination was observed at control (T_1:9.15), followed by T_4 (7.20), T_8 (7.17) and T_3 (7.04), T_9 (6.80). The maximum Timson germination index was found at control (17.14), followed by T_4 (16.15) and T_3 (13.98), T_9 (13.24). The highest shoot length was showed at control T_1 (9.29 cm), followed by T_4 (8.70 cm) and T_3 (7.58 cm), T_9 (8.08 cm). However, the highest root length was detected at control T_1 (10.04 cm), followed by T_4 (9.29cm), T_8(8.81cm) and T_9 (7.66 cm). The maximum seedling dry weight was showed at control (0.037 g plant^{-1}), followed by T_4 (0.034 g plant^{-1}), T_9 (0.032 g plant^{-1}). The highest chlorophyll a was detected at control

(6.05 mg g^{-1} FW), followed by T_4 (5.61 mg g^{-1} FW), T_9 (3.19 mg g^{-1} FW). The maximum chlorophyll b was detected at control T_1 (2.30 mg g^{-1} FW), followed by T_4 (1.90 mg g^{-1} FW) and T_9 (1.87 mg g^{-1} FW). The highest total chlorophyll a was detected at control T_1 (7.95 mg g^{-1} FW), followed by T_4 (7.91 mg g^{-1} FW), T_9 (5.07 mg g^{-1} FW). The maximum total carotenoids were observed at control T_1 (2.46 mg g^{-1} FW), followed by T_4 (2.11 mg g^{-1} FW), T_9 (1.21 mg g^{-1} FW). On the other hand, highest level of proline was observed in drought stress plots compared to the control (T_1) condition. Among all the treatments (T_2-T_9) under drought condition, the lowest level of proline observed T_4.

Coriander seed were again for second experiment artificially developed saline soil 30 days. The highest germination percentage was detected at control (T_1:88.66%) conditions, whereas the range of germination percentage at different salinity level was (77.00-88.66%). Among the treatments in drought stressed pots, the highest GP was found at T_4 (85%), followed by T_3 (82%), T_9 (77%). The maximum mean germination time was detected at control T_1 (15.29 days), followed by T_4 (14.66 days), T_3 (14.17 days), T_9 (14.03 days). The highest co-efficient of velocity of germination was observed at control T_1 (7.30), followed by T_4(7.13), T_8 (7.02) and T_3 (6.94), T9(7.01). The maximum Timson germination index was found at control (15.09), followed by T_4 (15.60) and T_3 (11.51), T_9 (12.49). The highest shoot length was showed at control T_1 (13.88 cm), followed by T_4 (13.88 cm) and T_3 (12.32 cm), T_9 (9.61). The highest root length was detected at control T_1 (9.01 cm), followed by T_8 (8.66 cm), T_4 (8.01cm) and T_9 (7.52 cm). The maximum seedling dry weight was showed at control T_1 (0.037 g plant-1), followed by T_4 (0.034 g $plant^{-1}$), T_9 (0.032 g plant-1). The highest chlorophyll a was detected at control (6.05 mg g^{-1} FW), followed by T_4 (5.61 mg g^{-1} FW), T_9 (3.19 mg g^{-1} FW). The maximum chlorophyll b was detected at control T_1 (2.30 mg g^{-1} FW), followed by T_4 (1.90 mg g^{-1} FW) and T_9 (1.87 mg g^{-1} FW). The highest total chlorophyll a was detected at control T_1 (7.95 mg g^{-1} FW), followed by T_4 (7.91 mg g^{-1} FW), T_9 (5.07 mg g^{-1} FW). The maximum total carotenoids were observed at control T_1 (2.46 mg g^{-1} FW), followed by T_4 (2.11 mg g^{-1} FW), T_9 (1.21 mg g^{-1} FW). On the other hand, highest level of proline was observed in drought stress plots compared to the control (T_1) condition. Among all the treatments (T_2-T_9) under salinity condition, the lowest level of proline observed T_4. In control conditions (tap water), all the traits of (*Coriandrum sativum* L.) revealed superior performance in both drought and saline conditions. Under the drought and saline stress conditions, 100 µM melatonin showed the best performance both in moderate and higher drought stress conditions, and both in the moderate and higher saline stress conditions compared to the non-melatonin treated plants. In drought conditions, T_4 (Moderate drought stress (-2 bars) + 100 µM MT) and showed the best result for germination, seedling growth, water relation, photosynthetic pigments but the lowest proline contents compared to the other treatments. In saline stress conditions, T_4 (Moderate salinity stress: 6 dS m^{-1} + 100 µM MT) revealed superior performance in the germination, seedling growth, water relation, photosynthetic pigments but the lowest proline contents compared to the other treatments. By testing different concentrations, the study identifies 100 µM as the most effective dose for promoting early growth and physiological stability under stress conditions in coriander. This study lays a foundation for further research into melatonin-based stress management strategies, potentially extending to other medicinal and spice crops. Overall, from the results of two experiments, it was observed that coriander plants suffered a lot both in drought and saline conditions. However, the application of exogenous MT at different doses considerably improved the germination, growth and physiological traits. Among the all treatments the best result was observed at (T_4:100 µM MT) in both water deficit and saline conditions. Therefore, the experiments concluded that melatonin @ 100 µM could be a suitable dose to improve the drought and salinity tolerance of coriander under the water deficit and saline areas of Bangladesh.

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CHAPTER 6

REFERENCES

Abdallah, M., El-Khalek, A., Sarah, N, & AbuEl-leil, E. F. 2022. Alleviation of water stress in coriander plants by foliar application of boron. Scientific Journal of Flowers and Ornamental Plants, 9(4), 307-317. https://doi.orgn/ 10.21608/sjfop.2022.286650

Abdel Latef, A. A. H, Abu Alhmad, M. F, & Abdelfattah, K. E. 2017. The possible roles of priming with ZnO nanoparticles in mitigation of salinity stress in lupine (*Lupinus termis*) plants. Journal of plant growth regulation, 36, 60-70.

Admasie, M. A, Kurunc, A, & Cengiz, M. F. 2023. Effects of exogenous selenium application for enhancing salinity stress tolerance in dry bean. Scientia Horticulturae, 320, 112238.https://doi.org/10.1016/j.scienta.2023.112238

Afshari, F, Nakhaei, F, Mosavi, S, Seghatoleslami, M. 2022. Physiological and biochemical responses of Stevia rebaudiana Bertoni to nutri-priming and foliar nutrition under water supply restrictions. Industrial Crops and Products, 176,114399.

Afshari, M., Rahimmalek, M, Sabzalian, M. R, Bielecka, M., Matkowski, A, Talebi, M. 2022. Changes in physiological, phytochemical traits and gene expression of two Perovskia species in response to water deficit. Scientia Horticulturae, 293, 110747.

Ahmad, I, Munsif, F, Mihoub, A, Jamal A, Saeed, M. F, Babar, S, & Zia, A. 2022. Beneficial effect of melatonin on growth and chlorophyll content in wheat (*Triticum aestivum* L.) grown under salt stress conditions. Gesunde Pflanzen, 74(4), 997-1009.

Ahmad, S, Cui, W, Kamran, M, Ahmad, I, Meng, X, Wu, X, & Han, Q. 2021. Exogenous application of melatonin induces tolerance to salt stress by improving the photosynthetic efficiency and antioxidant defense system of maize seedling. Journal of Plant Growth Regulation, 40, 1270-1283.

Ahmad, S, Kamran, M, Ding R, Meng, X., Wang, H, Ahmad, I., & Han, Q. 2019. Exogenous melatonin confers drought stress by promoting plant growth, photosynthetic capacity and antioxidant defense system of maize seedlings. PeerJ, 7, e7793.

Ahmad, S., Kamran, M., Zhou, X., Ahmad, I., Meng, X., Javed, T., & Han, Q. 2021. Melatonin improves the seed filling rate and endogenous hormonal mechanism in grains of summer maize. Physiologia Plantarum, 172(2), 1059-1072.

Ahmad, S, Muhammad, I., Wang, G. Y., Zeeshan, M., Yang, L., Ali, I, & Zhou, X. B. 2021. Ameliorative effect of melatonin improves drought tolerance by regulating growth, photosynthetic traits and leaf ultrastructure of maize seedlings. BMC Plant Biology, 21(1), 368.

Ahmad, S., Wang, G. Y., Muhammad, I., Chi, Y. X., Zeeshan, M., Nasar, J., & Zhou, X. B. 2022. Interactive effects of melatonin and nitrogen improve drought tolerance of maize seedlings by regulating growth and physiochemical attributes. Antioxidants, 11(2), 359.

Ahmadian, A., Ghanbari, A., Siahsar, B., Haydari, M., Ramroodi, M., Mousavinik, S. M 2011. Study of chamomiles yield and its components under drought stress and organic and inorganic fertilizers usage and their residue. Journal of Microbiology and Antimicrobials, 3(2), 23-28. http://www.academicjournals.org/JMA

Ahmed, A. M., Wais, A. H., Ditta, A., Islam, M. R., Chowdhury, M. K., Pramanik, M. H, Islam, M. S 2024. Seed Germination and Early Seedling Growth of Sorghum (*Sorghum bicolor* L. Moench) Genotypes Under Salinity Stress. Polish Journal of Environmental Studies, 33(3). https://doi.org/10.15244/pjoes/177180

Akram, M., M. Zahid, A.B.U. Farooq, M. Nafees and A. Rasool. 2020. Effects of different levels of NaCl on the seed germination of cyamopsis tetragonoloba L. Bangladesh J. Bot., 49(3): 625- 632. https://doi.org/10.3329/bjb.v49i3.49995

Al Garni,R. S, Cooke, M (2021). The concept of HRQoL for patients on hemodialysis in Saudi Arabia: an exploratory study. Health and quality of life outcomes, 19(1), 273.

Ali, M., Kamran, M., Abbasi, G. H., Saleem, M. H., Ahmad, S., Parveen, A., & Fahad, S. 2021. Melatonin-induced salinity tolerance by ameliorating osmotic and oxidative stress in the seedlings of two tomato (*Solanum lycopersicum* L.) cultivars. Journal of Plant Growth Regulation, 40, 2236-2248.

Alison., & M. R. 2005. Liver stem cells: implications for hepatocarcinogenesis. Stem cell reviews, 1, 253-260. https://doi.org/10.1385/SCR:1:3:253

Alom, R, Hasan, M. A., Islam, M. R., Wang, & Q., F. 2016. Germination characters and early seedling growth of wheat (*Triticum aestivum* L.) genotypes under salt stress conditions. Journal of crop science and biotechnology, 19, 383-392. https://doi.org/10.1007/s12892-016-0052-1

Al-Shammari, W. B., Altamimi, H., R, & Abdelaal, K 2023. Improvement in physio biochemical and yield characteristics of pea plants with nano silica and melatonin under salinity stress conditions1. https://doi.org/10.3390/horticultuare9060711

Altaf, M. A., Shahid, R., Ren, M. X., Naz, S., Altaf, M. M., Khan, L. U., & Nawaz, M. A. 2022. Melatonin improves drought stress tolerance of tomato by modulation plant growth, root architecture, photosynthesis, and antioxidant defense system. Antioxidants. 2022; 11 (2): 309. https://doi. org/10.3390/antiox11020309.

Amara, N, &Benrima, A. 2017. Salt stress effects on growth and development of coriander Coriandrum sativum L. AgroBiologia, 7(1), 203-209.

Amiri, H., Zamani, Z., Arnao, M. B., Ismaili, A., Gavyar, P. H. H., & Khodayari, H. 2024. Optimal concentration of melatonin enhances drought stress tolerance in fenugreek. Acta Physiologiae Plantarum, 46(2), 15.

Amiripour, A., Ghanbari Jahromi, M., Souri, M. K., & Mohammadi Torkasvand, A. 2021. Silicon stimulates physiochemical properties of coriander (*Coriandrum sativum* L.) to improve growth and yield under salt stress. Journal of Medicinal plants and By-product, 10(2), 209-216. https://doi.org/ 10.22092/jmpb.2021.353466.1324

Amiripour, A., Jahromi, M. G., Soori, M. K., & mohammadi Torkashvand, A. 2021. Changes in essential oil composition and fatty acid profile of coriander (*Coriandrum sativum* L.) leaves under salinity and foliar-applied silicon. Industrial Crops and Products, 168, 113599

Anitha, K., Senthil A., Kalarani, M. K, Senthil, N., Marimuthu S, Djanaguiraman M, Umapathi, M. 2022. Exogenous melatonin improves seed germination and seedling growth in greengram under drought stress. Journal of Applied and Natural Science, 14(4), 1190-1197.https://doi.org/10.31018/jans.v14i4.3818

Anitha, K., Senthil, A., Kalarani, M. K., Senthil, N., Marimuthu, S., & Umapathi, M. 2023. Melatonin mediated high-temperature tolerance at seedling stage in green gram (*Vigna radiata* L.). Journal of Applied and Natural Science, 15(1), 85-93.

Anitha, K., Senthil, A., Sritharan, N., & Ravikesavan, R. 2020. Melatonin improves germination and seedling growth under drought stress in finger millet. Multi-Dimens. Approaches Transform. Agric, 248.

Arif, M. U. H. A. M. M. A. D., Khurshid, H. A. R. I. S., & Khan, S. 2014. Genetic structure and green leaf performance evaluation of geographically diverse population of coriander (*Coriandrum sativum* L.). European Acedemic Research, 2(3), 3269-3285.https://doi.org/1 www.euacademic.org

Ashraf, R., Ghufran, S., Akram, S., Mushtaq, M., & Sultana, B. 2020. Cold pressed coriander (*Coriandrum sativum* L.) seed oil. In Cold pressed oils (pp. 345-356). Academic Press. https://doi.org/10.1016/B978-0-12-818188-1.00031-1

Azizi, F., Amiri, H., & Ismaili, A. 2022. Melatonin improves salinity stress tolerance of Phaseolus vulgaris L. cv. Pak by changing antioxidant enzymes and photosynthetic parameters. Acta Physiologiae Plantarum, 44(4), 40. https://doi.org/10.1007/s11738-022-03373-y

Bahcesular, B., Yildirim, E. D., Karaçocuk, M., Kulak, M., & Karaman, S. 2020. Seed priming with melatonin effects on growth, essential oil compounds and antioxidant activity of basil (*Ocimum basilicum* L.) under salinity stress. Industrial Crops and Products, 146, 112165. https://doi.org/10.1016/j.indcrop.2020.112165

Bai, Y., Xiao, S., Zhang, Z., Zhang, Y., Sun, H., Zhang, K., & Liu, L.2020. Melatonin improves the germination rate of cotton seeds under drought stress by opening pores in the seed coat. PeerJ, 8, e9450.https://doi.org/10.7717/peerj.9450/fig-5

Bajaya, T., Bajya, M., Ghasolia, R. P., & Shivran, M. 2022. Incidence of collar rot of groundnut in Rajasthan and its management. Legume Research-An International Journal, 45(7), 921-925.

Bajya, M., Kakralya, B. L., & Bajaya, T. 2017. Estimation of the effect of drought on morpho-physiological attributes in different coriander genotypes (*Coriandrum sativum* L.). Journal of Plant Science Research, 33(2).

Bakyani, M. R. F., Alinia, M., Kazemeini, S. A., Abadía, J., & Dadkhodaie, A. 2022. Foliar application of melatonin improves the salt tolerance, ion and redox homeostasis and seed oil fatty acid profile in Camelina sativa. Plants, 11(22), 3113. https://doi.org/ 10.3390/plant /11223113

Bashtanova, U. B., & Flowers, T. J. 2012. Effect of low salinity onion accumulation, gas exchange and postharvest drought resistance and habit of Coriandrum sativum L. Plant and soil, 355, 199-214.

Bates, L. S., Waldren, R. P. A., & Teare, I. D. 1973. Rapid determination of free proline for water-stress studies. Plant and soil, 39, 205-207.

Bera, S. K., Ajay, B. C., & Singh, A. L. 2013. WRKY and Na+/H+ antiporter genes conferring tolerance to salinity in interspecific derivatives of peanut ('*Arachis hypogaea*'L.). Australian Journal of Crop Science, 7(8), 1173-1180.

Bistgani, Z. E., Barker, A. V., & Hashemi, M. 2024. Physiology of medicinal and aromatic plants under drought stress. The Crop Journal.

Bradford, K. J. 2002. Applications of hydrothermal time to quantifying and modeling seed germination and dormancy. Weed Science, 50(2), 248-260.

Burdock, G. A., & Carabin, I. G. 2009. Safety assessment of coriander (*Coriandrum sativum* L.) essential oil as a food ingredient. Food and chemical Toxicology, 47(1), 22-34.CO;2 https://doi.org/10.1016/j.fct.2008.11.006

Castañares, J. L., & Bouzo, C. A. 2019. Effect of exogenous melatonin on seed germination and seedling growth in melon (*Cucumis melo* L.) under salt stress. Horticultural Plant Journal, 5(2), 79-87.

Cen, H., Wang, T., Liu, H., Tian, D., & Zhang, Y. 2020. Melatonin application improves salt tolerance of alfalfa (*Medicago sativa* L.) by enhancing antioxidant capacity. Plants, 9(2), 220.

Chen, L., Liu, L., Lu, B., Ma, T., Jiang, D., Li, J., & Li, C. 2020. Exogenous melatonin promotes seed germination and osmotic regulation under salt stress in cotton (*Gossypium hirsutum* L.). Plos one, 15(1), e0228241.

Chen, L., Lu, B., Liu, L., Duan, W., Jiang, D., Li, J., & Bai, Z. 2021. Melatonin promotes seed germination under salt stress by regulating ABA and GA3 in cotton (*Gossypium hirsutum* L.). Plant Physiology and Biochemistry, 162, 506-516.

Chowdhury, M. K., Hasan, M. A., Bahadur, M. M., Islam, M. R., Hakim, M. A., Iqbal, M. A., ... & Islam, M. S. 2021. Evaluation of drought tolerance of some wheat (*Triticum aestivum* L.) genotypes through phenology, growth, and physiological indices. Agronomy, 11(9), 1792.

Cicek, N., & Çakirlar, H. 2002. The effect of salinity on some physiological parameters in two maize cultivars. Bulgarian Journal of Plant Physiology, 28(1-2), 66-74.

Cipolla-Neto, J., & Amaral, F. G. D. 2018. Melatonin as a hormone: new physiological and clinical insights. Endocrine reviews, 39(6), 990-1028.

Cortés-Eslava, J., Gómez-Arroyo, S., Villalobos-Pietrini, R., & Espinosa-Aguirre, J. J.2004. Antimutagenicity of coriander (*Coriandrum sativum* L.) juice on the mutagenesis produced by plant metabolites of aromatic amines. Toxicology letters, 153(2), 283-292.

Cui, G., Zhao, X., Liu, S., Sun, F., Zhang, C., & Xi, Y. 2017. Beneficial effects of melatonin in overcoming drought stress in wheat seedlings. Plant Physiology and biochemistry, 118, 138-149.

da Silva Sá, F. V., Souto, L. S., de Paiva, E. P., Neto, M. F., da Silva, R. A., do Nascimento Silva, M. K., & Neto, A. A. 2016. Tolerance of coriander cultivars under saline stress. African Journal of Agricultural Research, 11(39), 3728-3732.https://doi.org/10 10.5897/ajar2016.11390

Daničić, M., Maksimović, I., Putnik-Delić, M., Kastori, R., Crnobarac, J., Jaćimović, G., & Šeremešić, S. 2021. Biomass production and mineral composition of coriander (*Coriandrum sativum* L.) exposed to NaCl. Biologia Futura, 72, 453-459.https://doi.org/10 .10.1007/s42977-021-00090-4.

Darughe, F., Barzegar, M., & Sahari M. A.,2012. Antioxidant and antifungal activity of Coriander (*Coriandrum sativum* L.) essential oil in cake. International Food Research Journal, 19(3), 1253-1260.

Devi, S., Gupta, E., Sahu, M., & Mishra, P. 2020. Proven health benefits and uses of coriander (*Coriandrum sativum* L.). In Ethnopharmacological investigation of Indian spices (pp. 197-204). IGI Global.

Diederichsen, A.,1996. Bioversity International. Coriander: *Coriandrum Sativum* L (Vol. 3). https://doi.org/10. 92-9043-284-5

Eidi, A., Moghadam-kia, S., Moghadam, J. Z., Eidi, M., & Rezazadeh, S. 2012. Antinociceptive and anti-inflammatory effects of olive oil (*Olea europeae* L.) in mice. Pharmaceutical biology, 50(3), 332-337.https://doi.org/10.3109/13880209.2011.600318

Eidi, M., Eidi, A., Saeidi, A., Molanaei, S., Sadeghipour, A., Bahar, M., & Bahar, K. 2009. Effect of coriander seed (*Coriandrum sativum* L.) ethanol extract on insulin release from pancreatic beta cells in streptozotocin-induced diabetic rats. Phytotherapy Research: An International Journal Devoted to Pharmacological and Toxicological Evaluation of Natural Product Derivatives, 23(3), 404-406. https://doi.org/10.1002/ptr.2642

Eirini, S., Paschalina, C., Ioannis, T., & Kortessa, D. T. 2017. Effect of drought and salinity on volatile organic compounds and other secondary metabolites of Citrus aurantium leaves. Natural Product Communications, 12(2).

Eisa, E. A., Honfi, P., Tilly-Mándy, A., & Mirmazloum, I. 2023. Exogenous Melatonin Application Induced Morpho-Physiological and Biochemical Regulations Conferring Salt Tolerance in Ranunculus asiaticus L. Horticulturae, 9(2), 228.

El Moukhtari, A., Cabassa-Hourton, C., Farissi, M., & Savouré, A. 2020. How does proline treatment promote salt stress tolerance during crop plant development? Frontiers in plant science, 11, 1127. https://doi.org/10.3389/fpls.2020.01127

El-Bauome, H. A., Abdeldaym, E. A., Abd El-Hady, M. A., Darwish, D. B. E., Alsubeie, M. S., El-Mogy, M. M., & Doklega, S. M. 2022. Exogenous proline, methionine, and melatonin stimulate growth, quality, and drought tolerance in cauliflower plants. Agriculture, 12(9), 1301.https://doi.org/10.3390/agriculture12091301.

El-Beltagi, H. S. 2022. Sulaiman; Mohamed, MEM; Ullah, S.; Shah, S. Effects of Ascorbic Acid and/or α-tocopherol on Agronomic and Physio-biochemical Traits of Oat (*Avena sativa* L.) under Drought Condition. Agronomy 2022, 12, 2296.

El-Beltagi, H. S., Sulaiman, Mohamed, M. E. M., Ullah, S., & Shah, S. 2022. Effects of ascorbic acid and/or α-tocopherol on agronomic and physio-biochemical traits of oat (*Avena sativa* L.) under drought condition. Agronomy, 12(10), 2296.

Ewase, A. E. D. S. S., El-Sherif, S. O., & Tawfik, N. 2013. Effect of salinity stress on coriander (*Coriandrum sativum* L.) seeds germination and plant growth. Egyptian Academic Journal of Biological Sciences, H. Botany, 4(1), 1-7.https://doi.org/10.21068/eajbsh.2013.17000

Farahani, H. A., Valadabadi, S. A., Daneshian, J., Shiranirad, A. H., & Khalvati, M. A. 2009. Medicinal and aromatic plants farming under drought conditions. Journal of Horticulture and Forestry, 1(6), 086-092. http://www.academicjournals.org/jhf

Farouk, S., & Al-Huqail, A. A. 2022. Sustainable biochar and/or melatonin improve salinity tolerance in borage plants by modulating osmotic adjustment, antioxidants, and ion homeostasis. Plants, 11(6), 765.https://doi.org/10.3390/plants11060765

Fredj M. B, Zhani K, Hannachi C, & Mehwachi, T. 2013. Effect of NaCl priming on seed germination of four coriander cultivars (*Coriandrum sativum* L.). EurAsian Journal of BioSciences, 7. https://doi.org/10. 5053/ejobios.2013.7.0.3

Gao, W., Feng, Z., Bai, Q., He, J., & Wang, Y. 2019. Melatonin-mediated regulation of growth and antioxidant capacity in salt-tolerant naked oat under salt stress. International journal of molecular sciences, 20(5), 1176.

García-Cánovas, I., Giraldo-Acosta, M., Cano, A., Arnao, M. B., & Hernández-Ruiz, J.2024. Effect of Melatonin on germination and seedling growth in aging seeds or under drought conditions. Seeds, 3(3), 341-356.

Ghamarnia, H., & Daichi, S. 2013. Effect of different water stress regimes on different coriander (*Coriander sativum* L.) parameters in a semi-arid climate. International Journal of Agronomy and Plant Production, 4 (4), 822-832.http:// www.ijappjournal.com

Ghane, S. G., Lokhande, V. H., & Nikam, T. D. 2014. Growth, physiological, and biochemical responses in relation to salinity tolerance for In Vitro selection in oil seed crop Guizotia abyssinica Cass. Journal of crop science and biotechnology, 17, 11-20.

Gholizadeh, A., Dehghani. H., Khodadadi, M. 2019. The effect of different levels of drought stress on some morphological, physiological and phytochemical characteristics of different endemic coriander (*Coriandrum sativum* L.) genotypes. Environmental Stresses in Crop Sciences, 12(2), 459-470.

Gul, N., Haq, Z. U., Ali, H., Munsif, F., Hassan, S. S. U., & Bungau, S. 2022. Melatonin pretreatment alleviated inhibitory effects of drought stress by enhancing anti-oxidant activities and accumulation of higher proline and plant pigments and improving maize productivity. Agronomy, 12(10), 2398.

Gulzar, S., Khan, M. A., & Ungar, I. A. 2003. Salt tolerance of a coastal salt marsh grass. Communications in Soil Science and Plant Analysis, 34(17-18), 2595-2605.

Guo, Y., Li, D., Liu, L., Sun, H., Zhu, L., Zhang, K., & Li, C. 2022. Seed priming with under PEG-6000 induced drought stress. Frontiers in Plant Science, 13, 932912.

Hancı, F. 2019. The effect of L-tryptophan and melatonin on seed germination of some cool season vegetable species under salinity stress. Düzce Üniversitesi Bilim ve Teknoloji Dergisi, 7(3), 1879-1891.Teknoloji Dergisi, 7(3), 1879-1891.

Haque, S. A. 2006. Salinity problems and crop production in coastal regions of Bangladesh. Pakistan Journal of Botany, 38(5), 1359-1365.

Hasan, A., Hafiz, H. R., Siddiqui, N., Khatun, M., Islam, R., Mamun, A. 2015. Evaluation of wheat genotypes for salt tolerance based on some physiological traits. Journal of Crop Science and Biotechnology, 18, 333-340. https://doi.org/10. DOI No. 10.1007/s12892-015-0064-2

Hasanuzzaman, M., Bhuyan.M. B., Parvin, K., Bhuiyan, T. F., Anee, T. I., Nahar, K., Fujita, M. 2020. Regulation of ROS metabolism in plants under environmental stress: A review of recent experimental evidence. International Journal of Molecular Sciences, 21(22), 8695. https://doi.org/10.3390/ijms21228695

Hassanein, R. A., Hussein O. S, Farag I. A, Hassan Y. E., Abdelkader A. F, Ibrahim M. 2022. Salt-stressed coriander (*Coriandrum sativum* L.) responses to potassium silicate, humic acid and gamma irradiation pretreatments. Agronomy, 12(10), 2268. https://doi.org/10.3390/agronomy12102268

He, M., Mei, S., Zhai, Y., Geng, G., Yu, L., & Wang, Y. 2023. Effects of melatonin on the growth of sugar beet (*Beta vulgaris* L.) seedlings under drought stress. Journal of Plant Growth Regulation, 42(8), 5116-5130.

Hernández-Almanza, A., de la Fuente-Salcido, N. M., Valenzuela-Gloria, M., Cano-González, C. N., & Contreras-Esquivel, J. C. 2024. Nutritional and Multi-Therapeutic Traits of Coriander (Coriandrum sativum) to Enhance Human Health. In the Role of Nutrition in Integral Health and Quality of Life (pp. 183-214). Apple Academic Press.

Hu, W, Zhang, J, Yan, K, Zhou, Z, Zhao, W, Zhang, X, Yu, R. 2021. Beneficial effects of abscisic acid and melatonin in overcoming drought stress in cotton (*Gossypium hirsutum*L.) PhysiologiaPlantarum, 173(4),2041-2054. https://doi.org/10.1111/ppl.13550

Huang, H, Nakamura, T, Yasuzawa, T, Ueshima, S. 2020. Effects of Coriandrum sativum on migration and invasion abilities of cancer cells. Journal of nutritional science and vitaminology, 66(5), 468-477. https://doi.org/10.3177/jnsv.66.468

Huang, Q., Yan, H., You, M., Duan, J., Chen, M., Xing, Y., & Li, X. 2023. Enhancing Drought Tolerance and Fruit Characteristics in Tomato through Exogenous Melatonin Application. Horticulturae, 9(10), 1083.

Hussain, R., Ayyub.C. M., Shaheen. M. R., Rashid, S., Nafees, M., Ali, S., & Mora-Poblete F. 2021. Regulation of osmotic balance and increased antioxidant activities under heat stress in Abelmoschus esculentus L. triggered by exogenous proline application. Agronomy, 11(4), 685. https://doi.org/10.3390/agronomy11040685

Hussain, S. S., Rasheed, M., Ahmed, Z. I., Jilani, G., Irfan, M., Aziz, M. K., & Zuhair, H. 2024. Melatonin-mediated induction of salt tolerance in maize at germination and seedling stage. Sarhad Journal of Agriculture, 40(2), 490-501.

Hussain, S. S., Rasheed, M., Saleem, M. H., Ahmed, Z. I., Hafeez., A, & Jilani G,Ali, S. 2023. Salt tolerance in maize with melatonin priming to achieve sustainability in yield on salt affected soils. Pakistan Journal of Botany, 55(1), 19-35.

Hussain, S., Nisar, F., Gul, B., & Hameed, A. 2024. Seed priming with melatonin improved salinity tolerance of halophytes during early life-cycle stages. Plant Growth Regulation, 103(2), 351-368. https://doi.org/10.1007/s10725-023-01110-0

Hussain, S., Nisar, F., Gul, B., & Hameed, A. 2024. Seed priming with melatonin improved salinity tolerance of halophytes during early life-cycle stages. Plant Growth Regulation, 103(2), 351-368.

Iftekhar, M. S., Islam, & M. R. 2004. Managing mangroves in Bangladesh: A strategy analysis. Journal of Coastal Conservation, 10(1), 139-146. https://doi.org/10.1652/1400-0350(2004)010 [0139: MMIBAS]2.0.CO;2

Imran, M., Latif Khan, A., Shahzad, R, Aaqil Khan, M, Bilal & S, Khan, A, Lee I. J. 2021. Exogenous melatonin induces drought stress tolerance by promoting plant growth and antioxidant defence system of soybean plants. AoB Plants, 13(4), plab026. https://doi.org/10.1093/aobpla/plab026

Iqbal, S., Hayat, F., Hussain, M., Mushtaq, N., Rehman.M & Asif, A., Shahid. M. A. 2024. Melatonin supplementation alleviates drought stress in peach (*Prunus persica*) seedlings by improving photosynthesis, root morphological traits, and antioxidant defense system. Acta Physiologiae Plantarum, 46(2), 18. https://doi.org/10.1007/s11738-023-03634-4

Islam M. R, Bhuiyan M. A. R, Prasad B, Quddus M. A. 2001. Salinity effect on yield and component characters in rapeseed and mustard varieties. Journal of biological sciences, 1(9), 840-842. https://doi.org/10.3923/jbs.2001.840.842

Islam, M. M., Hossain, M. A., Sanjowal, R. K. 2022. Bangladesh at Fifty: changes and challenges in population and development. Journal of Governance, Security & Development, 3(1), 1-38. https://doi.org/10.52823/PNIF4859

Islam, M. M., Jahan, K., Sen, A., Urmi, T. A., & Haque, M. M, Ali H. M, Murata Y et al. 2023. Exogenous application of calcium ameliorates salinity stress tolerance of tomato (*Solanum lycopersicum* L.) and enhances fruit quality. Antioxidants, 12(3),558. https://doi.org/10.3390/antiox12030558

Ismaeil, F. M., Ahmed, S. E. E., Jabereldar, A. A., Ibrahim, E. A., & El-Naim, A. M. 2022 Effects of Melatonin Priming on Seed Germination of Wheat under Salt Stress.

Jafari M, Shahsavar A. R, Talebi M., Hesami, M. 2022. Exogenous melatonin protects lime plants from drought stress-induced damage by maintaining cell membrane structure, detoxifying ROS and regulating antioxidant systems. Horticulturae, 8(3), 257.

Jalili, S., Ehsanpour, A. A., & Morteza Javadirad, S. 2023. Melatonin improves salt tolerance of in vitro root culture of alfalfa (*Medicago sativa* L.). Biologia, 78(4), 961-970.

Jamali M. M, Martirosyan H. 2013. Evaluate the effect of water deficit and chemical fertilizers on some characteristics of coriander (*Coriandrum sativum* L.). International Journal of Agronomy and Plant Production, 4(3), 413-417. http:// www.ijappjournal.com

Jamil M, Lee C. C, Rehman S. U, Lee D. B, & Ashraf M, Rha E. S. 2005. Salinity (NaCl) tolerance of Brassica species at germination and early seedling growth. Electronic Journal of Environmental, Agricultural and Food Chemistry, 4(4), 970-976. https://doi.org/10. 1579-4377

Jansen P. C. M. 1981. Spices, condiments and medicinal plants in Ethiopia, their taxonomy and agricultural significance. Wageningen University and Research. https://doi.org/10. .4236/jacen.2020.94021

Jiang, J., Shi, Z., Ma, F., & Liu, K. 2022. Identification of key proteins related to high-quality fiber in Upland cotton via proteomics analysis. Plant Cell Reports, 41(4), 893-904.

Jiang, X., Li, H., & Song, X. 2016. Seed priming with melatonin effects on seed germination and seedling growth in maize under salinity stress. Pak J Bot, 48(4), 1345-1352.

Kabiri, R., Hatami, A., Oloumi, H., Naghizadeh, M., Nasibi, F. & Tahmasebi, Z. 2018. Foliar application of melatonin induces tolerance to drought stress in Moldavian balm plants through regulating the antioxidant system. Folia Horticulturae, 30(1), 155-167. https://doi.org/10.2478/fhort-2018-0016.

Kamatchi, K. M., Senthil, A., Kalarani, M. K., Swarnapriya, R., Marimuthu, S., & Djanaguiraman, M. 2023. Anti-stress effects of melatonin pre-treatment on germination indicators in tomato (*Lycopersicon esculentum* L.) under polyethylene glycol induced drought stress. Journal of Applied Horticulture, 25(3), 319-324.

Kang, J. Y., Mishanina, T. V., Bellecourt, M. J., Mooney, R. A., Darst, S. A., & Landick, R. 2018. RNA polymerase accommodates a pause RNA hairpin by global conformational rearrangements that prolong pausing. Molecular cell, 69(5),802-815.

Karim-Kos, H. E., de Vries, E., Soerjomataram, I., & Lemmens, V., Siesling, S., Coebergh, J. W. W. 2008. Recent trends of cancer in Europe: a combined approach of incidence, survival and mortality for 17 cancer sites since the 1990s. European journal of cancer, 44(10), 1345-1389. https://doi.org/10.1016/j.ejca.2007.12.015

Karim-Kos, H. E., de Vries, E., Soerjomataram, I., Lemmens V, Siesling S, & Coebergh, J. W. W. 2008. Recent trends of cancer in Europe: a combined approach of incidence, survival and mortality for

17 cancer sites since the 1990s. European journal of cancer, 44(10), 1345-1389. Journal of Coastal Conservation, 10(1), 139-146.

Kassahun, F., Worku, C., Nigussie, A., Ganfurie, G. 2018. Prevalence of male attendance and associated factors at their partners antenatal visits among antenatal care attendees in Bale Zone, South East Ethiopia. International Journal of Nursing and Midwifery, 10(9), 109-120.

Kern, C., Gombert, C., Roso, A., & Garcia, C. 2020. Soothing effect of virgin coriander seed oil on sensitive skin. OCL, 27, 49.https://doi.org/10.1051/ocl/2020043

Khalid, M., Rehman, H. M., Ahmed, N., Nawaz, S., Saleem, F., Ahmad, S., ... & Lam, H. M. 2022. Using exogenous melatonin, glutathione, proline, and glycine betaine treatments to combat abiotic stresses in crops. International Journal of Molecular Sciences, 23(21), 12913.

KHAN, M. A., & Ungar, I. A. 1996. Influence of Salinity and Temperature on the Germination ofHaloxylon recurvumBunge ex. Boiss. Annals of Botany, 78(5), 547-551.

Khan, M. A., Ungar, I. A., Showalter, A. M., & Dewald, H. D. 1998. NaCl-induced accumulation of glycinebetaine in four subtropical halophytes from Pakistan. Physiologia Plantarum, 102(4), 487-492.

Khan, M. N., Zhang, J., Luo, T., Liu, J., Ni, F., Rizwan, M., & Hu, L. 2019. Morpho-physiological and biochemical responses of tolerant and sensitive rapeseed cultivars to drought stress during early seedling growth stage. Acta Physiologiae Plantarum, 41, 1-13.

Khan, M. N., Zhang, J., Luo, T., Liu, J., Rizwan, M., Fahad, S., & Hu, L. 2019. Seed priming with melatonin coping drought stress in rapeseed by regulating reactive oxygen species detoxification: Antioxidant defense system, osmotic adjustment, stomatal traits and chloroplast ultrastructure perseveration. Industrial Crops and Products, 140, 111597.

Khan, M. T., Ahmed, S., Sardar, R., Shareef, M., Abbasi, A., Mohiuddin, M., & Golokhvast, K. S. 2022. Impression of foliar-applied folic acid on coriander (Coriandrum sativum L.) to regulate aerial growth, biochemical activity, and essential oil profiling under drought stress. Frontiers in Plant Science, 13, 1005710.

Konuşkan, Ö., Gözübenli, H., Atış, İ., & Atak, M. 2017. Effects of salinity stress on emergence and seedling growth parameters of some maize genotypes (*Zea mays* L.). Turkish Journal of Agriculture - Food Science and Technology,5(12):1668-1672.

Korkmaz, N., AŞKIN, M. A., Altunlu, H., Polat, M., Okatan, V., & Kahramanoğlu, İ. 2022. The effects of melatonin application on the drought stress of different citrus rootstocks. Turkish Journal of Agriculture and Forestry, 46(4), 585-600.

Kumar, K. A., Kalarani, M. K., Vijayalakshmi, D., Geethalakshmi, V., Raveendran, M., & Anandhi, V. 2024. Evaluation of Melatonin Concentrations on Germination and Seedling Traits of Rice against Drought Stress. Indian Journal of Agricultural Research, 58(1), 29-35.

Li, D., Zhang, D., Wang, H., Li, H., Song, S., Li, H., & Li, R. 2019. Effects of melatonin on germination and amino acid content in different wheat varieties seeds under polyethylene glycol stress. BioRxiv, 710954.

Li, H. Y., Zhai, X. Z., Zhang, S. C., Shen, J. M., Yang, N., Li, H. R., & Li, D. X. 2021. Effect of exogenous melatonin on seed germination and leaf physiological characteristic of wheat seedling under drought stress.

Li, J., Zhao, C., Zhang, M., Yuan, F., & Chen, M. 2019. Exogenous melatonin improves seed germination in Limonium bicolor under salt stress. Plant Signaling & Behavior, 14(11), 1659705.

Li, X., Yin, X., Wang, H., Li, J., Guo, C., Gao, H., & Wang, X. 2015. Genome-wide identification and analysis of the apple (Malus× domestica Borkh.) TIFY gene family. Tree Genetics & Genomes, 11, 1-13. https://doi.org/ 10.1007/s11295-014-0808-z

Li, X., Yu, B., Cui, Y., & Yin, Y. 2017. Melatonin application confers enhanced salt tolerance by regulating Na^+ and Cl^- accumulation in rice. Plant Growth Regulation, 83, 441-454.

Li, Y., Zhang, L., Yu, Y., Zeng, H., Deng, L., Zhu, L.& Wang, Y. 2022. Melatonin-induced resilience strategies against the damaging impacts of drought stress in rice. Agronomy, 12(4), 813.

Li, Z., Di, H., Cheng, W., Zhang, Y., Ren, G., Ma, J., & Sun, B. 2023. Variation in health-promoting compounds and antioxidant activities in mustard (Brassica juncea) sprouts. Scientia Horticulturae, 309, 111673. https://doi.org/ 10.1039/c8ra05504a

Liang, D., Ni, Z., Xia, H., Xie, Y., Lv, X., Wang, J., & Luo, X. 2019. Exogenous melatonin promotes biomass accumulation and photosynthesis of kiwifruit seedlings under drought stress. Scientia Horticulturae, 246, 34-43.

Lichtenthaler, H. K. 1987. Chlorophylls and carotenoids: pigments of photosynthetic biomembranes. In Methods in enzymology (Vol. 148, pp. 350-382). Academic Press.

Lin, Q., Zong, Y., Xue, C., Wang, S., Jin, S., Zhu, Z., & Gao, C. (2020). Prime genome editing in rice and wheat. Nature biotechnology, 38(5), 582-585.

Liu Ling, L. L., Li Dong, L. D., Ma YiLin, M. Y., Wang LiJun, W. L., Zhao ShiMin, Z. S., Zhou JunXue, Z. J., & Wang YanFang, W. Y.2019. Alleviation of drought stress and the physiological mechanisms in tobacco seedlings treated with exogenous melatonin.

LIU, L., LI, D., MA, Y. L., WANG, L. J., ZHAO, S. M., ZHOU, J. X., & WANG, Y. F. 2019. Alleviation of drought stress and the physiological mechanisms in tobacco seedlings treated with exogenous melatonin. Acta Prataculturae Sinica, 28(8), 95.

Liu, R., Wang, T., Wang, J., Yan, D., Lian, Y., Lu, Z., & Li, R. 2024. The Physiological Mechanism of Exogenous Melatonin on Improving Seed Germination and the Seedling Growth of Red Clover (*Trifolium pretense* L.) under Salt Stress. Plants, 13(17), 2527.

Liu, Y., Li, Z., Zhong, C., Zhang, Y., Wang-Pruski, G., Zhang, Z., & Wu, J. 2023. Alleviating effect of melatonin on melon seed germination under autotoxicity and saline-alkali combined stress. Journal of Plant Growth Regulation, 42(4), 2474-2485.

Luo, M., Wang, D., Delaplace, P., Pan, Y., Zhou, Y., Tang, W., & Chen, M. 2023. Melatonin enhances drought tolerance by affecting jasmonic acid and lignin biosynthesis in wheat (*Triticum aestivum* L.). Plant Physiology and Biochemistry, 202, 107974.

Luo, Y., Hu, T., Huo, Y., Wang, L., Zhang, L., & Yan, R. 2023. Effects of exogenous melatonin on chrysanthemum physiological characteristics and photosynthesis under drought stress. Horticulturae, 9(1), 106. https://doi.org/10.3390/horticulturae9010106

Madebo, M. P., Luo, S. M., Li, W. A. N. G., Zheng, Y. H., & Peng, J. I. N. 2021.Melatonin treatment induces chilling tolerance by regulating the contents of polyamine, γ-aminobutyric acid, and proline in cucumber fruit. Journal of Integrative Agriculture, 20(11), 3060-3074.

Mahendra, P., & Bisht, S. 2011. Coriandrum sativum: A daily use spice with great medicinal effect. Pharmacognosy Journal, 3(21), 84-88.

Maroufi, K., Farahani, H. A., & Darvishi, H. H. 2010. Importance of coriander (*Coriandrum sativum* L.) between the medicinal and aromatic plants. Advances in Environmental Biology, 433-437.

Mazrou, R. M., Hassan, F. A., Mansour, M. M. F., & Moussa, M. M. 2023. Melatonin Enhanced Drought Stress Tolerance and Productivity of *Pelargonium graveolens* L. (Herit) by Regulating Physiological and Biochemical Responses. Horticulturae, 9(11), 1222.

Meena, N. K., Lal, G., Meena, S. S., Kant, K., & Meena, R. D. 2019. Screening of coriander genotypes for their relative susceptibility against aphids under field conditions. Journal of Horticultural Sciences, 14(2), 125-129.

Meena, Y. K., Jadhao, B. J., & Kale, V. S. 2014. Genetic analysis of agronomic traits in coriander. SABRAO Journal of Breeding and Genetics, 46 (2),265-273.

Megala, R., Kalarani, M. K., Jeyakumar, P., Senthil, N., Pushpam, R., & Umapathi, M. 2022. Standardization of optimum melatonin concentration for drought tolerance at germination and early development stage in rice (CO-54). Journal of Applied and Natural Science, 14(3), 1022-1030.

Mengesha, B., & Getinetalemaw, G. 2010. Variability in Ethiopian coriander accessions for agronomic and quality traits. African Crop Science Journal, 18(2).

Mengesha, K. b., Alemaw G,Tesfaye, B. 2013. Correlation studies and path coefficient analysis for seed yield and yield components in Ethiopian coriander accessions. African Crop Science Journal, 21(1), 51-59. https://doi.org/10. 1021-9730

Michel, B. E. 1983. Evaluation of the Water Potentials of Solutions of Polyethylene Glycol 8000. Plant Physiology, 72:66–70

Mishra P, Prasad S. M et al. 2021. Low dose UV-B radiation induced mild oxidative stress impact on physiological and nutritional competence of Spirulina (Arthrospira) species. Plant Stress, 2, 100039. https://doi.org/10.1016/j.stress.2021.100039

Mohamadi Esboei, M., Ebrahimi, A., Amerian, M. R., & Alipour, H. 2022. Melatonin confers fenugreek tolerance to salinity stress by stimulating the biosynthesis processes of enzymatic, non-enzymatic antioxidants, and diosgenin content. Frontiers in Plant Science, 13, 890613.

Mohammadi, E., Sadoughi, F., Younesi, S., Karimian, A., Asemi, Z., Farsad-Akhtar, N., & Yousefi, B. 2021. The molecular mechanism of nuclear signaling for degradation of cytoplasmic DNA: Importance in DNA damage response and cancer. DNA repair, 103, 103115.

Mohammadi, E., Sadoughi, F., Younesi, S., Karimian, A., Asemi, Z., Farsad-Akhtar, N., & Yousefi, B. 2021. The molecular mechanism of nuclear signaling for degradation of cytoplasmic DNA: Importance in DNA damage response and cancer. DNA repair, 103, 103115.

Moosavi, S. M., Moosavi, S. G. R., & Seghatoleslami, M. J. 2014. Effect of drought stress and nitrogen levels on growth, fruit and essential oil yield of fennel (*Foenicolum vulgare Mill*.). Iranian Journal of Medicinal and Aromatic Plants Research, 30(3), 453-462.

Muhammad, I., Ullah, F., Ahmad, S., AlMunqedhi, B. M., Al Farraj, D. A., Elshikh, M. S., & Shen, W. 2024. A meta-analysis of photosynthetic efficiency and stress mitigation by melatonin in enhancing wheat tolerance. BMC Plant Biology, 24(1), 427.

Muhammad, I., Yang, L., Ahmad, S., Farooq, S., Khan, A., Muhammad, N., & Zhou, X. B. 2023. Melatonin-priming enhances maize seedling drought tolerance by regulating the antioxidant defense system. Plant Physiology, 191(4), 2301-2315.

Naghizadeh, M., Kabiri, R., Hatami, A., Oloumi, H., Nasibi, F., & Tahmasei, Z. 2019. Exogenous application of melatonin mitigates the adverse effects of drought stress on morpho-physiological traits and secondary metabolites in Moldavian balm (*Dracocephalum moldavica*). Physiology and Molecular Biology of Plants, 25, 881-894.

Nawata, E., Itanai, J., & Masanaga, Y. I. 1994, August. The distribution and dissemination pathway of coriander in Asia. In Internat. Symposium on Medicinal and Aromatic Plants 390 (pp. 167-176).https://doi.org/10.17660/ActaHortic.1995.390.24

Neffati, M., Marzouk B. 2010. Salinity impact on growth, essential oil content and composition of coriander (*Coriandrum sativum* L.) stems and leaves. Journal of Essential Oil Research, 22(1), 29-34. https://doi.org/10.1080/10412905.2010.9700259

Neto M. F, Miranda R. S, Prisco J. T, Gomes-Filho, E. 2014. Changes in Growth Parameters and Biochemical Mechanisms of Coriander Plants Irrigated with Saline Water. An. do II Inovagri Int. Meet. - 2014, no, 3843-3850. https://doi.org/10.12702//ii.inovargi.2014-a514

Okkaoğlu H., Sönmez Ç., özge Şimşek, A,Bayram E.2015. Effect of Salt Stress on Some Agronomical Characteristics and Essential Oil Content of. Journal of Applied Biological Sciences, 9(3), 21-24.

Okunlola, G. O., Olatunji, O. A., Niewiadomska, E., Jimoh, M. A., Rufai, A. B., & Ogunkunle, C. O. 2023. Foliar application of melatonin alleviates the deleterious effects of drought on the three most cultivated capsicum species in Africa. Gesunde Pflanzen, 75(1), 139-149.

Oliveira-Spolaor, B., Chiari-Bertoli, S., Silva-Sukert, D., Sala, H. R., Picoli de Oliveira, B. F., de Freitas, Í. R., & Lima-Moro, A. 2022. Exogenous melatonin induces tolerance to drought stress damage in seedlings and soybean plants. Chilean journal of agricultural research, 82(4), 515-526.

Parida, A. K., Das A. B. 2005. Salt tolerance and salinity effects on plants: a review. Ecotoxicology and environmental safety, 60(3),324-349.

Park, H. S., Kazerooni E. A, Kang S. M, Al-Sadi A. M, Lee I. J. 2021. Melatonin enhances the tolerance and recovery mechanisms in Brassica juncea (L.) Czern. under saline conditions. Frontiers in plant science, 12, 593717.

Rajavel, M., & Vincent, S. 2009. Effect of seed hardening of pulses for drought tolerance.

Rehaman A, Mishra A. K, Ferdose A, Per T. S, Hanief M, Jan A. T, Asgher, M. (2021). Melatonin in plant defense against abiotic stress. Forests, 12(10),1404.

Ren, T., Liu, Z., Zhang, L., Liu, D., Xi, X., Kang, Y., Zhang, X. 2020. Early identification of seed maize and common maize production fields using sentinel-2 images. Remote Sensing, 12(13), 2140. https://doi.org/10.3390/rs12132140

Sadak M. S. 2016. Mitigation of salinity adverse effects of on wheat by grain priming with melatonin. International Journal of ChemTech Research, 9(2), 85-97.

Sadak, M. S., Bakry B. A. 2020. Alleviation of drought stress by melatonin foliar treatment on two flax varieties under sandy soil. Physiology and molecular biology of plants, 26, 907-919. https://doi.org/10.1007/s12298-020-00789-z

Saddiq, M. S., Iqbal, S., Hafeez, M. B., Ibrahim, A. M., Raza, A., Fatima, E. M., Ciarmiello, L. F. 2021. Effect of salinity stress on physiological changes in winter and spring wheat. Agronomy, 11(6), 1193. https://doi.org/10.3390/agronomy11061193

Sánchez-Navarro, A., Girona-Ruíz, A., Delgado-Iniesta, M. J. 2024. Green Manuring and Irrigation Strategies Positively Influence the Soil Characteristics and Yield of Coriander (*Coriandrum sativum* L.) Crop under Salinity Stress. Land, 13(3), 265.

Sardar, H., Ramzan M. A, Naz S., Ali, S., Ejaz, S., Ahmad, R., Altaf, M. An. 2023. Exogenous application of melatonin improves the growth and productivity of two broccoli (*Brassica oleracea* L.) cultivars under salt stress. Journal of Plant Growth Regulation, 42(8), 5152-5166. https://doi.org/10.1007/s00344-023-10946-9

Sardar, H., Ramzan, M. A., Naz, S., Ali, S., Ejaz, S., Ahmad, R., & Altaf, M. A. 2023. Exogenous application of melatonin improves the growth and productivity of two broccoli (*Brassica oleracea* L.) cultivars under salt stress. Journal of Plant Growth Regulation, 42(8), 5152-5166.

Sardar, H., Shafiq, M., Naz, S., Ali, S., Ahmad, R., & Ejaz, S. 2024. Enhancing Drought Tolerance in Broccoli (*Brassica oleracea* L.) through Melatonin Application: Physiological and Biochemical

Insights into Growth, Photosynthesis, and Antioxidant Defense Mechanisms. Biocatalysis and Agricultural Biotechnology, 103256.

Sattar, A., Sher, A., Ijaz, M., Ul-Allah, S., Hussain, S., Rasheed, U., & Ibrahim, M. F. 2023. Modulation of antioxidant defense mechanisms and Morpho-physiological attributes of wheat through exogenous application of silicon and melatonin under water deficit conditions. Sustainability, 15(9), 7426.

Sedratul J, Abu H. M, Bari Chowdhury A. K. M. M., & Rahman H. M. H, Ara S. T, Kumer, P. S, Rabiul, I. M. Physiological Indices and Yield Traits of Wheat Genotypes under Drought Stress Condition. International Journal of Agricultural Sciences and Veterinary Medicine, 11(1), 1-10.

Shah, N. A., Ullah, S., Nafees, M., Khan, M. N. 2023. Exogenous Effect of Sugar Beet Extract on Physio-biochemical Traits of *Hordeum vulgare* L. Under Induced Salinity Stress. Gesunde Pflanzen, 75(6), 2655-2667.https://doi.org/10. 10.1007/s10343-023-00894-5

Shaheen, S., Lalarukh, I., Ahmad, J., Zulqadar, S. A., Alharbi, S. A., Hareem, M., & Ansari, M. J. 2024. Physio-biochemical mechanism of melatonin seed priming in stimulating growth and drought tolerance in bread wheat. BMC Plant Biology, 24(1), 918.

Sharma, A., Zheng, Bm 2019. Melatonin mediated regulation of drought stress: physiological and molecular aspects. Plants, 8(7), 190. https://doi.org/10. 10.3390/plants8070190

Sharma, M. M., & Sharma, R. K. 2012. Coriander. In Handbook of herbs and spices (pp. 216-249). Woodhead Publishing.

Silva, F, Domingues, F. C. 2017. Antimicrobial activity of coriander oil and its effectiveness as food preservative. Critical reviews in food science and nutrition, 57(1), 35-47. https://doi.org/10.1080/10408398.2013.847818

Song, J., Fan, H., Zhao, Y., Jia, Y., Du, X., Wang, B 2008. Effect of salinity on germination, seedling emergence, seedling growth and ion accumulation of a euhalophyte Suaeda salsa in an intertidal zone and on saline inland. Aquatic Botany, 88(4), 331-337.

Stefan, M, Zhang, W., Concepcion, E., Yi, Z., & Tomer, Y. 2014. DNA methylation profiles in type 1 diabetes twins point to strong epigenetic effects on etiology. Journal of autoimmunity, 50, 33-37. https://doi.org/10.1016/j.jaut.2013.10.001

Stephen, K., Khan, F. A., Bhat, S. A., Narayan, S., Mir, S. A., Mir, M. S., & Lone, S. A. 2018. Optimizing priming concentration and duration of various priming agents for improved seed germination in chilli (*Capsicum annum* L.). Journal of Pharmacognosy and Phytochemistry, 7(4), 2689-2693.

Sun, F., Ding, L., Feng, W., Cao, Y., Lu, F., Yang, Q., Yu, H. 2021. Maize transcription factor ZmBES1/BZR1-5 positively regulates kernel size. Journal of Experimental Botany, 72(5), 1714-1726. https://doi.org/10.1093/jxb/eraa544.

Tan J, Lin L, Luo H, Zhou S, Zhu Y, Wang X, Zhang P et al 2022. Recent progress in the regeneration and genetic transformation system of cucumber. Applied Sciences, 12(14), 7180. https://doi.org/10.3390/app12147180

Thakur P,Thakur, A. 2018. Effect of water stress on yield and seed quality of coriander (*Coriandrum sativum* L.). International Journal of Bio-resource and Stress Management, 9(Feb, 1), 159-163. https://doi.org/10.23910/IJBSM/2018.9.1.3C0581

Thakur, P., Thakur, A. 2018. Assessment of effects of water stress on growth and seed yield of coriander. International Journal of Farm Sciences, 8(3), 1-5. https://doi.org/10. 10.5958/2250-0499.2018.00069.1

Ubaidillah, M., Farooq, M., & Kim, K. M. 2024. Enhancing salt tolerance in rice genotypes through exogenous melatonin application by modulating growth patterns and antistress agents. Scientific Reports, 14(1), 25217.

Uddin, M. N., Islam, M. T., Karim M. A. 2005. Salinity tolerance of three mustard/rapeseed cuitivars. Journal of the Bangladesh Agricultural University, 3(2), 203-208.

Vafadar, F., & Ehsanzadeh, P. 2023. Synergistic effects of calcium and melatonin on physiological and phytochemical attributes of Dracocephalum kotschyi genotypes under salinity stress. Physiologia Plantarum, 175(3), e13912.

Vafadar, F., Amooaghaie, R., Ehsanzadeh, P., Ghanati, F., & Allakhverdiev, S. 2021. Melatonin improves the photosynthesis in Dracocephalum kotschyi under salinity stress in a Ca2+/CaM-dependent manner. Functional Plant Biology, 49(1), 89-101.

Vinila, J. A, Paramaguru P, Arunkumar K, Vaidehi G 2020. Studies on bio-chemical parameters of coriander (*Coriandrum sativum* L.) genotypes under drought condition. The Pharma Innovation Journal, 9(8), 265-272

Vojodi Mehrabian, L., Valizadeh Kamran, R., Khurizadeh,S., Seiied Nezami, S. 2018. Response of coriander to salinity stress. Journal of Plant Physiology and Breeding, 8(2), 89-98. https://doi.org/10.2008-5168

Wang, D. Y., Wang, J., Shi, S. H., Huang, L. X., Zhu, M., & Li, F. H. 2021. Exogenous melatonin ameliorates salinity-induced oxidative stress and improves photosynthetic capacity in sweet corn seedlings. Photosynthetica, 59(2).

Wang, F., Wan, C., Wu, W., Yang, S., & Chen, X. 2024. Exogenous melatonin (MT) enhances salt tolerance of okra (*Abelmoschus esculentus* L.) plants by regulating proline, photosynthesis, ion homeostasis and ROS pathways. Vegetos, 37(1), 224-238.

Wang, J., Lv, P., Yan, D., Zhang, Z., Xu, X., Wang, T., & Li, R. 2022. Exogenous melatonin improves seed germination of wheat (*Triticum aestivum* L.) under salt stress. International Journal of Molecular Sciences, 23(15), 8436.

Wang, J., Yan, D., Liu, R., Wang, T., Lian, Y., Lu, Z., & Li, R. 2024. The physiological and molecular mechanisms of exogenous melatonin promote the seed germination of maize (*Zea mays* L.) under salt stress. Plants, 13(15), 2142.

Wang, L. Y., Liu, J. L., Wang, W. X., & Sun, Y. 2016. Exogenous melatonin improves growth and photosynthetic capacity of cucumber under salinity-induced stress. Photosynthetica, 54, 19-27.

Wang, L. Y., Liu, J., Wang, W. X,Sun,Y. 2016. Exogenous melatonin improves growth and photosynthetic capacity of cucumber under salinity-induced stress. Photosynthetica, 54, 19-27.

Wen, B. X, Hussain, S., Yang, J. Y., Shan, W. A. N. G., Zhang, Y., Qin S. S,Liu, W. G. 2020. Rejuvenating soybean (*Glycine max* L.) growth and development through slight shading stress. Journal of Integrative Agriculture, 19(10), 2439-2450.

Xiao, S., Liu, L., Wang, H., Li, D., Bai, Z., Zhang, Y., & Li, C. 2019. Exogenous melatonin accelerates seed germination in cotton (*Gossypium hirsutum* L.). PloS one, 14(6), e0216575.

Yang, Z., Li, C., Jia, Q., Zhao, C., Taylor, D. C., Li, D., Zhang, M. 2020. Transcriptome analysis reveals candidate genes for petroselinic acid biosynthesis in fruits of Coriandrum sativum L. Journal of agricultural and food chemistry, 68(19), 5507-552 https://doi.org/10.0. 10.1021/acs.jafc.0c01487

Yasmeen, S., Wahab, A., Saleem, M. H., Ali, B., Qureshi, K. A., Jaremko, M. 2022. Melatonin as a foliar application and adaptation in lentil (*Lens culinaris Medik*.) crops under drought stress. Sustainability, 14(24), 16345. https://doi.org/10.3390/su142416345

Ye, J., Wang, S., Deng, X., Yin, L., Xiong, B., & Wang, X. 2016. Melatonin increased maize (*Zea mays* L.) seedling drought tolerance by alleviating drought-induced photosynthetic inhibition and oxidative damage. Acta physiologiae plantarum, 38(2), 48.

Yeganehpoor, F., Zehtab-Salmasi, S., Shafagh-Kolvanagh, J., Ghassemi-Golezani K,Dastborhan, S. 2018 Improve growth and fruit yield of coriander under water deficit? Acta Scientiarum Polonorum Hortorum Cultus, 18(3),87-97.

Yoosefzadeh Najafabadi, M., Hesami, M., Eskandari, M. 2023. Machine learning-assisted approaches in modernized plant breeding programs. Genes, 14(4),777.

Yu, R., Zuo, T., Diao, P, Fu J, Fan Y, WangY, Wuriyanghan, H. 2021. Melatonin enhances seed germination and seedling growth of Medicago sativa under salinity via a putative melatonin receptor MsPMTR1. Frontiers in Plant Science, 12, 702875.

Yu, Y., Deng, L., Zhou, L., Chen, G., & Wang, Y. 2022. Exogenous melatonin activates antioxidant systems to increase the ability of rice seeds to germinate under high temperature conditions. Plants, 11(7), 886.

Zahedi S. M, Moharrami F, Sarikhani S, Padervand M. 2020. Selenium and silica nanostructure-based recovery of strawberry plants subjected to drought stress. Scientific reports, 10(1), 17672.

Zeng, H., Liu, M., Wang, X., Liu, L., Wu, H., Chen, X., & Wang, Y. 2022. Seed-soaking with melatonin for the improvement of seed germination, seedling growth, and the antioxidant defense system under flooding stress. Agronomy, 12(8), 1918.

Zhang, N., Yan, J., & Li, M. 2020. Melatonin enhanced short-term salt tolerance through improving water status in maize seedlings.

Zhang, N., Zhao, B., Zhang, H. J., Weeda, S., Yang, C., Yang, Z. C., & Guo, Y. D. 2013. Melatonin promotes water-stress tolerance, lateral root formation, and seed germination in cucumber (*Cucumis sativus* L.). Journal of pineal research, 54(1), 15-23.

Zhang, T., He, Y., DePauw, R., Jin ,Z., Garvin ,D., Yue, X,,Yang , X. 2022. Climate change may outpace current wheat breeding yield improvements in North America. Nature communications, 13(1), 5591.

Zhang, Z., Huang, J., Yao, Y., Peters, G., Macdonald, B., La Rosa, & A. D,Scherer ,L. 2023. Environmental impacts of cotton and opportunities for improvement. Nature Reviews Earth & Environment, 4(10), 703-715. https://doi.org/10.10.1038/s43017-023-00476-z

Zhang, Z., Ke, M, Qu, Q, Peijnenburg ,W. J. G. M, Lu ,T, Zhang ,Q., & Qian ,H. 2018. Impact of copper nanoparticles and ionic copper exposure on wheat (*Triticum aestivum* L.) root morphology and antioxidant response. Environmental Pollution, 239, 689-697.https://doi.org/10.1016/j.envpol.2018.04.066

Zhao, J., Hu, J. 2023. Melatonin: Current status and future perspectives in horticultural plants. Frontiers in Plant Science, 14, 1140803.

Zhou, R., Yu, X., Li, X., Dos Santos,T. M, Rosenqvist, E., & Ottosen C. O. 2020. Combined high light and heat stress induced complex response in tomato with better leaf cooling after heat priming. Plant physiology and biochemistry, 151, 1-9.

Zhu, L., Li, A., Sun, H., Li, P., Liu, X., Guo, C., & Li, C. 2023. The effect of exogenous melatonin on root growth and lifespan and seed cotton yield under drought stress. Industrial Crops and Products, 204, 117344.

APPENDICES

Appendix I: Factorial ANOVA for studied traits of Experiment 1 (Improvement of drought tolerance of coriander (*Coriandrum sativum* L.) through application of melatonin)

Sources of variation	Degrees of freedom	Mean square (MS)				
		GP	MGT	GRI	CVG	TGI
Treatment	8	436.840	0.696	76.115	1.424	11.180
Error	18	38.374	0.355	11.290	0.078	2.523
Total	26	-	-	-	-	-
Here, GP - Germination percentage, MGT- Mean germination time, GRI -Germination rate index, CVG - Co- efficient of velocity of germination, TGI-Timson germination index						

Sources of variation	Degrees of freedom	Mean square (MS)		
		SL	RL	SDW
Treatment	8	1.159	4.250	2.6880
Error	18	0.113	0.146	1.717
Total	26	-	-	-
Here, SL- Shoot length, RL- Root length, SDW- Seedling dry weight				

Sources of variation	Degrees of freedom	Mean square (MS)			
		Chlorophyll (C_a)	Chlorophyll (C_b)	Total Chlorophyll (C_{a+b})	Total Carotenoids ($Cx+c$)
Treatment	8	3.054	0.616	5.394	0.902
Error	18	0.567	0.116	0.803	0.003
Total	26	-	-	-	-

Sources of variation	Degrees of freedom	Mean square (MS)	
		Proline	RWLC
Treatment	8	3.509	93.346
Error	18	1.037	1.202
Total	26	-	-
Here, RWLC= Relative leaf water content			

Appendix II: Factorial ANOVA for studied traits of Experiment 2 (Improvement of salinity tolerance of coriander (*Coriandrum sativum* L.) through application of melatonin)

Sources of variation	Degrees of freedom	Mean square (MS)				
		GP	MGT	GRI	CVG	TGI
Treatment	8	296.785	0.833	65.339	0.8339	11.850
Error	17	9.916	0.098	6.137	0.0988	1.230
Total	25	-	-	-	-	-

Here, GP – Germination percentage, MGT- Mean germination time, GRI -Germination rate index, CVG -Co- efficient of velocity of germination, TGI-Timson germination index

Sources of variation	Degrees of freedom	Mean square (MS)		
		SL	RL	SDW
Treatment	8	18.632	2.164	3.661
Error	17	1.391	0.242	2.260
Total	25	-	-	-

Here, SL- Shoot length, RL- Root length, SDW- Seedling dry weight

Sources of variation	Degrees of freedom	Mean square (MS)			
		Chlorophyll (C_a)	Chlorophyll (C_b)	Total Chlorophyll (C_{a+b})	Total Carotenoids ($Cx+c$)
Treatment	8	2.362	0.472	7.911	7.215
Error	17	0.727	0.006	0.265	0.234
Total	25	-	-	-	-

Sources of variation	Degrees of freedom	Mean square (MS)	
		Proline	RWLC
Treatment	8	1.396	1.396
Error	17	3.556	3.556
Total	-	-	-

Here, RWLC= Relative leaf water content

Appendix IV: Some pictorial view of research field during research

Figure 1: Melatonin

Figure 2: Growth of plants under saline conditions

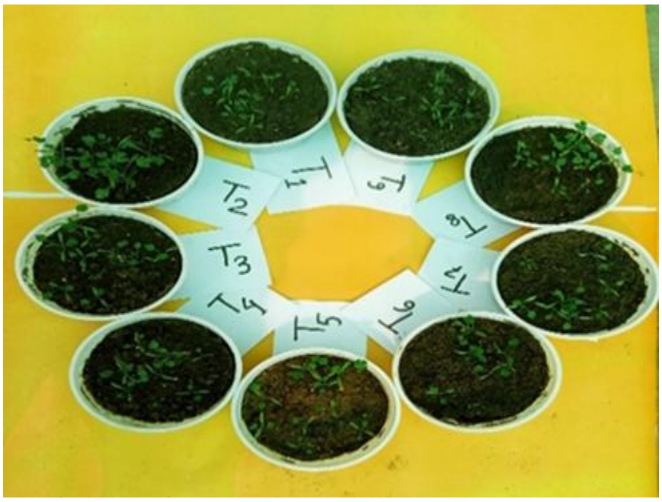

Figure 3: Growth of plants under drought conditions

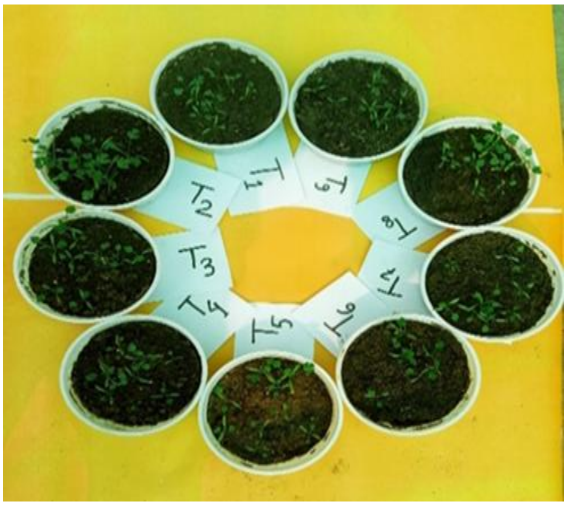

Figure 4: Growth of plants under salinity conditions