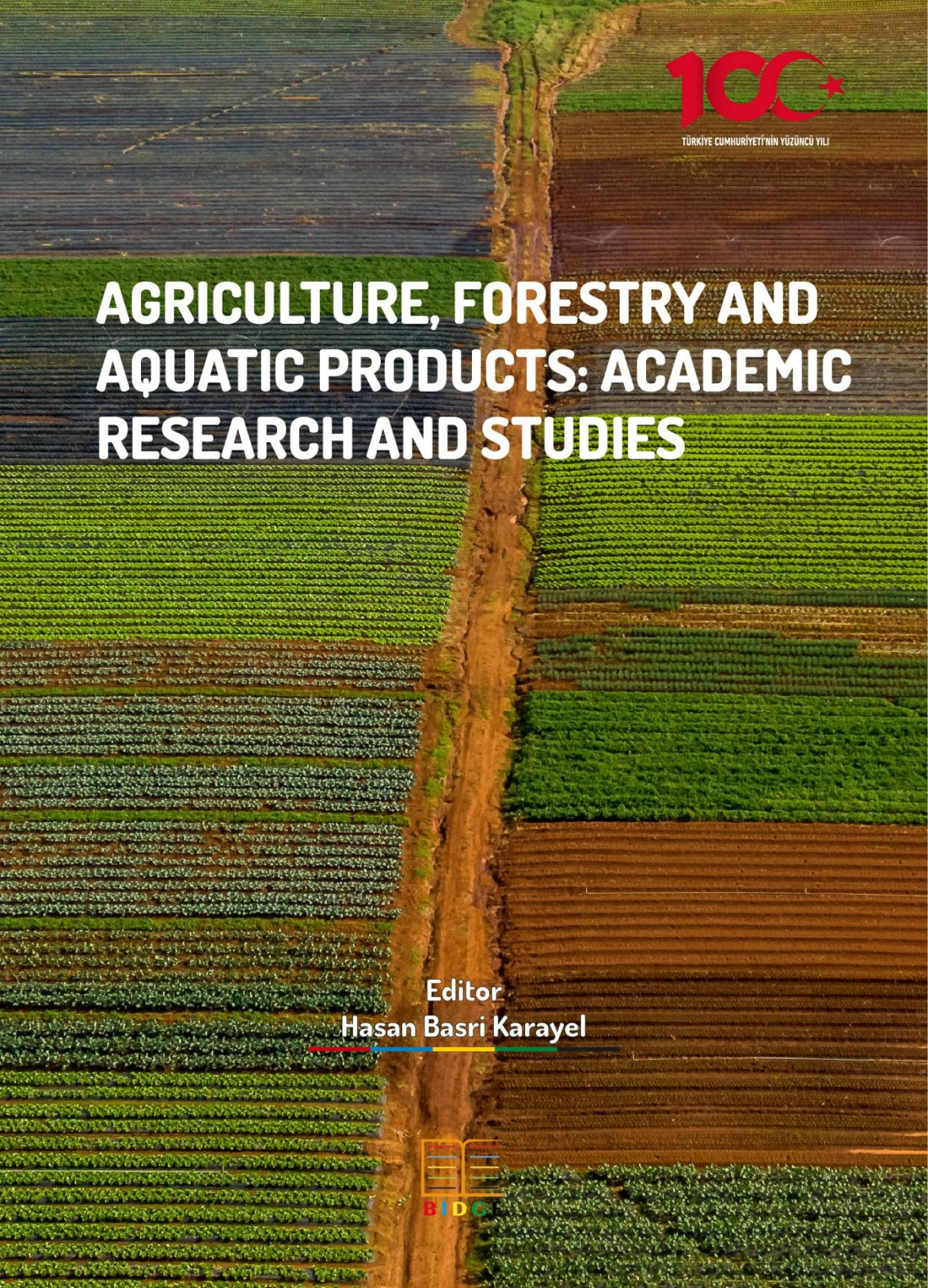

TÜRKİYE CUMHURİYETİ'NİN YÜZÜNCÜ YILI

AGRICULTURE, FORESTRY AND AQUATIC PRODUCTS: ACADEMIC RESEARCH AND STUDIES

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Hasan Basri Karayel

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AGRICULTURE, FORESTRY AND AQUATIC PRODUCTS: ACADEMIC RESEARCH AND STUDIES

Editor: Doç. Dr. Hasan Basri Karayel

ISBN: 978-625-372-474-0

Page Layout: Gözde YÜCEL

1st Edition:

Publication Date: 25.12.2024

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Güzeltepe Mahallesi Abidin Daver Sokak Sefer Apartmanı No: 7/9 Çankaya / Ankara

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CHAPTER I

Machine Learning Based Modeling and Classification in Heat and Drought Stress Management In Food Legume Crops

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Sibel IPEKESEN[2]
Murat TUNC[3]
Behiye Tuba BICER[4]

1. Introduction

Global climate change caused by global greenhouse gas emissions, feeding the world's population is increasingly challenging (Vermulen et al., 2012). Nowadays, the world hosts 7.5 billion people, however, it is expected that the population will increase to 10 billion people by 2050 (UN, 2019). In the people's

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nutrition, protein consumption has the most significant impact on greenhouse gas emissions and water usage Ritchie and Roser, 2020). Legume crops are rich in digestible protein, vitamins and minerals needed for a healthy diet. It is known that legumes have environmental benefits because they improve soil quality through nitrogen fixation, thus reducing the need for nitrogen fertiliser, increase the yield and quality of the next crop in the rotation, and are cheap (Foyer et al., 2016). However, they have also been reported to have annual yield variability due to biotic and abiotic stresses (Zandalinas et al., 2021).

In recent years, the effects of global warming, attributed to increasing in atmospheric CO_2 levels, has been felt remarkably in agricultural production areas. The global climate change has precipitated a notable decline in agricultural production. Drought and heat stress are significant abiotic stress factors decreasing crop yield with climate change. Some researchers have reported the

detrimental effects of heat and drought stress on plant growth and development particularly in regions where temperatures, which are mid-latitude and subtropical dry areas, have risen to excessively high levels and mean rainfall has diminished (Prasad et al., 2008; Jewell et al., 2010; Suzuki et al. 2014; Raza et al., 2019; Shukla et al., 2022). As indicated in the IPCC report, even in cases with the lowest CO_2 emissions, temperatures are estimated to rise by 1.5 degrees until 2040 (IPCC, 2022). Given the correlation between rising temperatures and increased droughts, it is inevitable that the combined effects of these two factors will result in a significant decline in plant production (Zandalinas et al., 2021). Drought, which results in a decrease in soil water content, reduces the usable water

content in the soil, leading to cellular dehydration in plants and stress. However, heat stress results from high temperatures and its effect increases with increasing solar radiation. Drought and heat stress interaction causes to increase in crop water consumption and evaporation from the soil as temperature increases from the leaf surface (Zandalinas et al., 2018). Therefore, in the case of drought and heat stress combined occurs severe decrease in crop production compared with the individual stresses. Heat and drought stress also affect the metabolism, cell structure and enzyme activities of legume crops, reducing the photosynthesis rate and inhibiting plant growth and development (Djanaguiraman et al., 2023). Especially, The effect of high-temperature and drought stress during reproductive stages is harmful to morphological and yield-related traits due to disturbed phenological development in legume crops such as chickpea (Samarah et al., 2009; Kumar et al. 2015), faba bean (Abdelmula & Abuanja 2007), dry bean (Beebe et al., 2011; Seidel et al. 2016) and lentil (Sehgal et al. 2017). In recent years, the effects of these stresses have been aggravated by global climatic change and these stresses become uncontrolled and unpredicted factors on legume plants (Varshney et al., 2013).

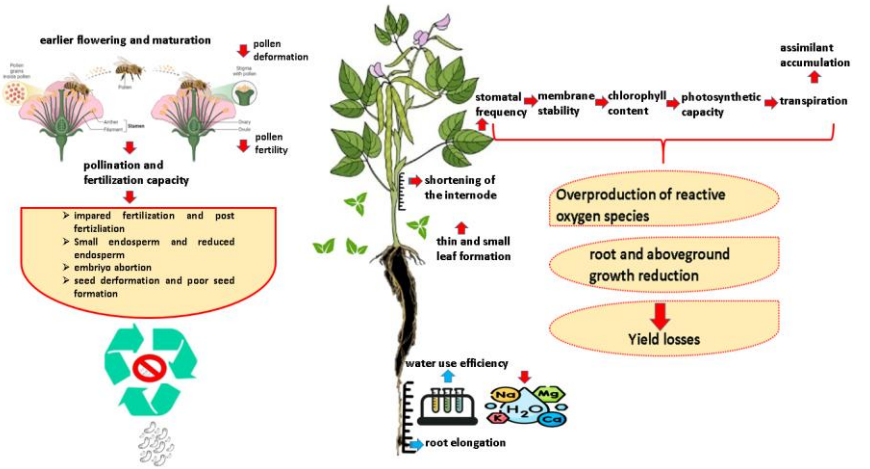

Figure 1. Presentation of morphological and physiological effects of combined drought and heat stress

Researchers reported that stress conditions disturb crop morphology, physiology, growing period and enzyme activation of legume crops (Awari et al., 2015; Li et al., 2018). Additionally, the chlorophyll content, chlorophyll fluorescence, stomatal conductance and photosynthesis decline under stress conditions (Hao et al., 2013; Siddiqui et al., 2015; Abdel et al., 2016; Abid et al., 2016). Drought and heat stress during the reproductive stage cause 50% of yield losses in legume crops (Gaur et al., 2009). Furthermore, yield loss was estimated to be 10%–15% for every 1 °C above the optimum temperature in the reproductive stage (Upadhaya et al., 2011). Dubey et al., (2011) noted that yield reduced by 38.5 kg ha^{-1} with every 0.1 °C temperature rise and 31% reduction in seasonal rainfall. Farooq et al., (2016) also reported that stress conditions were harmful to reproductive organs and caused to 27-87% yield decline. Fahad et al., (2016) stated that the reproductive stage was highly affected by

high temperatures and drought stress, and poor pollen viability, pollen shedding, poor pollen germination and growth and pollen elongation were increased by temperature ≥ 30 °C. Drought and heat stress often occur concurrently, and their combined impact on yield is greater than the sum of their individual effects. Consequently, both stresses should be considered in legume production areas (Dreesen et al., 2012).

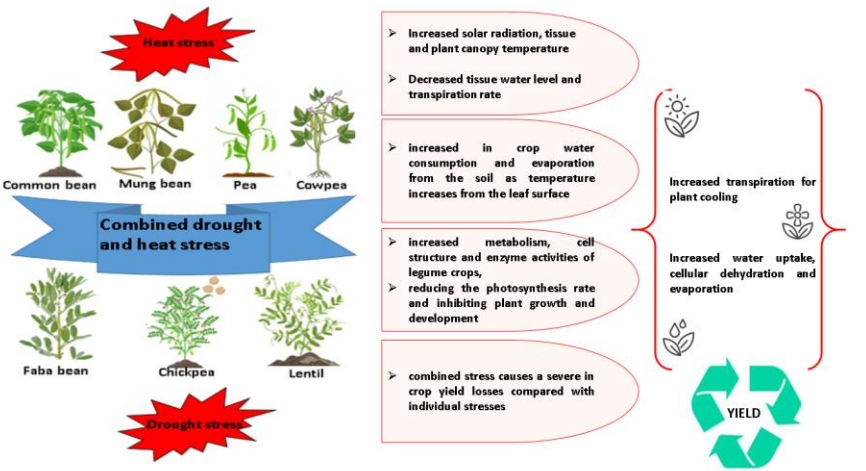

Figure 2. Effects of combined and individually of drought and heat stress on legume plants.

Some researchers reported that yield losses occurred in legume crops caused by drought, heat and combined drought and heat stresses (Table 1).

Table 1. Yield loss in legume crops under heat, drought and combined stress conditions reported by researchers

Stress	**Crop**	**Yield reduction %**	**References**
HS and DS	Chickpea	42.5	Rani et al., 2020
HS and DS	Chickpea	61.5	Awasthi et al., 2017
HS and DS	Lentil	57.1	Choukri et al., 2020
HS and DS	Cowpea	49.5	Nascimento et al., 2011
DS	Lentil, chickpea, cowpea, pea, common bean and faba bean	40	Daryanto et al., 2015
DS	Faba bean	28.47	Mansour et al., 2021
HS	Chickpea	39	Devasirvatham et al., Nascimento 2015
DS	Chickpea	44.5	Awasthi et al., 2017
HS	Chickpea	33	Awasthi et al., 2017
DS	Chickpea	42.5	Ahmed et al., 2005
DS	Field pea	37.5	Kumar et al., 2016
HS	Cowpea	>10	Sung et al., 2003
DS	Cowpea	44	Ndiso et al., 2016
HS	Common bean	26	Vargas et al., 2021
HS	Chickpea	50	Gaur et al., 2012
HS	Lentil	41	Delahunty et al., 2015
HS	Lentil	53.5	Choukri et al., 2020

HS; Heat stress and DS; Drought stress.

To cope with the challenges caused by drought and high-temperature stress and maintain crop productivity, it is necessary to follow developments in crop management practices and new breeding methods. Using these methods in case of the occurrence of drought and heat stress during crop growth stages is very important in predicting crop yield (Zhao et al., 2017).

This review goals to reveal the effects of drought and heat stress on legume plants and the effectiveness of machine learning algorithms that can be used to determine and classify yield losses caused by these stresses.

2. Using of machine learning and classification-based models

Machine learning (ML) models are increasingly used to analyse and predict climate change challenges such as drought and heat stress. These stressors pose significant risks to critical areas such as agriculture, water resources management, and ecosystem health. ML offers an effective solution to better understand these risks and develop appropriate countermeasures. In drought prediction, satellite images (drought indices such as NDVI, SPI), meteorological data (precipitation, temperature, evaporation rates), soil moisture measurements and hydrological data are used to detect drought symptoms early, such as decrease in precipitation, decrease in soil moisture and depletion of water resources. These data predict future drought conditions based on past data with neural networks such as LSTM (long short-term memory) and GRU, and DL can be used to create a drought severity classification model using historical weather and drought data. In heat stress prediction, historical temperature data, solar radiation and humidity, plant physiology and growth data are used to estimate the timing, duration and effects of

high heat waves. When evaluating this data, regression models can be used to estimate the effects of temperature increase on plants in a specific region, and regional temperature trends can be created by processing satellite images and weather data. Some machine learning algorithms such as RF algorithm can reveal the effect of different weather conditions on plant growth, while LSTM models can reveal the long-term effects of heat waves on crops with time series data. Additionally, support vector machines (SVM) can classify the water needs of plants, and clustering algorithms can be classify areas under water stress. Moreover, CNN (convolutional neural networks) model can be monitor the health status of vegetation from satellite images. RF or XGBoost can be used to classify drought severity while regression models can predict crop losses due to heat stress. LSTM can detect temperature and drought trends in time series data, and CNN can analyse land use changes to detect drought effects. Flowchart of the use of machine learning models in drought and heat stress conditions were given Figure 3.

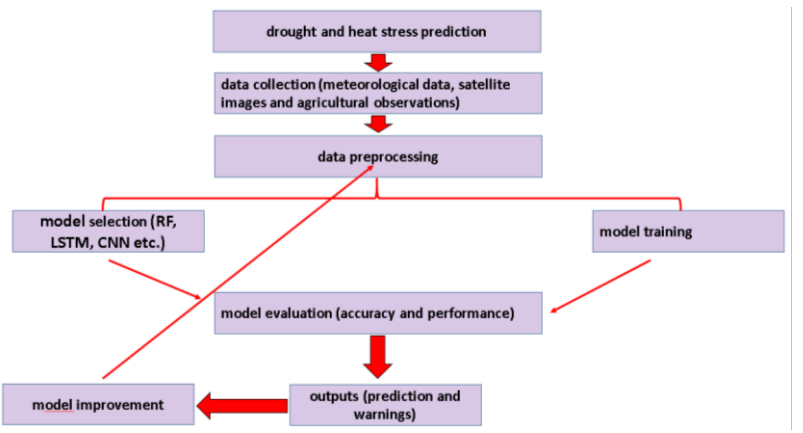

Figure 3. Flowchart of the use of machine learning models in drought and heat stress conditions

Machine learning-based modelling and classification in heat and drought stress management in legume plants is important to increase efficiency in agricultural production and develop plant species resistant to stress conditions. Studies in this field utilize machine-learning techniques to understand the stress responses of crops, determine suitable genotypes, and optimize agricultural practices. Machine learning is a powerful tool, which analyses biological, genetic, and environmental factors and processes complex and large datasets to determine resistance to drought and heat stress (Zhang & Yuan, 2020). These methods are successfully used in different sciences (Liakos et al., 2018; Yuan et al., 2020). Moreover, these methods are used in agricultural production to predict the effects of stress conditions on crops by using physical-based models such as machine learning (ML) and deep learning (DL) methods (Park et al., 2016). In this technique, resistant legume crops that can cope with stress can be determined with data-based solutions by processing large data sets such as genotype data, phenotypic traits, soil conditions, and climate variables. Brief workflow diagram of the machine learning method to yield prediction under stress conditions is given below.

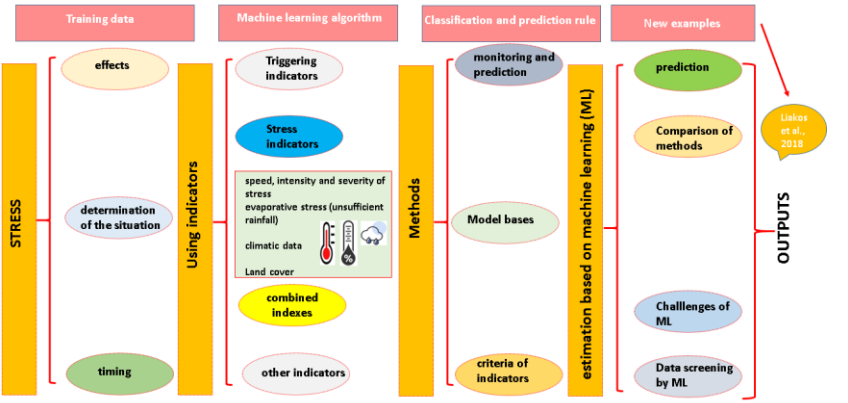

Figure 4. Workflow diagram of the machine learning method for yield production

Effects of drought and temperature conditions on plant development can be simulated using data estimation and simulation models, and the performance of genotypes in different environmental conditions can be evaluated (Prodhan et al., 2021). Machine techniques have the advantage of rapidly detecting stress compared to traditional methods because these techniques can produce almost real-time results. Additionally, sensing methods near the purpose have been used in these techniques by small and portable optical sensors. However, these optical sensors, which provide convenience in the data collection, require advanced data processing and statistics for complex and large-scale hyperspectral imaging. The patterns specific to stress in plant production can be created by analysing the data obtained using machine learning techniques. However, there is limited literature on the role of machine and deep learning methods in predicting the impact of stress. Therefore,

machine-learning methods should be used for stresses such as heat, drought, diseases etc. in agricultural production areas.

Some researchers stated that RGB and thermal image-based machines could be used to determine diseases (López-López et al., 2016; Yee-Rendon et al., 2021). Visible and thermal imaging techniques used in machine learning are one of the best and most widely used techniques in plant stress studies (Cohen et al., 2021), and these techniques provide information based on surface canopy area and canopy colour (Lee and Lee, 2013). Madurapperumage et al., (2024) have been used to measure the nutritional properties of legume plants by using infrared spectroscopy techniques such as FT-NIR and FT-MIR spectroscopy (Figure 5).

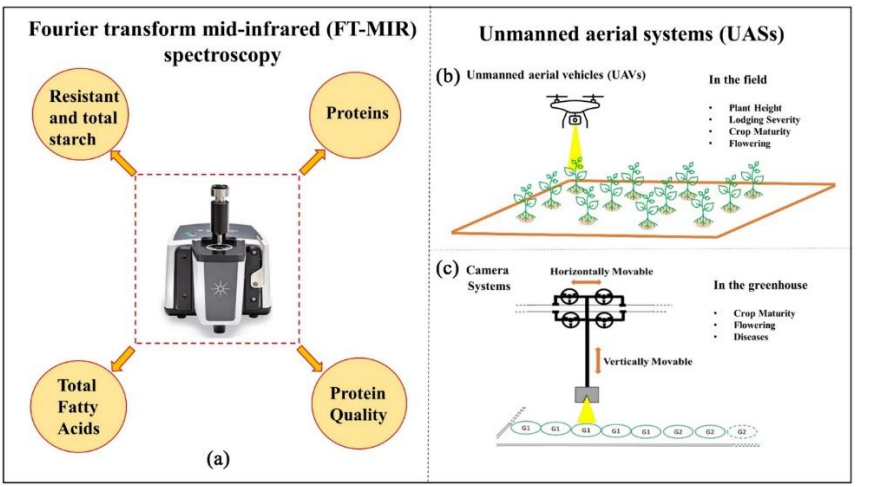

Figure 5. Using of FT-NIR and FT-MIR spectroscopy in legume crops

Additionally, some researchers also machine learning methods by imaging to control diseases (Singh et al., 2022). Machine learning, an emerging science, has produced remarkable results in

agricultural production using algorithms and processing techniques (Xing et al., 2022). Among legume crops, multispectral, hyperspectral and thermal remote sensing techniques have been used to detect Ascochyta blight, which causes serious yield losses in chickpea production (Zhang et al., 2019). Moreover, it has been reported that the classification of chickpea seeds can be detected with approximately 85% accuracy with image processing and machine learning algorithms (Kini et al. (2021). Furthermore, it is stated that these techniques can also be used in disease detection and classification with 92.55% accuracy (Belay et al. (2022). In addition, disease detection has been made in pea with chlorophyll fluorescence imaging (Bannihatti et al. (2022).

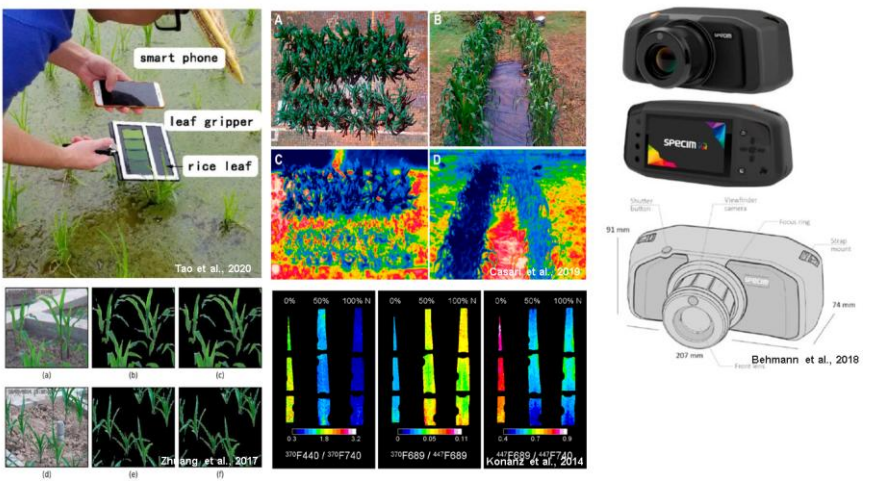

Figure 6. Some researchers reported that optic machines such as smartphones, thermographic image data, hyperspectral cameras, RGB and SVM optic machines, fluorescence emission spectra and fluorescence ratio could be used in agricultural areas.

Zhao et al., (2017) reported that faba bean varieties are adaptable to local climate and soil conditions and cultural practices, and the k-NN classification supported this with 84.5% accuracy. Additionally, Okumus et al., (2024) stated that the effect of temperature conditions on pea germination percentage, root and length, fresh and dry weight could be predicted by using MARS, Xgboost, and GPC models, however, the XGBoost model had the highest performance for the dataset. Okumus et al., (2024) also reported that when temperature from 10 °C to 20 °C conditions increased, shoot length, root length, fresh weight and dry weight of pea became less sensitive to salt stress, and predicting germination according to environmental conditions with machine learning methods reduced time and workload. In addition, Kisi et al. (2020) used artificial neural networks and radial basis function to improve the prediction performance of ML models with Bayesian model. Yang et al. (2021) also used a support vector machine, multiple adaptive regression spline and ridge regression models to predict evaporation with the Bayesian model, and this model had better performance results in terms of accuracy of daily evaporation estimates than other models. Singh et al., (2023) noted that among the ML models tested, the Cubist model consisting of the WS + IN dataset and the LAD model in the ML models built using the WS + PLS-IN dataset can be the best predictors of wilt severity. Aski et al., (2023) declared that artificial intelligence algorithms can help simulate yield under climate change and that the use of machine learning techniques will enable understanding of the genetic determinants of abiotic stress in lentil. Gain et al., (2024) stated that they successfully predicted yield per plant and number of pods per plant in lentils using the RF model, one of the machine learning

techniques. Some researchers used LiDAR and UAVs sensors to measure plant height and lodging sensitivity in legume plants and reported that these sensors can estimate the height of the plant by transmitting laser pulses (Bazrafkan et. al., 2023). APSIM model also was used in a study on lentils, and this model helped to better understand the synergies of ideotypes and agronomic practices and to identify the high yield potential of lentil crops in certain environments (Tefera et al., 2022). Machine learning provides information on machine learning based tools such as SVM and ANN in phenotyping biotic and abiotic stress by combining large data sets. Gou et al., (2024) stated that one of the machine learning models, TERRA-REF model, gave good results. Mokhtar et al., (2023) applied machine models such as SVR, LSTM, CNN, LSTM and CNN to estimate the irrigation water requirement in beans with real field experiments and reported that LTSM and CNN models gave the most satisfactory results. SVM models can be outperformed RF models in predicting the climate zone and cultivation region of mung beans with 100% accuracy (He et al., 2023). Moreover, in the cultivation of common bean, one of the most important legumes for human consumption, every 1°C increase in atmospheric temperature causes a decrease in yield by up to 9%, and the use of GWAS algorithms such as SUPER, FarmCPU and BLINK to identify loci associated with environmental heterogeneity in heat stress is possible to determine genome-wide environmental relationships (López-Hernández and Cortés, 2019). In a field experiment including 38 faba bean varieties, it was reported that the integration of UAVs equipped with RGB and multispectral cameras together with machine learning algorithms could provide accurate results in

predicting classical phenotyping measurements such as plant height and yield (Mohammadi et al., (2024).

3. Conclusion

Machine learning models are a powerful tool for managing and decreasing climate change-induced drought and heat stress by providing early warnings. Managing drought and heat stress in legumes is critical to agricultural sustainability and food security. New techniques have been used to understand and reduce the effects of these stress factors. Machine learning-based modelling and classification provide effective tools for heat and drought stress management in legume crops. It is possible to determine the effects of stress conditions on crop yield by analysing soil moisture, air temperature and plant development data with ML models, optimize irrigation timing and amount, model the loss of biodiversity in ecosystems and the long-term effects of stress, and predict future events by using past data on drought and heat stress conditions. Machine learning approaches significantly contribute to the development of new cultivars resistant to stress conditions, and offer significant advantages to both farmers and researchers by enabling innovative solutions that increase stress tolerance. Machine learning models offer a practical solution for fast and effective phenotyping in legume crop breeding programs. However, the use of machine learning models in agricultural areas is not yet at the desired level due to the lack of high-resolution, long-term and accurate data, the interaction of environmental factors in agricultural production and the inadequacy of applicable adaptation strategies. In addition, high-quality data, strong computational infrastructure, and interdisciplinary collaboration are required to make accurate

predictions. In the future, wider adoption of these technologies will contribute to creating a society and environment that is more resilient to the adverse effects of climate change.

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CHAPTER II

An Alternative Species for Grasslands and Lawns under Drought and Heat Stress: Buffalo Grass (*Bouteloua dactyloides* (Nutt.) J.T. Columbus)

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Introduction

Poaceae is a family of monocotyledonous flowering plants, commonly known as the *Gramineae*. It contains around 12 000 species distributed across 780 genera, this family is the fifth-largest plant family in number of species, behind only the *Asteraceae*, *Orchidaceae*, *Fabaceae* and *Rubiaceae* (Christenhusz & Byng, 2016; Anonymous, 2024a). The *Poaceae* constitute the most economically significant plant family, providing the primary source

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of nourishment in the form of domesticated cereals, including maize (*Zea mays* L.), wheat (*Triticum* sp.), rice (*Oryza sativa* L.), oats (*Avena sativa* L.), barley (*Hordeum vulgare* L.), and millets, for human consumption.

Apart from cereals, many cultivated or naturally growing grasses are an important source of animal feed. Grasses are used in animal nutrition as hay, herbage, silage and grazing. Grasses have stems that are hollow except at the nodes and narrow alternate leaves borne in two ranks. The lower part of each leaf encloses the stem, forming a leaf-sheath. The leaf grows from the base of the blade, which is an adaptation that enables the plant to cope with frequent grazing. Perennial species are most commonly used as hay. The most commonly utilized plants for this purpose are *Lolium perenne* L., *Phleum pratense* L., *Agrostis alba* L., *Dactylis glomerata* L., *Festuca pratense* (Huds.) Darbysh., *Bromus inermis* Leyss. and etc. In some cases, the following grasses are used for hay: *Choris gayana* Kunth., *Paspalum dilatatum* Poir., *Agropyron desertorum* (Fisch) Schult., *Agropyron cristatum* L. Gaertn., *Holcus lanatus* L., *Avena elatior* L. and *Agropyron trachycaulum* (Link) Malte. The majority of annual species constitute the group of plants utilized as green fodder. While the majority of annual species are used for silage production, maize, sorghum (*Sorghum bicolor* [L.] Moench) and sudan grass (*Sorghum sudanense* (Piper) Stapf.), which have rich above-ground parts, are predominantly employed for this purpose. Some species of the *Poaceae* are employed as construction materials, including bamboo, thatch, and straw. Others are utilized as a source of biofuel, primarily through the conversion of maize to ethanol.

In addition to all these uses, grasses are the first plant group that can be thought of in keeping the soil in place and preventing erosion due to the high number of underground and above-ground organs. Species with strong rhizome and stolon are used as soil retainers on beaches, around dams and water arcs, on the edges of railways and highways and bridges. Additionally, plants of this family are utilized on the walls and roofs of houses in temperate regions.

It is estimated that grasslands, which are dominated by grasses, constitute approximately 40.5% of the Earth's land area, with the exclusion of Greenland and Antarctica (Reynolds, 2005). These grasslands include savannahs and prairies. Furthermore, grasses constitute a significant component of the vegetative cover in a multitude of other habitats, including wetlands, forests, and tundra. Despite the common designation of "grasses," taxonomic groups such as seagrasses, rushes, and sedges are not included within this classification. The rushes and sedges are classified as members of the *Poaceae*, which is part of the order *Poales*. In contrast, the seagrasses are members of the order *Alismatales*. Nevertheless, they are all classified as monocots.

The term "C_3" and "C_4" are used to describe grasses based on their photosynthetic pathway for carbon fixation. The C_4 grasses possess a photosynthetic pathway linked to specialized Kranz leaf anatomy, which allows for increased water use efficiency (Gibson, 2009). This adaptation renders them better adapted to hot, arid environments. The C3 grasses are classified as "cool-season" grasses, whereas the C4 plants are regarded as "warm-season" grasses (Cope & Gray, 2009).

Many research that the average temperatures throughout the world will rise in the next few decades, resulting in higher global temperatures, affecting rainfall regimes and increasing extreme weather events such as heat waves, droughts, strong winds, and heavy rains. The occurrence of heat waves can result in the development of extreme heat stress in plants, which may subsequently lead to a reduction in the yield of grasslands if the events occur during specific phases of the plant's life cycle (Ates, 2016, Tenikecier & Ates, 2021). In today's world, where measures are being rapidly implemented to address high temperatures and drought caused by global warming, there is growing interest in species that have a high tolerance or resistance to these conditions. Because it is tolerant to drought and heat and needs less fertilization, one of the warm season grasses is the buffalo grass (*Bouteloua dactyloides* (Nutt.) Columbus) is important as an alternative species in similar ecologies in the world (Avcıoğlu & Geren, 2012), especially in the arid states of the USA, and in regions where temperatures increase and the dry period is prolonged due to climate change.

Adaptation

The primary source of forage for American bison is the native North American buffalo grass. This species is notable for its high tolerance to heat and drought stress (Beard, 1973, Avcıoğlu & Geren, 2012), which enables it to remain green throughout the summer and form a dense layer of grass (Avcıoğlu & Kavut, 2009). It usually grows naturally in regions with annual rainfall of 200-550 mm. Buffalo grass is capable of growth even in regions that receive between 30 and 70 mm of rainfall per year (Balcı, 2012). Buffalo

grass enters a state of dormancy in the event of an exceptionally severe drought. It displays remarkable resilience to elevated temperatures and is capable of withstanding temperatures below the freezing point. In the most extreme conditions of its habitat, the species is capable of surviving temperatures as low as -34.5 °C or as high as 49 °C (Wasowski & Wasowski, 1993).

Although buffalo grass grows in almost all types of soil, it grows best in medium to fine textured soils (Hatch & Pluhar, 1995) and grows sparsely in sandy soils and can be overwhelmed by shifting sands (Weaver et al., 1956). The species shows a wide range of altitudinal tolerance, thriving from sea level up to 2000 meters (Beetle, 1950, Howard, 1995).

It should be noted that the buffalo grass found in North America is not the same species of grass commonly known as "Buffalo" in Australia. The species has become established in Spain and Greece in Europe. It is absent from south-central and southeastern China (Anonymous, 2024b). It is also listed as growing outside cultivation in New Zealand (Hassler, 2024). The plant demonstrates resilience to a multitude of diseases and pests, exhibits minimal water consumption, and necessitates minimal care. In its natural habitat, the plant exhibits rapid vegetative propagation by stolons, resulting in the formation of a self-sustaining and ecologically compatible vegetation community.

Systematic and morphology

Buffalo grass is classified within the subclass *Magnoliidae* of class *Equisetopsida*, *Poales* order, genus *Bouteloua* Lag. of grass family (*Poaceae*). The family *Poaceae* comprises seven sub-families, the subfamilies *Pooideae* and *Panicoideae* containing

species of greater agricultural importance. Almost all forage grasses and turf grasses are found in these two subfamilies and organized under 13 tribes (*Andropogoneae*, *Arundinelleae*, *Aveneae*, *Brachypodieae*, *Bromeae*, *Isachneae*, *Maydeae*, *Meliceae*, *Neurachneae*, *Paniceae*, *Poeae*, *Seslerieae*, *Triticeae*) (APG, 2003, Tekeli and Ateş, 2009). *Bouteloua* Lag. is found exclusively in the Americas, with the majority of its diversity concentrated in the southwestern United States (Gould, 1951). It is also present in the Ciénaga de Zapata Biosphere Reserve in Cuba (CZNP, 2003). A considerable number of species within the genus are of significant importance as livestock forage and turfgrass.

Bouteloua genus includes both annual and perennial grasses that often forms stolons (Snow, 2019). The species in the genus have an inflorescence of between 1 and 80 racemes or spikes, which are arranged alternately on the stem. The rachis of the spike is flattened, with the spikelets positioned along one side. Each spikelet contains one fertile floret and, typically, one sterile floret (Bixing & Phillips, 2006).

Buffalo grass is a warm-season perennial grass and typically dioecious (Figures 1 and 2), exhibiting strong stoloniferous growth and, in some cases, forming dense mats. In optimal experimental settings, stolons have been observed to exhibit growth rates of up to 5.71 cm per day (Mueller, 1941). A single plant is capable of extending stolons outward to reach a length of between 15 and 45 cm by the end of the growing season (Albertson, 1937). The roots of buffalo grass are also numerous and thoroughly occupy the soil. The roots are notably finer than those of the majority of other plains grasses, with a diameter of less than 1 mm. Despite their narrow

diameter, the roots are notable for their toughness and wire-like structure.

Figure 1: Male buffalo grass

Source: Strickland, 2004

Figure 2: Female buffalo grass

Source: Wasowski & Wasowski, 1988

Although the roots may extend to depths of 1.2 to 1.8 m, 70% of their mass is located within the upper 15 cm of the soil, with 81% situated within the upper 30 cm. The primary roots exhibit a tendency to grow almost directly downward, with only minimal branching and a paucity of side roots. Additionally, the plants produce surface roots that grow horizontally for a distance of 24 to 36 cm from the plant. (Weaver et al., 1956, Weaver, 1958, Chase, Clark & Pohl, 1996). The culms are 2-35 cm in length, erect, solid, and mostly unbranched. Those of the pistillate inflorescences are notably shorter than those of the staminate inflorescences, and the nodes are predominantly glabrous. The leaves are basally tufted and not clustered or strongly distichous. The leaf blades of buffalo grass are narrow, soft, somewhat curly, and hairy on both sides, with a grey-green coloration (Figure 3). The dimensions of the individual leaf blades range from 1.5 to 16 cm in length and from 1.0 to 2.5 mm in width (Weaver et al., 1956, Snow, 2019). The sheaths are open and rounded, often sparsely pilose near the collar. The ligules are membranous or of hairs, and the blades are usually flat basally, curling when dry, glabrous or sparsely pilose, and with an involute apex.

Figure 3: Leaves of buffalo grass

Source: Original

The staminate inflorescences are terminal and typically extend beyond the upper leaves. They are arranged in panicles of 1-3(4), exhibiting unilateral, pectinate branches. Upon reaching maturity, the branches are not enclosed, and the spikelets are densely crowded in two rows. The staminate spikelets (Figure 4) comprise two florets and are characterized by unequal glumes that are glabrous and have one or two veins.

Figure 4: Staminate spikelets of buffalo grass

Source: Original

The lemmas are three-veined, glabrous and unawned, while the anthers are brownish to red or orange in color. Pistillate inflorescences (Figure 5) are terminal and form panicles that are partially hidden within bracteate leaf sheaths. The branches are 2-4, measuring 2.5-4.5 mm, and are burlike with 2-7 spikelets. Disarticulation occurs at the base of the panicle branches. The lower glumes are irregular and reduced in size. The branch axes and lower portion of the upper glumes are globose, white, indurate, and terminate in three awn-like teeth. The lemmas are firmly membranous, glabrous, and have three veins. They are either unawned or have short awns.

Figure 5: Pistillate spikelets of buffalo grass

Source: NAS, 2024

Buffalo grass typically produces pollen or seeds on discrete plants, and given that it reproduces via stolons, extensive monocultures of either sex may emerge. The flower stalks responsible for seed production are markedly shorter than those responsible for pollen production, with the seed heads typically situated at the same level as the grass blades (Quinn, 1998, Snow, 2019). Once the seeds have reached maturity, they are enclosed within a hard, circular diaspore measuring between 3 and 4 mm in diameter (Quinn et al., 1994, Ortmann et al., 1998, Figure 6). The haploid chromosome number for buffalo grass is x=10, and the species may be diploid (2n=20), tetraploid (4n=40), or hexaploid (6n=60). Diploid and tetraploid plants are more frequently observed in the southern regions of the species' range, whereas hexaploids are more prevalent in the northern regions of USA (Wachholtz et al., 2013, Snow, 2019).

Figure 6: Diaspores of buffalo grass

Source: TSC, 2024

Establishment and management

Buffalo grass is a species that can be utilized by all livestock and is regarded as a source of high-quality forage. Its nutritional qualities remain stable throughout the curing process. It is predominantly employed as pasture grass and constitutes a vital element of the shortgrass and mixed grass prairies (Hitchcock, 1951, Leithead et al. 1971, Howard, 1995, Brakie, 2013). Furthermore, it widely used in the reclamation of areas with limited maintenance and irrigation facilities, as well as in erosion control measures. Buffalo grass can be established in two ways: through direct seeding or by using vegetative plugs and sod. The utilization of sod is an effective method for achieving successful outcomes in smaller areas. However, it is a more costly approach than the use of seed or plugs for the initial establishment of vegetation. While buffalo grass is drought-tolerant, it is important to recognize that significant amounts of supplementary water are necessary for establishing lawn and

pasture in hot, arid regions. The quantity of water necessary for the establishment of a buffalo grass lawn or pasture from seed, sod, or plugs will be equivalent to (and on occasion greater than) that which is required for the establishment of a perennial ryegrass (*Lolium perenne* L.), Kentucky bluegrass (*Poa pratensis* L.), or tall fescue (*Festuca arundinacea* Schreb.) lawn and pasture. Seedbed preparation should start well in advance of spring planting. It is essential to establish a clean and weed-free seedbed, either through tillage or the use of herbicides. Prior to planting, the soil should be in a firm and have accumulated sufficient moisture. Spring is usually the best time to seed buffalo grass and mixtures containing it. The germination of buffalo grass seeds (Figure 7) is contingent upon the soil temperature reaching a minimum of 13-16 °C. Sowing time should be determined accordingly. In order to achieve optimal results, soil moisture levels should be maintained for a period of between one and two weeks following sowing, through the application of precipitation or irrigation. In conditions that are conducive to germination, the process may be observed to take place within a timeframe of between 14 and 21 days and full coverage can be obtained within 60-90 days (Avcıoğlu & Kavut, 2009, TSC, 2024).

Figure 7: Germinated diaspore of buffalo grass

Source: NAS, 2024

For pasture, rangeland and wildlife plantings, seeding rates for a monoculture stand range from 0.9 to 3 kg per live seed per 1000 square meter depending upon the intended use of the planting (Boltz, 2012). For lawn planting, when broadcasting seed, using 14.5 to 24.5 g of seed per square meter is sufficient. Seed should be planted to 1-1.25 cm depth.

In addition, pre-rooted plugs for buffalo grass lawn can also be used. The utilization of pre-rooted plugs can facilitate comprehensive coverage for a period of six to 12 weeks following the planting process, contingent upon the spacing of the plugs and the prevailing weather conditions. As with the seeding method, the implementation of an appropriate soil preparation regimen is a crucial determinant of success when employing plugs. Plant plugs should generally be planted using 30 to 45 cm spacing following the last spring frost and at least 4-6 weeks prior to the first expected fall frost. The application of herbicide can be undertaken either prior to

or just after planting, with the objective of reducing the impact of weed competition. Irrigation is recommended for a period of seven to ten days in order to maintain a moist soil surface, and thereafter for the purpose of maintaining active growth. It is not uncommon for buffalo grass plugs to exhibit browning after planting, even when irrigation is sufficient. This is a normal phenomenon; if the plugs have been receiving consistent moisture, they have not died. Once a healthy root system has been established, the grass will emerge from its dormancy (Koski & Cox, 2014).

Besides, buffalo grass can be sodded like many other grass species to produce an instant lawn. However, the cost of buffalo grass sod is considerably higher, and its availability is considerably more restricted. Nevertheless, it is the most expeditious and straightforward method for establishing a buffalo grass lawn. When laying a lawn using the sod method, extra care is needed during transplanting to ensure the surface is smooth and level. The sod pieces are typically placed closer together, and watering should be applied to improve survival rates and achieve quicker coverage. It is not uncommon for buffalo grass sod to rapidly lose its green coloration following transplantation, despite the presence of irrigation. The plants may remain dormant for a period of one to two weeks while new roots are formed. New root growth, visible as white lines on the bottom of the sod, can be observed after a few days of watering, despite the grass appearing entirely brown. Once sufficient root development has occurred, the buffalo grass will begin to form new leaves and display green foliage. Pistillate plants are preferred for both pre-rooted and sod because they don’t produce staminate

flowers that extend above the foliage, which can detract from the lawn's appearance.

Established lawns should be fertilized with 4.5-5 kg of total N per 1000 square meter in late May to mid-June, and again in late July. The application of excessive fertilizers, particularly in conjunction with an excess of water, can precipitate the rapid invasion of weeds into buffalo grass lawns. Buffalo grass is occasionally susceptible to iron chlorosis in soils with elevated pH levels. The application of supplemental iron can effectively prevent or address this issue. To sustain active growth, buffalo grass lawns require 25 to 50 mm of water every two to four weeks during the summer (Koski & Cox, 2014). In the event of drought-induced stress, the lawn will enter a dormant state until favorable growing conditions prevail (Dunn & Ervin, 2001).

Disease and insect management

No serious diseases affect buffalo grass lawns in numerous geographical regions across the globe. Leafhoppers belonging to the family *Cicadellidae* and grasshoppers belong to the suborder *Caelifera* are commonly encountered pests, but they do not typically cause significant damage to healthy buffalo grass lawns. Additionally, the presence of *Tridiscus sporoboli* (buffalo grass mealybug), *Trionymus* sp. and *Blissus* sp. has been confirmed in certain regions where buffalo grass lawns are cultivated (Koski & Cox, 2014).

Conclusion

Buffalo grass is a significant forage grass species within the shortgrass and mixed-grass prairies. It is a valuable forage resource

for all ruminants and non-ruminants throughout the year. Furthermore, buffalo grass plays an important role in providing forage for wildlife. The foliage is nutritious and palatable when it's green, and its nutritional quality remains relatively stable as it dries (Johnson & Nichols, 1970, Iffrig, 1983). The palatability of buffalo grass has been evaluated as favorable for cattle, domestic sheep and horses and its highly resistant to grazing (Archer & Tieszen, 1986).

The term of 'forage quality' is defined as the characteristics that make forage valuable to animals as a source of nutrients, or the combination of chemical and biological characteristics of forage that determine its potential to produce meat, milk, wool or work (Barnes, Miller & Nelson, 1995a, 1995b). Such characteristics include protein content, fiber composition and percentage of water-soluble carbohydrates. The dry matter content of fresh and mature buffalo grass is 48.9%, which includes 6.1% ash, 13% crude fiber, and a digestible protein content of 2.7-2.9% (NAS, 1971). However, buffalo grass is a C_4 grass, meaning it contains a higher proportion of slowly digestible vascular bundle tissue and less easily digestible mesophyll tissue compared to C_3 grasses (Akin & Chesson, 1995). Buffalo grass is found to contain, on average, 77% neutral detergent fiber (NDF), 38% acid detergent fiber (ADF), 40% hemicellulose and 4.4% lignin (Jack, 1999).

Good buffalo or short grass pastures are made possible only through the maintenance of the vigor of the grass stand which is best assured by those grazing practices that permit the plants to make enough top-growth to function properly. This cannot be over-emphasized because, once the stand is lost, many years and much expense are involved in either rejuvenating the original stand or in

reseeding. Since most buffalo grass pastures contain mixtures of other grasses, it appears that where circumstances permit, rotational grazing will provide an opportunity for increased pasture yields. This system of grazing, which calls for dividing large pastures into two or three smaller units which are grazed periodically either in succession or in a deferred and rotated order, keeps the grass thrifty and stimulates production.

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CHAPTER III

Screening of the Effects of Drought Stress on Yield, Antioxidant Enzyme Activities and Reactive Oxygen Species of Legume Plants

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1. Introduction

Global climate change is causing serious crop yield losses worldwide due to rising temperatures, changing precipitation patterns, droughts and extreme weather events. Environmental stress

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factors including heat, salinity, water logging, drought etc. nearly disrupt all developmental stages of the crop and reduce optimum yield (Nadeem et al., 2019). Among environmental factors, drought is a critical restring factor in the agricultural production of crops (Hussain et al., 2018). Drought stress reduces nutrient uptake and water use efficiency in grain legumes, impairs cell growth and leaf development, inhibits the photosynthesis circle and leads to yield losses. However, crops suffer from a lack of water especially grown in arid and semi-arid areas. Since Türkiye is located in the Mediterranean climate zone, which is rapidly feeling the effects of climate change, increasing temperatures, decreasing rainfall, drought and changing rainfall patterns significantly affect legume production. Drought stress experienced by plants during various growth and developmental stages reduces leaf area, disrupts the carbon cycle, decreases turgor pressure, increases oxidative stress harms, changes leaf gas exchange and the photosynthesis cycle and leads to reduced last yields (Chowdhury et al., 2016; Conesa et al., 2016).

As reported by researchers, drought stress causes serious yield losses in legume crops. Therefore, new strategies should be improved to cope with yield losses in legume crops grown in drought-affected especially arid and semi-arid zones by using biotechnological, transcriptomics and genomics approaches. In addition, drought-resistant varieties should be developed, balanced irrigation and water management strategies should be developed, the physicochemical structure of the soil should be improved, balanced fertilization should be done, and planting time and pattern should be well adjusted. Additionally, improving drought-resistant cultivars,

practising water management systems, enhancing soil physicochemical properties, applying balanced fertilization, adjusting sowing time and planting geometry can increase yield performance.

The review takes over the impact of drought stress on legume crops yield and yield-related traits, drought tolerance mechanism, antioxidant enzyme activity and reactive oxygen species. This review generally debates the influences of drought stress on food legume crops. The influences of drought stress on yield loss of legume crops are presented below.

2. Yield loss in legume crops

Edible legumes are an important part of human nutrition in many developing countries, especially in regions with large, impoverished populations, as they are rich in essential amino acids like lysine, complementing grain-based diets. Legume crops including chickpea, lentil, common bean, mung bean, field pea, cowpea and faba bean play critical a role in diet of humans and animals richness of protein, vitamins and minerals (Abebe et al., 2005; Ipekesen et al., 2022). Furthermore, these crops improve soil physiological and chemical properties thanks to their root bacteria fixed atmospheric nitrogen (Rubiales, 2015) and increase crop adaptability against nitrogen deficiency. However, pulses grown in rained regions have suffered from drought stress caused by climate change effects in the last few years.

Stress results in various changes in cell division, leaf development, stem and root growth, carbon assimilation, the photosynthesis cycle, nutrient uptake, cell turgor pressure, gas

exchange (Nadeem et al. 2019), and the photosystem (Ullah et al. 2019). Additionally, the strength of photosynthesis and turgor in cells decrease, and increase sucrose viscosity (SUT_s) (Sevanto, 2014). The sucrose transporters (SUT_s) help to translate sucrose, however, drought stress decreases SUT_s during the photosynthesis cycle (Xu et al., 2018), and this case disrupts translocation assimilation sources. Moreover, drought stress disrupts the symbiotic nitrogen fixation, reducing nitrogenase activity and translation of O_2 in Rhizobium bacteria, thus yield loss occurs in legume crops (Duo et al., 2020). Besides, drought stress affects the phenological stages of legume crops, especially the reproductive stages. Drought stress decrease assimilate translocation, which influences flowering, and pod formation, and this case results from pollen sterility, abnormal pollen development and pollen abortion (Fang et al. 2009; Chowdhury et al.2016). Drought stress causes earlier flowering, fewer flowers, infertile pollens and seed development, and fewer pods and seed formation since drought stress impairs photosynthetic activities and assimilated translocation in reproductive stages in crops (Mondal et al., 2011; Sehgal et al., 2019). These cases reduce in optimum yield (He et al., 2017). Moreover, drought can also affect seed protein content in legume crops. Although some studies have reported that protein yields in chickpeas (Mansourifar et al., 2011), mung beans (Yagoob & Yagoob, 2014) and common beans (Khalil & Ismael, 2010) are reduced under drought stress, it has also been noted that drought increases the protein content of legumes but decreases their oil content (Farooq et al., 2018).

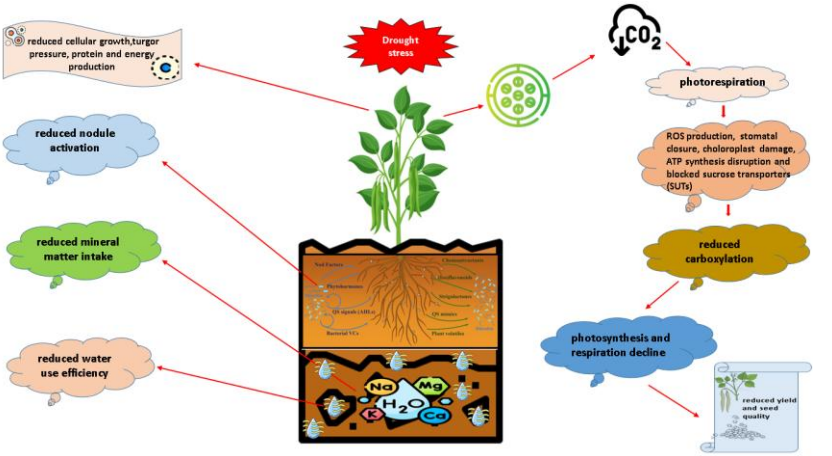

Figure 1. The graphical representation of the impact of drought stress on legume crops. Drought stress decreases cellular growth, turgor pressure, protein and energy production, photosynthesis and respiration in plants, causes stomatal closure and decreases CO_2, water use efficiency, mineral matter intake and nodule activation.

During seed-filling stage drought, legume crop yield can be decreased by 58-95% compared to those grown in irrigated conditions (Leport et al., 2006). Some researchers noted that drought stress during the reproductive stage in legume crops cause on yield loss and yield-related traits (Table 1).

Table 1. Findings reported by some researchers

Legume crop	**Yield-related properties**	**Yield loss**	**References**
Mung bean (*Vigna radiata*)	Plant height, number of leaves, dry matter weight, number of root nodules, root dry matter	26%	Ranawake et al., 2012; Baroowa & Gogoi, 2013
Chickpea (*Cicer arietinum*)	Root activity and seed size	45-69%	Singh et al., 1995; Kashiwagi et al., 2006; Nayyar et al., 2006
Common bean (*Phaseolus vulgaris*)	Leaf , plant biomass, pod and stem biomass and harvest index	58-87%	Martínez et al., 2007; Rao et al., 2013
Cowpea (*Vigna unguiculata*)		34-66%	Ahmed & Suliman, 2010
Faba bean (*Vicia faba*)	Number of leaves, root length, shoot dry weight, root dry weight,	65%	Daryanto et al., 2015; Essa et al., 2023
Lentil (*Lens culinaris*)	Root height, shoot height, dry weight and plant growth	24%	Allahmoradi et al., 2013
Pea (*Pisum sativum*)	Seedlings height, fresh weight, plant dry weight, pod dry weight, chlorophyll and protein content and nitrogen accumulation	33.6%	Mahieu et al., 2009; Akarsh et al., 2020; Al-Quraan et al., 2021; Mazhar et al., 2022

The global request for legume crops is growing in many countries, since the effects of global warming and climate change

(Daryanto et al., 2015. Therefore, food legumes are significant strategic crops for all countries due to the rich nourishment value in seeds. The impacts of drought stress on antioxidant enzyme activity and reactive oxygen species mechanism of legume crops are presented below.

3. Change of antioxidant enzyme activity and reactive oxygen species in legume crops

Drought stress results in a complex series of biochemical and physiological responses in legume crops. Water deficiency negatively affects carbon assimilation by reducing the photosynthetic rate of plants, resulting in energy imbalance. This triggers various stress responses in legume crops caused by oxidative stress. Under drought stress, plants increase the production of reactive oxygen species (ROS) and ABA activates (Nadeem et al., 2019). While ROS are useful as signalling molecules at controlled levels, the overproduction of ROS can lead to negative effects in cell tissue, such as lipid peroxidation, protein oxidation and DNA damage (Meng et al., 2014). The chlorophyll content of legume crops is reduced since drought disrupts biosynthesis and photosynthesis (Keerthi et al., 2023). Thus, the plant biomass production and yield performance of crops negatively affects (Nemeskeri et al., 2015). Under drought stress, crops increase the production of reactive oxygen species (ROS), which is used as a drought indicator (Zhang et al., 2021).

Crops activate various antioxidant enzyme systems such as superoxide dismutase (SOD), catalase (CAT), ascorbate peroxidase (APX), glutathione reductase (GR), peroxidases (POD), hydrogen peroxide (H_2O_2) and malondialdehyde (MDA) to balance ROS

levels and prevent cellular damage (Noctor & Foyer 1998; Iturbe Ormaetxe et al. 1998). SOD is the first defence mechanism in plants under drought stress. It converts superoxide radicals into hydrogen peroxide, a less harmful ROS. Increased SOD activity keeps the level of superoxide radicals accumulated in the plant due to drought under control (Siddiqui et al. 2015). SOD enzymes found in different organelles of plants (such as mitochondria, chloroplasts and cytosol) provide ROS detoxification. Catalase (CAT) breaks down hydrogen peroxide (H_2O_2) into the harmless components of water and oxygen. H_2O_2 accumulates in chloroplasts and other cell components under drought stress conditions (Kafi & Mahdavi Damghan, 2000).

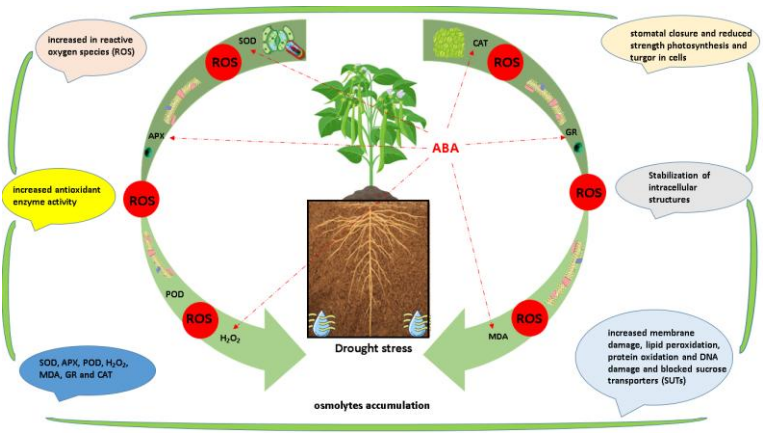

Figure 2. The graphical representation of the impact of drought stress on antioxidant enzyme activity and ROS. Drought stress effects reactive oxygen species (ROS), antioxidant enzyme activity, membrane tissue, lipid peroxidation, protein oxidation, DNA, stabilization of intracellular structures, stomatal closure and osmolytes accumulation.

Catalase rapidly degrades these ROS to maintain intracellular homeostasis. Catalase activity is mostly seen in peroxisomes; however, it provides important protection against oxidative stress throughout the cell. Helaly et al., (2017) stated that SOD and CAT are critical for plant systems, and these enzymes clean the ROS under drought-stress crops to fight against H_2O_2 and O_2. Drought stress causes oxidative stress and increases SOD and CAT in legume crops (Reddy et al., 2005; Xia et al., 2016). APX plays an active role in the ascorbate-glutathione cycle to prevent ROS accumulation in the chloroplasts and mitochondria. Additionally, APX reduce hydrogen peroxide to water, using the ascorbate molecule, and protects photosynthetic activity by reducing oxidative stress, especially in chloroplasts where photosynthesis takes place. GR ensures glutathione activity and plays a key role in antioxidant defence. GR reduces oxidized glutathione disulphide and converts it back into active GSH, thus maintaining intracellular redox balance. This enzyme functions through the glutathione-ascorbate cycle and strengthens the defence against ROS (Farooq et al., 2013). Peroxidases (POD) play a role in lignin synthesis, strengthen the cell structure and increase physical resistance to drought stress. MDA stands for determination of the cytotoxic product of lipid peroxidation and commonly presents an index of ROS level during drought stress (Zhao & Tan, 2005). Some researchers had reported that drought affected on the antioxidant enzyme activity such as APX, SOD, CAT, MDA, POD, GR and H_2O_2, and defence system in legume crops (Table 2).

Table 2. Some studies reported in food legumes such as chickpea, faba bean, common bean, cowpea, pea, mung bean and lentil

Legumes	**References**
Chickpea (*Cicer arietinum*)	Mohammadi et al., 2011; Sistu et al., 2024; Mafakheri et al., 2011; Patel et al., 2012
Faba bean (*Vicia faba*)	Abid et al., 2017; Siddiqui et al, 2015; Orabi & El-Noemani 2015; Kenawy et al., 2022
Common bean (*Phaseolus vulgaris)*	Doklega et al., 2024; Zheng et al., 2023; Yin et al., 2021; Saglam et al., 2011; Yasar et al., 2013
Cowpea (*Vigna unguiculata*)	Tiwari et al., 2023; Melo et al., 2024; de Souza Silva et al., 2024; Kumar et al., 2022
Pea (*Pisum sativum*)	Hayat et al., 2021; Farooq et al., 2021; Sutulienė et al., 2021; Shemi et al., 2021
Mung bean (*Vigna radiata*)	Bano et al., 2021; Meena et al., 2021; Nawaz et al., 2021; Zhao et al., 2022
Lentil (*Lens culinaris*)	Shah et al., 2021; Yasmeen et al., 2022; Sita et al., 2023; Bakır et al., 2022

Drought stress affects antioxidant enzyme activities, ROS and drought tolerance in legume crops, and is highly correlated with theirs (Tiwari et al., 2023). Legume crops have become more sensitive to oxidative damage resulting in ROS overproduction with climate change (Jameel et al., 2021).

4. Drought resistance in legume crops

Legume crops respond to drought stress with different morphological, biochemical, physiological and molecular

mechanisms responses. Drought resistance mechanism of legume crops are presented below.

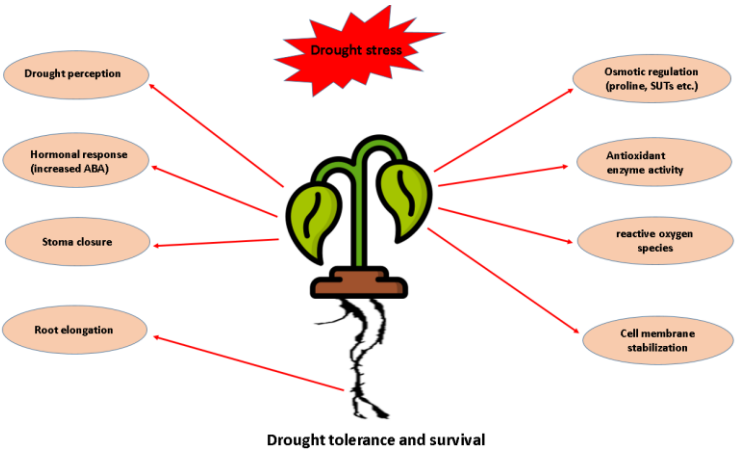

Figure 3. The graphical representation of the impact of drought stress on plant tolerance mechanism. Plant perceives drought stress, ABA increases, stomatal cells close, root elongates, osmotic regulators are activated, antioxidant enzyme activity increases, reactive oxygen species are activated, cell membrane stabilizes and plant drought tolerance improves.

Crops grown in drought stress conditions responses to cope with drought stress and demonstrate drought tolerance. Legume yields have fluctuated recently due to climate change and drought, especially in arid to semi-arid Mediterranean countries. Since crop cultivation in these areas depends on rain-fed, the insistent water restriction and meteorological fluctuations result in yield loss. Legume crops resist drought conditions by avoiding drought (stoma closure) and by tolerating drought (ostomic regulation which enables root elongation under drought stress conditions) (Vadez et al., 2008). Common bean and cowpea can maintain leaf water content and

desist from dehydration by managing stomatal conductance and closing stoma under slight drought (Campos et al., 1999). Crops reduce water consumption by closing their stoma cells to prevent yield loss, reducing the number and size of leaves. Root elongation increases under drought stress and the development rate, density, spread and size of roots are greater in small-leaf legume plants than in large-leaf plants (Varshney et al., 2018). Since osmotic regulation in legume crops demands less energy under drought conditions (Amede et al., 2003), crop production is less affected (Tuner, 1986). Some food legumes such as chickpea, cowpea and pea maintain turgor pressure and protect water content by decreasing epidermal conductivity (Sinclair & Ludlow, 1986). However, common bean and faba bean had low resistance to drought by reducing osmotic regulation. Moreover, common bean and cowpea have higher performance under drought due to increasing stomatal conductivity and osmotic regulation mechanisms (Amede et al., 2003).

The effects of drought on legume production vary depending on species, geographic regions, agroecosystems, soil types, drought severity and timing (growth and development stages) (Daryanto et al., 2015). Daryanto et al., (2015) stated that drought adaptability following drought stress varies among legume crops and under severe drought conditions, the lowest yield loss was in lentil among legume crops with 21.7%. However, they also stated that faba bean dramatically exhibited yield loss (40%) under severe drought and under slight drought conditions yield loss was reported as 60.8, 44.3, 40.4 and 20% for common bean, cowpea, chickpea and field pea, respectively. Jaganathan et al., (2015) stated that roots elongated under water stress conditions and plants with high root length density

performed better in terms of yield and drought resistance than those with low root length. In addition, the critical moisture level required for seed germination varies by species. Pea, lentil, chickpea and broad bean require relatively more water to germinate. However, it is sufficient for the moisture content to be below field capacity. Legume plants such as chickpeas and broad beans with high root system development can more easily overcome drought stress. Leaf water deficiency in later stages of development also varies by species (Kobraee et al., 2011). Although drought stress varies depending on the developmental stage of the plant, plants that are adequately nourished can tolerate drought stress well. Nutrient mobility and uptake by the plant are prevented in soils with low soil moisture. In soils with normal moisture, nitrogen, phosphorus and potassium uptake is already low, but it can decrease even more with drought. However, due to the decrease in fertilizer effectiveness in dry conditions, yield and product quality decrease and a significant increase in production costs occurs.

Studies had been carried out to eliminate stress by supplementing plant nutrients in reducing drought stress (Lynch & Brown, 2012; Chen et al., 2015). Atkinson et al., (2010) also noted that using biochar improves water bioavailability and crop nutrient uptake under drought stress. Although some studies have indicated that nitrogen fixation may be impeded by water deficit, a substantial body of evidence has demonstrated that genetic diversity exists among species, exhibiting varying degrees of tolerance to water deficient (Marulanda et al., 2009; Saharan et al., 2011). The capacity for nitrogen fixation is a significant factor influencing yield potential; however, drought causes a remarkable reduction in root

nitrate contents and nitrogen supply (Silveira et al. 2001). Among legume crops, mung bean has greater nitrogen-fixing capabilities during drought stress compared to other crops (Sarma et al., 2014). Additionally, nodulation in the root system of faba bean successfully maintain under drought stress because indeterminate nodules form at endodermis tissue. However, determinate nodules in cowpea root system attach to the soil from the surface (Sprent et al., 2008).

5. Increasing the drought resistance in legume plants

Enhancing the drought tolerance of legume crops is imperative for sustaining agricultural productivity in water-scarce environments. To address this challenge, a range of strategies has been investigated, including advanced breeding approaches, biotechnological innovations, optimized agronomic practices, and the exploitation of beneficial plant-microbe interactions.

6. Breeding and Genetic Approaches

Conventional breeding methods have concentrated on selecting and crossbreeding legume varieties with drought-tolerant traits. Marker-assisted selection (MAS) has been a crucial tool in identifying quantitative trait loci (QTLs) associated with drought resistance, thereby facilitating the development of resilient cultivars. For example, QTLs linked to the root system and water-use efficiency have been identified in crops such as chickpea and common bean, enabling the selection of drought-tolerant genotypes (Khatun et al., 2021). Recent steps in plant genetics have facilitated the incorporation of specific genes associated with drought tolerance into legume genomes. CRISPR/Cas9 has been utilized to modify key genes involved in stress response pathways, thus drought resilience

has improved. The overexpression of genes encoding osmoprotectants, such as proline, has played a significant role in increasing drought tolerance in transgenic legume plants (Nadeem et al., 2019).

7. Agronomic practices

Using effective agronomic practices is crucial for moderating the negative impacts of drought on pulse production. Techniques such as conservation tillage, mulching, and the implementation of optimized irrigation strategies contribute to improved soil moisture retention and reduced water loss (Ben Gaied et al., 2024). Furthermore, aligning planting schedules with periods of sufficient rainfall and optimizing planting densities can significantly enhance the drought resistance of pulses (Kumari et al., 2021; Biswas et al., 2023).

8. Microbial Associations

The symbiotic interaction between legumes and rhizobia bacteria is critical for biological nitrogen fixation and overall plant health. Inoculation of legume seeds with drought-tolerant rhizobial strains has been demonstrated to enhance plant growth and performance under water-deficit conditions. Additionally, associations with arbuscular mycorrhizal fungi significantly improve water uptake and nutrient acquisition, contributing to increased drought tolerance in legume crops (Petrushin et al., 2023).

9. Physiological and Biochemical Strategies

Legume crops employ physiological and biochemical mechanisms to diminish the effects of drought (Hossain et al., 2020). These include stomatal regulation to reduce water loss and the

accumulation of osmoprotectants, such as proline and trehalose, which regulate cellular turgor in water deficient (Zhang et al., 2022). Additionally, strengthening the antioxidant defence system (ROS) generated during drought stress is a vital adaptation. Exogenous application of plant growth regulators, such as abscisic acid (ABA), has also been investigated for its ability to activate drought-responsive pathways and enhance stress tolerance in legumes (Savita et al., 2020).

Improving the drought tolerance of legume crops requires integrating genetic, agronomic, and microbial strategies (He et al., 2023). Advances in modern breeding techniques, biotechnological innovations, and an enhanced understanding of plant-microbe symbiotic relationships provide promising pathways for the development of legume cultivars with improved resilience to drought stress (Furlan et al., 2022). Such integrative strategies are essential for ensuring sustainable agricultural production amidst increasing climate variability (Ye et al., 2018).

10. Conclusion

Legume crops are an essential diet and inexpensive source of protein and micronutrients for world population. These crops also fix nitrogen due to their symbiosis with rhizobium bacteria, making them attractive crops for soil amendment in agricultural systems. However, climate change causes abiotic stresses such as heat, drought, salinity etc., and these stresses decrease the yield and quality of pulses. However, drought stress highly affects pulse production compared to other stresses. Minimizing the adverse impacts of drought stress on legumes is crucial for promoting sustainable agriculture and ensuring global food security. To

improve the capacity of legumes to survive in water deficient conditions, it needs to improve their resistance through genetic and agronomic methods. In this direction, genetic interventions that optimize the hormonal regulation of plants, agricultural practices that increase water use efficiency and soil management techniques make great contributions. In particular, regulation of ABA and other stress hormones that increase under drought stress can protect the yield of legumes by reducing water loss. These studies provide promising steps towards ensuring the sustainability of legume production by allowing the development of plants resistant to the effects of climate change.

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CHAPTER IV

(*Salvia fruticose* Mill.) Türünün Farklı Bölgelerde Uçucu Yağ Bileşenlerin Çevre Etkileşimlerinin Araştırılması

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Giriş

Lamiaceae familyasına bağlı olan *Salvia* cinsinin dünyanın her iki yarım küresinde, özellikle tropik ve subtropik bölgelerle, Akdeniz ve Orta Avrupa'ya dağılmış 986'dan fazla türü bulunmaktadır. Türkiye, *Salvia* cinsi tür zenginliği bakımından dünyada 13. sırada yer almaktadır (Arslan ve ark., 1995). Ülkemizde adaçayı olarak bilinen bitkilerin dâhilen ve haricen çok sayıda geleneksel kullanımı olduğu tespit edilmiştir. Bunlar arasında sindirim sistemi (iştah açıcı, gaz söktürücü, mide ağrılarını giderici), solunum sistemi (öksürük kesici, bronşit ve astıma karşı), bağışıklık

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sistemi (enfeksiyonlara ve soğuk algınlığına karşı, antiseptik, yara iyileştirici), ağrı kesici ile ilgili durumlardaki kullanımlar kaydedilmiştir (Bayram, 2001; Küpeli ve ark., 2007). Adaçayı, ekolojik olarak sıcağı seven bir bitki olmasına rağmen; karasal iklim şartlarında da kolayca yetiştirilebilir. Adaçayının birinci yılında düzenli olarak sulanması gerekmektedir. İkinci yılında ise suya çok ihtiyaç duymamaktadır. Kireç oranı yüksek tınlı topraklarda yetiştiricilik yapılabilir (Zeybek ve Zeybek, 1994). Türkiye tıbbi bitkiler ticaretinde dünyada en önemli ülkeler arasında yer almaktadır. Türkiye'de, doğadan toplanarak iç ve dış ticareti yapılan 347 tür bulunmakta ve bunların %30'unun dış ticareti yapılmaktadır (Faydalıoğlu ve ark., 2011). Türkiye'de tarımı yapılan ve doğadan toplanan adaçayı üretimi incelendiğinde 2012 yılında 348 ton olan adaçayı üretimi 2015 yılında 989 ton olarak gerçekleşmiştir. Kültürü yapılan adaçayı üretiminde Karaman, Denizli ve Kütahya illeri en fazla üretim yapılan illerdir. Türkiye'nin tıbbi bitki ihracatının artmasını sağlamak için tıbbi ve aromatik bitkilerin kültüre alınması ve ıslah çalışmalarının yapılması gerekmektedir. Ayrıca, tıbbi ve aromatik bitkilerin doğadan toplanması ve üretilmesi ile ilgili mevzuat eksikliklerinin giderilmeli ve toplayıcılara doğanın tahrip edilmesini ve tıbbi bitki türlerinin neslinin tehlikeye girmesini engellenmek amacıyla eğitimler verilmelidir (Bayraktar ve ark., 2017). *Salvia* türleri içinde kışlık *Salvia* ekilişinin büyük bölümünü Anadolu adaçayı ile Tıbbi adaçayı oluşturmaktadır (Baytop, 1984). Ülkemizde doğal koşullarda yetişen ancak üzerinde fazla çalışma yapılmamış olan tibbi değeri olabilecek *Salvia* türlerinin farklı iklim koşullarında yetiştirilerek bitkisel özellikleri ile etken maddelerinin değişimleri konusunda araştırmalar yapılması yararlı olacaktır.

Kültüre alınmış örnekler, yabani örneklere göre daha yüksek toplam fenolik içeriğe sahipti. Aksine, yabani örnekler daha yüksek ekstrakt verimlerine, toplam flavonoidlere ve toplam uçucu yağlara sahipti. Yedi fenolik asit ve on flavonoidden oluşan on yedi farklı fenolik bileşik, hem kültüre alınmış hem de yabani *S. fruticosa*'da tanımlandı ve miktarları belirlendi. Rosmarinik, p-kumarik ve kafeik asitlerin başlıca fenolik asitler olduğu belirlendi. Bununla birlikte, başlıca flavonoidler mirisetin, morin ve luteolindi. Vanillik asit, gallik asit, klorojenik asit, p-kumarik asit, mirisetin ve morinin fenolik bileşenleri yetiştiriciliğe bağlı olarak artarken, kafeik asit, kateşin, epikateşin, luteolin ve apigenin yetiştiriciliğe bağlı olarak azaldı. Fenolik bileşenlerin ardışık hasat yıllarında daha düşük olduğu veya değişmediği bulunmuştur (Dincer ve ark., 2012) tarafında tespit edilmiştir.

Dört *Salvia* türünün hidrodistile edilmiş uçucu yağlarının kimyasal bileşimi GC-MS ile analiz edildi. Bu çalışmada analiz edilen üçü (*Salvia aramiensis* Rech. fil., *Salvia fruticosa* Mill., *Salvia tomentosa* Mill.) Hatay florasında doğal olarak yetişmektedir. Öte yandan *S. aramiensis* Hatay florasının endemik bir bitkisidir. Dördüncü tür (*Salvia officinalis* L.) Türkiye florasında yetişmemekte, sadece kültürü yapılmaktadır. En yüksek uçucu yağ içeriği (%5,31) *S. aramiensis*'te, en düşük ise %1,68 ile *S. officinalis*'te bulunmuştur. *Okaliptüs, S. aramiensis, S. fruticosa* ve *S. tomentosa* için ana bileşendir. Bu bileşen *S. aramiensis*'te %58.65 iken *S. tomentosa* ve *S. fruticosa*'da sırasıyla %44.70 ve %34.97 olarak belirlendi. *S. officinalis*'te ise ana bileşen δ-Thujone (%33.83) ve kafur (%21.46) olarak belirlendi. Florada yetişen adaçayı türlerinde ana bileşen olarak okaliptol tespit edilmiştir (Türkmen, M.

2021). Girit'te vahşi doğada yetişen üç *S. fruticosa* popülasyonunun esansiyel yağ verimi ve bileşiminde önemli farklılıklar gösterdiğini ve bu değişkenliğin esas olarak genetik çeşitliliğe atfedildiğini bildirmiştir. Yazar, başlıca uçucu yağların α-pinen, β-pinen, kamfen, mirsen, sineol, kafur, α-tüyon ve β-tüyon olduğunu buldu, oysa Putievsky ve diğerleri (1990) *S. fruticosa*'nın diğer popülasyonlarında α-tüyon veya β-tüyon tespit etmedi. *Salvia*'ya ait bitkilerden çeşitli kimyasal gruplara ait çeşitli yararlı ikincil metabolitler izole edilmiştir. Bu metabolitler arasında esansiyel (uçucu) yağlar da bulunur. *S. fruticosa*'daki uçucu yağların kimyasal bileşimi mono-seskiterpen hidrokarbonlar (α-pinen, β-pinen, kamfen, mirsen, karyofilen) ve (1,8-sineol, kafur, borneol, α-terpinil asetat) oksijenli monoterpenlerdir (Putievsky ve Ark., 1986). Peloponnese'nin (Yunanistan) farklı yerlerinden on popülasyona ait yüz ayrı bitki örneğinde uçucu yağ (EO) ve morfolojik özellikler ölçüldü. Hem EO'nun verimi ve bileşiminde hem de morfolojik özelliklerde popülasyonlar arasında önemli farklılıklar gözlemlendi. Aslında, EO bileşenleri örneklerin çoğunu ilgili popülasyona atayabilir (%80-100). EO verimi ve ana bileşenler, üç yıllık örnekleme periyodunda popülasyonlardan birinde tutarlıydı ve genetik arka planın baskınlığını gösteriyordu. Morfolojik özellikler, toplama alanının rakımı, enlemi ve mikro iklim koşullarıyla ilgili olarak geniş bir çeşitlilik gösterdi, ancak EO profiliyle ilişkilendirilmedi. Popülasyonların çeşitliliğinin genetik analizi ve değerlendirilmesi için dokuz mikrosatelit belirteci kullanıldı (Leontaritou ve ark., 2020). Libya'da yabani olarak yetişen *Salvia fruticosa*'dan izole edilen uçucu yağın bileşimi GC ve GC-MS ile analiz edildi. Kırk beş bileşik tanımlanabildi. Uçucu yağ 1,8-sineol

(%49,34), kafur (%7,53), β-pinen (%7,38), mirsen (%7,38), α-pinen (%5,15), β-karyofilen (%4,13) ve α-terpineol (3,25) içeriyormuş (Giweli ve ark., 2013). Adaçayı bitkisinin sığır gübresi, koyun gübresi ve kümes hayvanı gübresi olmak üzere farklı organik gübre uygulamalarının kuru ağırlık, uçucu yağ içeriği ve bitki başına yağ miktarına etkileri araştırılmıştır. Gübre uygulanan bitkilerde kuru ağırlık artışları istatistiksel olarak önemli bulunmuş ve kuru ağırlık artışının %3,96 ile %42,63 arasında değiştiği bulunmuştur. Ayrıca, bitki başına uçucu yağ miktarındaki artış istatistiksel olarak önemli bulunmuş ve en fazla artış %68,90 ile kanatlı gübresi uygulamalarında görülmüştür. En az artış ise %45,86 ile koyun gübresi-tavuk gübresi-sığır gübresi karışımından elde edilmiştir. Sonuç olarak, gübre uygulamalarının tıbbi bitki adaçayının kuru ağırlığının, uçucu yağ içeriğinin ve bitki başına yağ miktarının artırılmasında etkili olduğu görülmüştür (Kaplan ve ark., 2007).Yunan adaçayı olarak bilinen *Salvia fruticosa*, Doğu Akdeniz'e özgü çok yıllık bir çalıdır. Tarihsel olarak, yaprakları tıbbi özellikleri nedeniyle, özellikle anti-inflamatuar, antimikrobiyal ve sindirim rahatsızlıkları için geleneksel ilaçlarda değerlidir (Alqudah ve ark., 2024). Bu araştırma ile; üç farklı lokasyonda Anadolu Adaçayı'nın yetiştirilip yetiştirilemeyeceği, yetiştirilebilecekse uçucu yağ ve uçucu yağ bileşenlerin etkisinin kontrol edilmesi amaçlanmıştır. Bu araştırmada *Salvia* türlerinden (*Salvia fruticose* Mill.) ait türün farklı çevrelerde bitkisel özellikleri ile uçucu yağ bileşenlerini incelemek amacıyla yürütülmüştür.

MATERYAL VE METOD

Bu çalışmada materyal olarak kullanılan türün tohumlarının alındığı kurum adı çizelge 1'de gösterilmiştir.

Çizelge 1. Materyal olarak belirtilen türün tohumların alındığı kuruluşun adı

Tür Adı	Temin edilen kurum/kuruluşlar
S.fruticosa Mill. *(S.triloba* L.*)*	Ankara üniversitesi Ziraat Fakültesi Tarla Bitkileri Bölümü

Deneme materyalinin bazı özellikleri ile kullanım alanlarına ait bilgiler aşağıda verilmiştir.

Anadolu Adaçayı (*Salvia fruticosa* Mill.) veya (*Salvia triloba* L.)

Anadolu adaçayı bir Akdeniz bitkisi olup Güneydoğu, Balkanlar ve Batı Anadoluda yetişmektedir. Çalımsı ve oldukça aromatik kokulu bir bitkidir. Gövdeler dik olup 1 m'ye kadar boylanabilir. Genç bireylerin gövdeleri dört köşelidir. Gövdedeki tüy örtüsü çok varyasyon gösterir (Doğan ve ark., 2008). Yapraklar basit ve üç loplu, bazen küçük yan segmentler olabilir; bazılarında olmayabilir. Yapraklar genellikle gövde üzerinde dağılmıştır. Yapraklar eliptik'den ovate-oblong'a kadar çeşitli şekillerde görünüşe sahiptir (Şekil 1)'de verilmiştir. Çiçeklenme; Mart-Mayıs (Haziran) aylarında görülür. Bu türün yaprakları *S. pomifera*'nın yapraklarına çok benzer. Çiçek özellikleri bakımından da *S. tomentosa*' ya benzemektedir. Halk tarafından çay olarak tüketilen önemli bir türdür. Bodrum ve Didim civarında "Kekik Elması" adıyla bilinir (Nakıpoğlu, 1993; Doğan ve ark., 2008). Uçucu yağ oranı (%0,9-3,7) biçim sayısına göre değişir. Uçucu yağındaki etken maddeler cineol, Burneol, kafur, lineol'dür. Kulanılan kısmı yaprak ve çiçekleri. Kullanımı gaz söktürücü, midevi, idrar söktürücü, antiseptik etkilerinde faydalanılmaktadır. Derinlere inebilen bir kök sistemine sahiptir. Fidelerde dikim 30-60 cm sıra üzeri ve sıra arası mesafade yapılır. İklim ve toprak istekleri tıbbi adaçayı ile aynıdır.

İlk yıl verim az olup ikinci yılda en yüksektir. *S. fruticosa'*nın tohumlarının 1000 dane ağırlığı 3,1-4,9 g arasında değişiklik göstermektedir (Ceylan, 1996). Ülkemizde kültürü yapılan bir türdür.

Şekil 1. Salvia fruticosa Mill. bitkisinin görünümü

Deneme Çevreleri

Araştırma 2014-2015 ve 2015-2016 yıllarında Çanakkale, Kütahya ve Balıkesir lokasyonlarında 2 yıl süreyle yürütülmüştür. Denemelerin kurulduğu lokasyonlar aşağıda verilmiştir.

1. Lokasyon; Çanakkale Onsekiz Mart Üniversitesi Ziraat Fakültesi Dardanos Yerleşkesi deneme alanı, rakımı 43 m, Boylam: $26{,}2186^0$, Enlem: $40{,}444^0$

2. Lokasyon; Balıkesir Edremit Kale Natürel A.Ş. Tıbbi Bitkiler Bahçesi, rakımı 620 m, Boylam: 27,931°, Enlem: 39,4029°

3. Lokasyon; Kütahya Belediyesi Hekim Sinan Tıbbi Bitkiler Botanik Bahçesi, rakımı 993 m, Boylam: 29,5574°, Enlem: 39,2759°

Lokasyonlara ait toprak özellikleri Çizelge 2'de verilmiştir. Çizelgede görüldüğü gibi Balıkesir lokasyonunda deneme yerinin

toprak tekstürü kumlu-tınlıdır. Bu lokasyonun toprak yapısı geçirgen, su tutma kapasitesi ve kireç oranı düşük, organik madde bakımında ise fakirdir. Çanakkale ve Kütahya lokasyonlarındaki deneme alanı toprakları ise killi-tınlı'dır. Bu lokasyonlardan Çanakkale lokasyonu organik madde bakımından iyi durumda iken Kütahya lokasyonu organik madde bakımından fakirdir.

Çizelge 2. Deneme alanlarına ait bazı toprak özellikleri (Anonim, 2016a)

Analiz tipi	Balıkesir		Çanakkale		Kütahya	
	Sonuç	Durumu	Sonuç	Durumu	Sonuç	Durumu
Potasyum(K_2O) kg/da	20.6072	Orta	13.467	Az	20.0348	Orta
Fosfor (P_2O_5) k/da	4.9846	Az	3.1502	Az	6.819	Orta
Kireç (%)	0.8348	Az kireçli	2.5044	Kireçli	4.0222	Kireçli
Organik Madde (%)	0.7955	Çok az	3.178	İyi	0.8944	Çok az
Toplam Tuz (%)	0.0032	Tuzsuz	0.0034	Tuzsuz	0.0037	Tuzsuz
PH	7.07	Nötr	7.14	Nötr	7.21	Nötr
Saturasyon (%)	50	Kumlu-Tınlı	52	Killi-Tınlı	54.5	Killi-Tınlı

Deneme Alanlarının İklim Özellikleri

Deneme yerlerinin iklim değerleri Çizelge 3'de belirtilmiştir. Deneme çevreleri ayrı ayrı değerlendirildiğinde Marmara Bölgesinde (Çanakkale, Balıkesir) Akdeniz iklimi; İç Ege Bölgesinde (Kütahya) ise karasal iklim hâkimdir. Uzun yıllar ortalaması olarak toplam yağış verilerine göre deneme çevreleri içerisinde en düşük toplam yağış (511,5 mm) Kütahya lokasyonunda, en fazla yağış (735,2 mm) ise Balıkesir lokasyonunda kaydedilmiştir (Çizelge 3). Deneme yıllarına göre toplam yağış

miktarı incelendiğinde en yüksek yağış, uzun yıllar yağış ortalamasında olduğu gibi 788,5 mm ile 2016 yılında Balıkesir lokasyonunda belirlenmiş iken, en düşük toplam yağış ise 513,7 mm ile 2016 yılında Çanakkale lokasyonunda elde edilmiştir. Lokasyonların Aylık ortalama sıcaklık değerleri incelendiğinde, en düşük ortalama sıcaklık -1.0 °C ile 2016 yılının Aralık ayında Kütahya lokasyonda ölçülmüş iken en yüksek sıcaklık ise 28,5 °C ile Balıkesir lokasyonunda belirlenmiştir. Yılların ortalamaları olarak sıcaklık değerlerinde ise en düşük ortalama sıcaklık değerleri hem 2015 hemde 2016 yıllarında Kütahya lokasyonunda sırasıyla 11,3°C ve 11,9 °C olarak ölçülmüştür.

Çizelge 3. Araştırmanın yürütüldüğü lokasyonların yıllar ve uzun yıllara ait bazı iklim verileri (Anonim, 2016b)

	Lokasyonlar								
	Çanakkale			**Balıkesir***			**Kütahya**		
Aylar	**Yıllar**		**U.Y.**	**Yıllar**		**U.Y.**	**Yıllar**		**U.Y.**
	2015	**2016**		**2015**	**2016**		**2015**	**2016**	
	Toplam yağış (mm)								
Ocak	119,0	109,5	70,9	126,9	208,5	107,6	79,2	143,2	71,6
Şubat	80,3	88,7	67,8	96,8	159,0	112,0	84,2	34,8	43,5
Mart	65,4	53,4	59,5	107,6	67,1	84,2	36,6	80,2	45,1
Nisan	76,2	15,0	38,9	36,9	28,5	54,2	63,9	19,3	47,0
Mayıs	5,6	25,8	22,8	7,8	33,6	31,3	73,2	53,8	58,8
Haziran	61,6	39,9	31,3	31,1	15,4	32,3	125,6	42,5	45,0
Temmuz	0,0	0,0	6,7	0,4	0,0	0,8	1,2	2,2	10,7
Ağustos	3,2	0,0	4,8	0,0	0,0	6,3	86,2	20,6	18,1
Eylül	63,5	1,4	25,2	33,7	6,4	30,6	27,2	36,9	39,9
Ekim	108,9	70,0	77,7	177,8	90,0	92,2	31,6	0,1	42,3

Kasım	47,6	60,0	67,1	46,6	80,0	88,1	36,2	40,0	40,1
Aralık	1,6	50,0	67,3	0,4	100,0	95,6	2,8	42,0	49,4
Toplam	632,9	513,7	540,0	666,0	788,5	735,2	647,9	515,6	511,5
Ortalama Sıcaklık (◦C)									
Ocak	6,7	7,0	6,3	7,9	7,4	7,4	-0,2	0,7	0,3
Şubat	7,5	10,9	6,7	8,5	12,5	8,0	2,8	7,4	1,8
Mart	9,3	11,1	8,5	10,9	12,3	10,3	6,3	7,4	5,3
Nisan	11,9	15,7	12,6	13,6	17,7	14,6	8,0	13,7	10,1
Mayıs	19,4	18,2	17,5	21,2	19,6	19,6	16,1	14,4	14,5
Haziran	220	24,5	22,3	23,8	26,2	24,3	16,9	20,8	18,3
Temmuz	26,2	26,9	25,1	27,8	28,2	27,0	22,1	22,5	20,9
Ağustos	27,1	27,0	25,0	28,5	28,3	26,7	21,8	22,2	20,8
Eylül	23,4	22,5	21,1	25,0	23,5	22,6	20,4	17,5	16,8
Ekim	17,0	16,6	16,2	18,5	17,2	17,4	13,1	11,6	11,7
Kasım	14,4	11,6	11,7	15,1	12,8	12,4	8,3	5,0	6,3
Aralık	8,2	5,0	8,1	9,4	5,0	8,9	0,1	-1,0	1,9
Ortalama	16,1	16,4	15,1	17,5	17,6	16,6	11,3	11,9	10,7
Ortalama Nisbi Nem (%)									
Ocak	78,2	72,9	82,1	70,4	70,4	68,7	88,2	81,9	76,7
Şubat	71,8	78,1	80,0	66,0	70,6	66,0	78,1	73,5	71,9
Mart	75,7	74,3	79,8	67,0	65,1	63,2	74,0	66,5	66,5
Nisan	68,3	67,9	78,1	56,9	57,1	61,3	64,8	57,9	62,9
Mayıs	66,5	70,1	75,7	52,6	58,3	55,7	61,6	68,7	62,1
Haziran	65,7	62,3	70,7	54,4	50,9	49,9	77,5	59,5	60,2
Temmuz	58,6	55,4	66,4	44,9	44,6	46,3	58,8	56,8	58,1
Ağustos	59,8	59,0	67,0	49,2	50,2	48,6	67,3	64,5	59,2
Eylül	70,8	60,1	71,0	59,6	51,3	54,5	64,9	66,0	61,7
Ekim	75,0	62,9	76,8	66,8	63,5	63,1	78,7	68,0	67,5

Kasım	74,8	69,2	80,6	67,4	68,4	68,9	72,7	58,0	71,5
Aralık	73,6	67,5	82,2	64,7	-	69,6	83,9	72,0	77,2
Ortalama	69,9	66,6	75,9	60,0	59,1	59,7	72,5	66,1	66,3

Yöntem

Bu araştırma 2015 ve 2019 yıllarında Çanakkale, Balıkesir-Edremit ve Kütahya koşullarında tesadüf blokları deneme desenine göre 3 tekerrürlü olarak yürütülmüştür. Denemeler Çanakkale Onsekiz Mart Üniversitesi Ziraat Fakültesi Dardanos Yerleşkesi'nde, Balıkesir-Edremit Kale Natürel A.Ş. arazisinde ve Kütahya Belediyesi Hekim Sinan Tıbbi Bitkiler Botanik Bahçesi'nde yürütülmüştür. Denemeler tarla koşullarında kurulmadan önce 2014 yılının Aralık ayında tohumlar içleri torf ile doldurulmuş fide kaplarına ekilmiş çimlenmeleri sağlanmıştır. Fideler sera koşullarında yeterli büyüklüğe ulaşınca, 2015 yılı Nisan ayı sonunda önceden hazırlanan deneme alanlarına dikilmiştir (Çizelge 4). Denemelerde 50 x 30 cm dikim mesafeleri kullanılmış, parseller 3 sıradan oluşmuş, parsellerde 72 adet bitki yer almıştır. Parseller 7,2 m boyunda oluşturulmuş, aralarında 1'er m mesafe bırakılmıştır. Deneme toplam 21 (altı *Salvia* türüne ait yedi genotip x 3 tekerrür) parselden oluşmuştur. Dikim işleminden hem sonra her lokasyonda can suyu verilmiştir. Tüm denemelerde bitkiler ilk iki hafta belirli aralıklarla sulanmış ve tutmayan bitkilerin yerine yenileri dikilmiştir Böylece her parselde bitki sayıları eşitlenmiştir. Birinci deneme yılında Çanakkale ve Kütahya lokasyonlarında 10.07.2015 tarihinden itibaren sulama 15 günde bir kez sulama yapılırken, Balıkesir lokasyonunda ise toprağın kumlu olmasından dolayı 10 günde bir sulama yapılmıştır. İkinci yıl ise tüm lokasyonlarda yıl boyunca ihtiyaca göre belirli aralıklarla damla

sulama sistemi ile sulama yapılmıştır. Tüm lokasyonlarda her türe ait parsellerin ortasında yer alan bitkilerden 9'ar adet bitki etiketlenmiş, her iki senede de yapılan gözlem ve ölçümler, bu bitkiler üzerinde yapılmıştır. Tüm lokasyonlarda tarlalar, dikimden hemen önce dekara yaklışık 3,6 kg saf azot ve 9,2 kg saf fosfor olacak şekilde DAP gübresi ile gübrelenmiştir. Daha sonraki aşamalarda herhangi bir gübreleme yapılmamıştır. Her iki deneme yılında da tüm lokasyonlarda yabancı ot mücadelesi çapalama ve elle mücadele şeklinde yapılmıştır.

Çizelge 4. Denemenin yürütüldüğü lokasyonlara ait dikim tarihleri

Lokasyonlar	2014-2015 yılı dikim tarihleri
Çanakkale	27.04.2015
Kütahya	28.04.2015
Balıkesir	27.04.2015

Deneme süresince yapılan biçimler ve tarihleri Çizelge 5.'de verilmiştir. İkinci yıl ise ilk biçim tüm lokasyonlarda parseldeki bitkilerin çiçeklenme döneminde her türde etiketlenen 9'ar adet bitkiden yapılmıştır. Tüm lokasyonlarda birinci yıl için bir biçim, ikinci yıl için üç biçim yapılmıştır. Bu deneme yılında tüm lokasyonlarda bitkiler çiçek tomurcukları oluştuktan sonra hasat edilmiştir. Biçimler bağ makası ile toprak seviyesinden 5 cm olacak şekilde yapılmıştır. Biçilen adaçayları özel hazırlanan kurutma alanlarında yaklaşık 20 cm kalınlığında serilip belirli aralıklarla karıştırılarak, doğal koşullarda kurutulmuştur. Kurutma yapılmadan önce yeşil herba ve yeşil yaprak ölçümleri yapılmış, kuru herba ve uçucu yağ analizleri için ise numuneler alınmıştır.

Çizelge 5. Adaçayı türlerinin lokasyonlara göre biçim tarihleri

Lokasyon	Tür	1.Yıl	2.Yıl		
		1.Biçim	1.Biçim	2.Biçim	3. Biçim
Çanakkale	*Salvia fruticosa* Mill.	06.08.2015	06.05.2016	25.06.2016	27.08.2016
Balıkesir	*Salvia fruticosa* Mill.	20.08.2015	14.05.2016	03.07.2016	04.09.2016
Kütahya	*Salvia fruticosa* Mill.	3.09.2015	27.05.2016	21.07.2016	16.09.2016

Deneme süresince tüm lokasyonlarda hastalık ve zararlı gözlemleri alınmıştır. Tür ve lokasyonlarda herhangi bir hastalık ve zararlıya rastlanmamıştır.

Uçucu Yağ Oranı (%)

Her parselden etiketlenen 9'ar adet bitkiden alınan örnekler karıştılarak kurutulmuş, uçucu yağ oranı su distilasyonu yöntemiyle belirlenmiştir. Uçucu yağ analizinin başlangıcında 20 g kuru materyal tartılmıştır. Örnekler tabanı yuvarlak boynu traşlı 500 ml'lik balona alınmıştır. 200 ml (örnek miktarına göre değişebilir, yaklaşık 10 kat) saf su eklenmiştir. Balon Neo -Clevenger düzeneğinin ısıtmalı ceket kısmına yerleştirilip dikey dereceli cam borunun alt kısmı cam balona, üst kısmı ise soğutucu sistemine bağlanmıştır. Dereceli boru ve eğik boruya saf su doldurulduktan sonra soğutucu sistem çalıştırılıp, balon ısıtılmaya başlanmıştır. 2 saat süreyle hidrodestilasyon işlemine tabi tutulmuştur. Sistem soğuduktan sonra ve dereceli kısma toplanan uçucu yağ sulu fazdan ayrıldıktan sonra miktarı (ml) tespit edilmiştir. Tartımı alınan örnek miktarına (g) göre 100 g örnekteki uçucu yağ miktarı uçucu yağ oranı (%) olarak hesaplanmıştır (Skoula ve ark., 2000).

Uçucu Yağ Bileşenleri (%)

Her türe ait örnekler 1:100 oranında hekzan ile seyreltilmiş, gaz kromatografisinde bileşenlerin ayrımı için kapiler kolon kullanılmıştır. Kütle dedektörü için tarama aralığı olarak 35-450 (m/z) atomik kütle ünitesi ve elektron bombardımanı iyonizasyon enerjisi 70 eV değeri kullanılmıştır. Uçucu yağın bileşenlerinin teşhisinde Oil Adams, Wiley ve Nist kütüphanelerinin verileri esas alınmıştır (Özek, 2010).

BULGULAR VE TARTIŞMA

Salvia fruticosa Mill. türünün uçucu yağ bileşimi tüm biçimlerin ortalaması olarak lokasyonlara göre ayrı ayrı olacak şekilde Çizelge 6.'de gösterilmiştir. *Salvia fruticosa* Mill. türünde ana bileşen 1,8-cineole, Camphor, β-thujone olarak kaydedilirken, üç lokasyonda da ana bileşen olarak 1,8-cineole, Camphor, β-caryophyllene olarak bulunmuştur. Ana bileşenlerin lokasyonlara göre oranları sırasıyla aşağıda verilmiştir. Çanakkale lokasyonunda; birinci yıl 1,8-cineole % 49,60, ikinci yıl %35,2, birinci yıl Camphor % 22,21, ikinci yıl %21,37, β-caryophyllene birinci yıl % 2,31, ikinci yıl % 4,54 olarak bulunmuştur. Balıkesir lokasyonunda; birinci yıl 1,8-cineole % 33,36, ikinci yıl %62,11, birinci yıl Camphor %17,51, ikinci yıl %3,57, β-caryophyllene birinci yıl %3,31, ikinci yıl %12,88 olarak tespit edilmiştir. Kütahya lokasyonunda birinci yıl 1,8-cineole % 56,02, ikinci yıl %55,01, birinci yıl Camphor %6,62, ikinci yıl %9,43, β-caryophyllene birinci yıl %3,22, ikinci yıl %6,19 olarak belirlenmiştir. *Salvia fruticosa* Mill. türünde Çanakkale lokasyonunda birinci yıl 21 bileşen ve toplamı %99,8, ikinci yıl 17 bileşen ve toplam %99,82, Balıkesir lokasyonunda birinci yıl 20 bileşen ve toplam %98.45, ikinci yıl 9 bileşen ve toplam %99,77,

Kütahya lokasyonunda birinci yıl 22 bileşen ve toplam % 99,58, ikinci yıl 14 bileşen tespit edilmiş ve uçucu yağın toplam %99,76'ünü açıklamıştır. Bu türün diğer önemli bileşenleri de birbirinden farklılık göstermektedir. Lokasyon sırasına göre diğer önemli bileşenler Çanakkale; α-pinene, Camphene, β-pinene, Balıkesir; α-thujone, β-pinene, Camphene, Kütahya; β-pinene, Myrcene, α-pinene şeklinde sıralanmıştır. Türlerin lokasyonlara göre uçucu yağ bileşenleri belli ölçüde değişiklik göstermektedir. *Salvia fruticosa* Mill. türünde ana bileşeni üç lokasyonda da 1,8-cineole olarak gerçekleşmiştir. Bu durum, uçucu yağ bileşenleri üzerine ekolojik faktörlerin ne derece etkili olduğunu göstermektedir. Çalışmamıza benzer şekilde, Libya'da yabani olarak yetişen *Salvia fruticosa*'dan izole edilen esans yağı bileşimi GC ve GC-MS ile analizi yapılmış, kırk beş bileşik tespit edilmiş ve uçucu yağ bileşenlerinin, 1,8-cineole (%49,34), camphor (%7,53), mircene (%7,38), α-pinen (%5,15), β-caryophyllene (%4,13) ve α-terpineol (%3,25) olduğu belirlenmiştir (Giweli ve ark., 2013). *Salvia fruticosa* Mill. türünde yapılan bir başka araştırmada uçucu yağ oranının %0,80-2,45 aralığında değişim gösterdiği ve uçucu yağların ana bileşenlerinden 1,8-cineole oranı %11,8-45,9, isoborneol %0,36-26,12 ve β-caryophyllene %2,16-17,17 oluştuğu tespit edilmiştir (Karık ve ark., 2014). Arnavutluk ve Yunanistan'ın dokuz farklı bölgesinden toplanan *Salvia fruticosa* Mill. türünün uçucu yağının incelendiği bir araştırmada 19 farklı popülâsyon kullanılmıştır, analizlerinde elde edilen yağların %79,15–97,83'ünü temsil eden toplam 75 bileşen tespit edilmiş, tüm örneklerde on üç bileşen (α-pinen, kamfen, β-pinen, mirerken, 1,8-sineol, γ-terpinene, cis-tujon, trans-thujone, kâfur, terpinen-4-ol, trans- (E) -karyofilen

ve α-humulen) belirlemiştir (Cvetkovikj ve ark. 2015). Bir çok araştırmacının elde ettikleri sonuçlar ile bu tez çalışmasındaki *S. fruticosa* Mill. türünün uçucu yağ bileşenleri sonuçları benzerlik göstermektedir. Bir başka araştırmada *Salvia fruticosa* Mill. türünde uçucu yağlardaki ana bileşenlerin 1,8-sineol, kâfur ve karyofillen olduğu saptamıştır (Uysal, 2015). Muğla, Antalya, İzmir, Aydın, Çanakkale, Balıkesir ile Tekirdağ illerinde olmak üzere toplam 17 lokasyondan toplanan ada çayı tohumlarından oluşturulana populasyonda uçucu yağ bileşiminin en önemli maddesinin 1,8-Cineol olduğu bu maddenin klonlara göre %15,96-75,50 aralığında değişim gösterdiği bildirilmiştir (Bayram, 2001). Akdeniz bölgesine özgü çok yıllık aromatik bir bitki olan *Salvia fruticosa*, Lübnan'da en çok kullanılan tıbbi bitkidir. *S. fruticosa* uçucu yağları (EO'lar), Lübnan geleneksel tıbbında çeşitli rahatsızlıkları tedavi etmek için yaygın olarak kabul edilmektedir (Zgheib ve ark., 2019). *S. fruticosa*'nın uçucu yağlarındaki kafur bileşeni üzerindeki rakımın etkisi %1 seviyesinde istatistiksel olarak anlamlı bulundu. Bitkilerin uçucu yağlarındaki kafur yüzdesi %0,55 ile %13,40 arasında değişti ve en yüksek kafur oranı (%6,87-8,38) 600-800 m rakımda toplanan bitkilerden elde edildi. Kafur, 600-800 m ve 0-200 m rakımda toplanan bitkilerin ikinci en önemli uçucu yağ bileşeniydi, β-tuyon ise 300-500 m rakımda toplanan bitkilerde ikinci en önemli uçucu bileşendi. Birçok çalışmada, kafurun *S. fruticosa* bitkisinin ikinci en önemli uçucu yağ bileşeni olduğu bildirilmiştir (Giweli ve Ark.., 2013). Geleneksel tıpta, bitki uzmanları genellikle *S. fruticosa*'nın toprak üstü kısımlarını, soğuk algınlığı, ağız ve boğaz iltihabı, öksürük ve karın ağrısı semptomlarını hafifletmek için dahili olarak infüzyonlarını tüketerek veya harici olarak uygulayarak

kullanırlarmış (Boukhary ve ark., 2016). *Salvia* türleri gibi aromatik ve tıbbi bitkiler, çok çeşitli rahatsızlıkların tedavisinde önemli terapötik potansiyelleri nedeniyle tanınmıştır (Michel ve Ark., 2020). Yaygın olarak Doğu Akdeniz adaçayı olarak bilinen bu özel tür, *Salvia officinalis*'e kıyasla daha yaygın olarak Amerika Birleşik Devletleri'ne ithal edilmektedir (Farhat ve ark., 2001). Esansiyel yağ bileşimlerindeki bu değişiklikler çevrenin (iklimsel, mevsimsel, coğrafi) (Bellomaria ve Ark., 1992), genetik faktörlerin (Perry ve Ark., 1999) ve tarımsal uygulamaların (Sarrou ve Ark., 2016) etkisi altında değişebilir (*Salvia officinalis* × *Salvia fruticosa,* cv. Newe Ya'ar No. 4 , *Lamiaceae*) bitkilerinin bireysel yaprak çiftlerinden elde edilen ekstraktiflerde gelişimsel olarak kontrol edilen değişiklikler de kaydedilmiş. Üst genç yapraklarda, oksijenli diterpen manool ve seskiterpen hidrokarbonlar α-humulen ve β-karyofilen toplam ekstraktiflerin sırasıyla %20, %8 ve %4'ünü oluşturuyormuş. Daha yaşlı yapraklarda, bu bileşenlerin bolluğu genç yapraklardaki seviyelerinin yaklaşık yarısına kadar istikrarlı bir şekilde düştü. Tersine, monoterpenlerin, özellikle ketonlar kafur ve α-tuyonun oranları, yaprak pozisyonuyla istikrarlı bir şekilde arttığını belirtmiştir (Dudai ve ark., 1999). *S. fruticosa*'nın uçucu yağ bileşenleri üzerine yapılan çalışmalarda en önemli uçucu yağ bileşeninin 1,8-sineol olduğu belirtilmektedir (Bayrak ve Akgul, 1987; Leontaritou ve ark., 2020). Bitkinin ticari kurutulmuş toprak üstü kısımlarından hidrodistilasyonla izole edilen *Salvia* esansiyel yağları, biyolojik aktiviteye ve farmakolojik özelliklere sahiptir. Yağlar, esas olarak Monoterpen hidrokarbonlar, Oksijenli monoterpenler, Seskiterpen hidrokarbonlar, Diterpenler, İzoprenoid olmayan bileşikler ve Oksijenli seskiterpenler olmak üzere 100'den

fazla farklı biyoaktif bileşik içerir. Antimikrobiyal, antioksidan, antikolinesteraz, bilişsel performans ve ruh halinin iyileştirilmesi, iş kaynaklı stresin azaltılması, anti-mutajenik, antikanser, anti-inflamatuar, koleretik aktiviteler vb. dahil olmak üzere bir dizi farmakolojik etkiye sahiptir. Mevcut inceleme *Salvia* esansiyel yağlarının farmakolojik aktivitelerine odaklanmıştır (Fu ve ark., 2013). Ancak, esansiyel yağ bileşimi *S. fruticosa*'nın tüm popülasyonlarında aynı değilmiş (Skoula ve ark., 2000). Araştırmacılar arasında yerel ilaçları ve bunların potansiyel etkilerini ve faydalarını keşfetmeye yönelik küresel bir ilgi vardır. Etnofarmakolojik çalışmalar bağlamında, doğal kaynakların araştırılması yeni terapötik ajanların araştırılmasında önemli bir rol oynar. Ek olarak, bitkilerde doğal olarak bulunan ve esas olarak monoterpenlerden oluşan esansiyel yağlar (EO), iltihaplanma ve ağrı tedavisinde yaygın olarak kullanılmaya başlanmıştır (Miguel, 2010). İklim bakımından farklılık gösteren coğrafi alanlardaki popülasyonların uçucu yağ profilleri yıldan yıla belirgin ve tutarlıdır. *Salvia fruticosa*'nın uçucu yağ oranı ve bileşimi değişkenlik göstermektedir. Farklı tipteki morfolojik özelliklerin rakım, enlem ve iklim gibi çevresel parametrelere verdiği tepkiler farklı *Salvia* L. popülasyonlar tarafından kullanılıyor gibi görünmektedir.Yukarıda sonuçları verilen araştırmaların çoğunluğu ile bizim elde etmiş olduğumuz sonuçlar uyum içerisindedir.

Çizelge 6. Salvia fruticosa Mill. türünün yaprakta uçucu yağının lokasyonlara ve yıllara göre bileşen miktarının (%)

		Çanakkale		Balıkesir		Kütahya	
S.no	Bileşen adı	1.Yıl	2.Yıl	1.Yıl	2.Yıl	1.Yıl	2.Yıl
1	α-pinene	3,41	4,52	4,82	2,19	3,54	1,33
2	Camphene	4,09	5,87	6,89	-	2,30	-
3	β-pinene	5,45	7,63	7,52	1,57	7,62	2,87
4	Sabinene	0,25	1,05	1,31	-	-	-
5	Myrcene	2,25	5,71	4,14	2,71	5,93	1,72
6	Limonene	1,86	2,73	1,80	-	1,31	1,98
7	1,8-cineole	49,60	35,2	33,36	62,11	56,02	55,01
8	γ –terpinene	0,42	0,96	0,95	-	0,51	-
9	α-terpinolene	0,30	0,65	-	-	0,22	-
10	α-thujone	2,42	0,55	5,35	1,07	1,44	2,39
11	β-thujone	1,43	2,15	3,46	12,77	2,53	6,18
12	Transsabinenhydrate	0,45	0,33	0,64	-	0,63	2,92
13	Camphor	22,21	21,37	17,51	3,27	6,62	9,43
14	Linalool	0,27	-	1,05	-	0,20	-
15	Cis-sabinenehydrate	-	-	-	-	0,21	-
16	Bornylacetate	0,30	3,14	1,32	-	3,04	1,64
17	Terpinen-4-ol	0,53	0,86	0,82	-	0,32	-
18	β-caryophyllene	2,31	4,54	3,31	12,88	3,22	6,19
19	δ-terpineol	-	-	-	-	0,42	-
20	α-humulene	0,64	1,18	1,55	-	1,20	-
21	α terpineol	0,23	-	1,04	-	0,72	-
22	γ- terpineol	-	-	0,64	-	-	-
23	Borneol	1,17	1,14	1,64	-	1,35	-
24	Viridiflorol	0,21	-	0,67	1,20	0,23	1,59
25	Myrtenol	-	0,24	-	-	-	-
26	cyclohexadecane	-	-	-	-	-	5,33
27	phytol	-	-	-	-	-	1,18
	Toplam%	99,8	99,82	98.45	99,77	99,58	99,76

SONUÇ

Bu çalışmada uçucu yağ oranı (%), uçucu yağ ana bileşenleri belirlenmiştir. Uçucu yağ oranında birinci yıl en yüksek değerler Çanakkale lokasyonunda *Salvia fruticosa* Mill. türünde (%1,80), Kütahya lokasyonunda *Salvia fruticosa* Mill. türünde (%4), Balıkesir lokasyonunda ise *Salvia fruticosa* Mill. türünden elde edilmiştir. İkinci yıl uçucu yağ oranında en yüksek oranlar Çanakkale lokasyonunda *Salvia fruticosa* Mill. türünde (%2,51), Kütahya lokasyonunda *Salvia fruticosa* Mill. türünde (%2,38), Balıkesir lokasyonunda ise *Salvia fruticosa* Mill. (%2,26) türünde tespit edilmiştir.

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CHAPTER V

Consistencies and Obstacles in Cameroonian Forest Resource Protection

Marcel Ndasack NDIFON
Askin KIRAZ

Introduction

Forestry is essential because it provides nearby woodland populations with fuel, wood, and feed. They also have a significant impact on the control of climate (Ekoungoulou, 2018). A greater variety of participants, including regional populations, countries, and international groups, are placing a rising degree of pressure on these woodlands, which range from agricultural environments to diversified ecologies (Ustin & Middleton, 2021).

Comparably, woods offer a variety of societal and recreational, including social amenities (Kock & Cáceres-Escobar, 2022). These many tasks and responsibilities highlight reduced agricultural performance due to ineffective government policies and land-

management practices, as well as forest exhaustion, logging, and deterioration (Ernst et al., 2013).

Forest preservation and oversight are becoming increasingly important because of a growing need for timber resources and services (Blatter et al., 2020). As the general understanding regarding the regulations governing the utilization of natural assets grows, the concepts surrounding conserving forests are evolving from simple logging agreements to exploiting trees regarding carbon capture and storage, preservation of biological diversity, managing resources, and the establishment of sustainability as a form of entertainment and relaxation (Garnett et al., 2018; Maukonen et al., 2020). Due to their tendency to reduce pollution from forests and increase ecological carbon sinks, environmental attempts at preservation also aid in mitigating the effects of the changing climate (Assumma et al., 2022). The same technical and scientific equipment that have made this feasible, such as media outlets like television, radio, the use of geographic information systems (GIS), and satellite imagery, have further developed as well as raised regulations, conversation techniques, supplies initiatives, and forest preservation efforts (Weber, 2012).

Case Study Interpretation

As seen in Figure 1, approximately 475,440 km2 of land, mostly made up of rainforests (42%), agricultural (20.6%), as well as other occupations of land (37.7%), make up the West African nation of Cameroon (Cianconi et al., 2020). Situated primarily in the southern regions of the nation, these woods form the western boundaries of the Congo Basin Ecosystem (Angelakis et al., 2023).

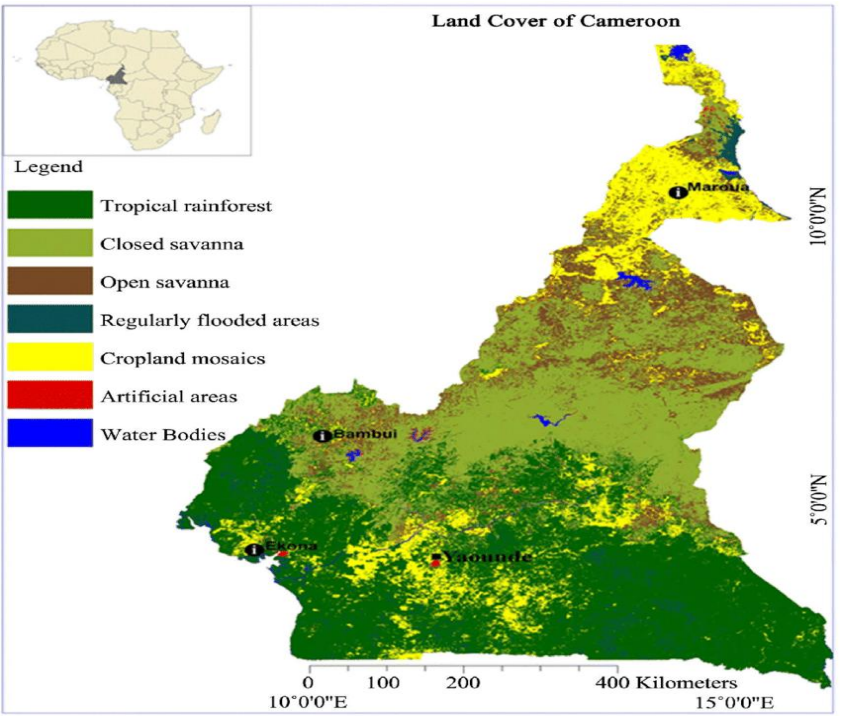

Figure 1. Cameroonian Land Use (Yengoh & Ardö, 2014)

Importance of the Study

To work together efficiently in developing initiatives that promote environmentally friendly living and forest preservation aimed at reducing the loss of trees, woodland loss, deterioration, and hunger in rural areas, decision-makers in the forestry industry, the head of state in Cameroon, and local populations residing in forests can use the current research as a starting point (Estrada et al., 2017; Thi et al., 2015). The advantages of this productive partnership could prove critical in furnishing the indigenous forest-dwelling societies with necessities like firewood, timber for handicrafts, traditional remedies, a place to live, a variety of ecosystems for animals and

plants, and protection fishing nets regarding the effects of changes in the climate (Watson et al., 2018).

Methodology

An extensive examination of the available scientific work was conducted using Semantic Scholar, Research Gate, Web of Science, Mendeley, and Google Scholar in order to get a broad and thorough understanding of preservation policies regarding Cameroon's forest resources. While investigating the forest industry and conservation principles in the study, the country of focus is Cameroon. While researching the relevant literature in the research, terms such as Cameroon, difficulties in protecting forests, destruction and loss of forests, protection of forests, protection of forest resources, climate change, lifestyles in rural areas and environmental conditions of the field in Africa were used, taking examples from similar studies (Foley, 2022; Nsah, 2023; Kountios et al., 2023; Tengö et al., 2017).

To achieve this, a broad but thorough investigation was conducted by selecting and evaluating scientific research and internet data spanning approximately three decades. The forests sector in the African continent, the destruction of forests surrounding Cameroon, problems with the preservation of forests, decline in forests and preservation, how to manage forests, environmental change, traditional livelihoods, and over 70 internet papers were retrieved from literature (Fokeng et al., 2020; Leakey et al., 2022; Wijethilaka & Liyanage, 2021).

Only papers about the care and preservation of forests, biodiversity, climate change, agricultural livelihoods, the forest services sector in Cameroon, obstacles to the protection of forests,

forest loss, and the loss of forests in the region within Cameroon have been examined under this point of view (Insects to Feed the World 2020, Virtual Conference, 2020). The majority of the papers that were acquired were focused on different, unconnected issues and preference types. The papers about, for example, environmental responsibility, the environment, and global warming research, or about impending disasters in the field of how to manage woodland resources, climate change, rural livelihoods, the African forestry industry, difficulties in conserving forests, forest clearing, and loss of forests were thrown out (Frieler et al. 2017). Just over 20 of the roughly 70 retrieved documents had some connection to Cameroonian forest protection. This is mainly because knowledge from different parts of the world primarily Asia, Africa, European countries, and Latin America was included in more than 70 percent of the mentioned texts, with little to no material regarding Cameroon.

With specific emphasis on Cameroon, the data gathered from these documents and other papers was utilized to provide a broad overview of preserving forests in Cameroon. Comparably, the past context of maintaining forests in Cameroon has been extensively studied. This work is broken into a total of 3 subsections. The first examines the backdrop of the preservation of forests in Africa generally and in Cameroon specifically. The following segment examines Cameroonian forest management from several angles. The obstacles to forest conservation are examined in the third section (Figure 2).

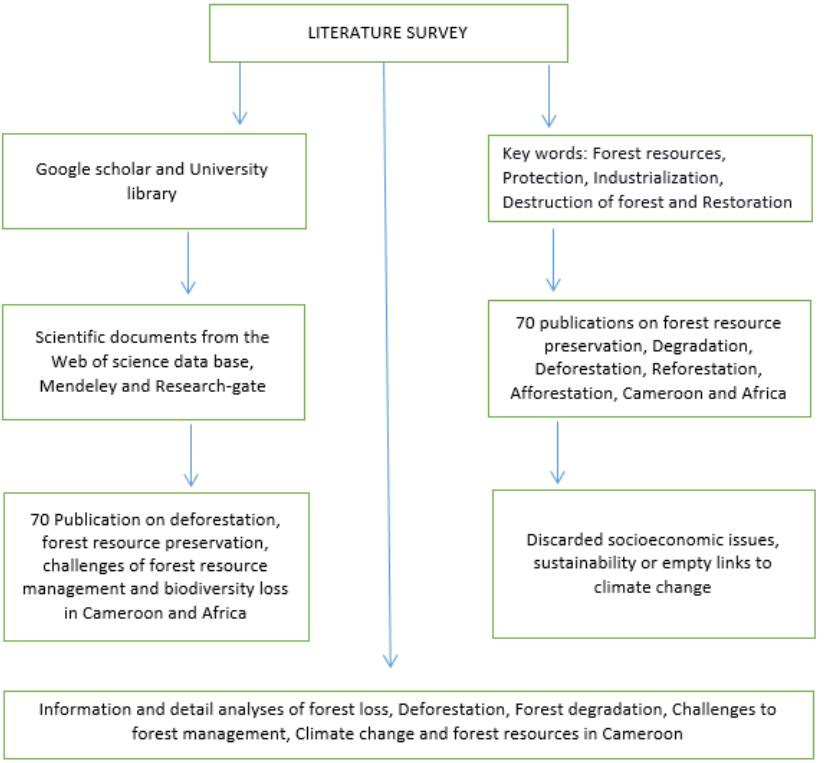

Figure 2. Methodological Diagram

This investigation aimed to verify, determine, and evaluate the different problems that Cameroonian forest conservation initiatives face through the utilization of published research (Tambutoh and Tarh, 2018). Additionally, it aims to raise public knowledge of the risks linked with the destruction of forests, forest clearing, and their effects (Wassie, 2020). It also refers to improving social programs, teaching rural forest populations different subsistence methods, and helping authorities create a range of plans to deal with problems related to forest preservation (Olsen, 2007).

Findings

Cameroon's Forest Management History

As stated by Bailey et al., 2017, the continent's inhabitants and forest's historical events, particularly following the Iron Age, are divided into three significant eras: before-colonization activity during these Africans had unrestricted and inexhaustible woodland accessibility; colonization and the contemporary era during and these Africans neglected their independent and unconstrained accessibility to forests land; alongside at last, a more recent time characterized by shifting preservation that involves various techniques such as logging that were not exclusive to collective forest supervisors (Chikalipah, 2017; Forkuor et al., 2017).

Many studies were used earlier than colonialism began. This may be seen in the African forests after the Iron Age progressed from northward across the southwards and western (Malhi, 2018). Environmental resource preservation, especially freshwater and livestock grounds, had to be regulated by community-level regulations and was generally met with harsh penalties (Ushamba, 2022). Forest protection was additionally essential since woodlands were frequently used as hiding places, places of worship, and holy trees. Throughout colonization, Africans gave up their legal entitlements to nearby or remote forest usage (Silva et al., 2019). This was due to colonial rulers purposefully reserving these woods to service and give forests for their nation-states at the expense of African populations (Mentan, 2023).

Right up until the second half of the 1990s, the country's woods had been preserved under a nationally controlled framework

and procedure that confiscated assets and power from the indigenous people. The legislation barred individuals like these from gaining possession of the forests and reaping revenues through them (Pham et al., 2021). The country's initial forest legislation was enacted in 1974, updated in 1981 (the law N 81 - November 13 November 21, 1981), and finalized in 1983 (decree N 83 - 169 of April 12, 1983) (Weidlich et al., 2020). A range of intersecting causes, notably donation expectations, global financial motivations, local policy issues, local agricultural status, the utilization of land, and democratic organization challenges, are welcomed in a people-friendly framework. All of this resulted in the passage of the 1994 Forests Regulation, including its accompanying implementation regulation (Stickler et al., 2017).

The legislative Laws on Forests, as well as Biodiversity (Law N 94 - 01 of January 20 1994), is the legislative structure that contributes to the execution of the National Forests Activities program (NFAP) (Tamungang, 2016). This is a vital element of the legislature's policy to secure the ongoing preservation, including utilization of its forests, biodiversity, and fishery resources. The legislation establishes laws to achieve the broad goals of the country's new forest policies (Pecl et al., 2017).

The legislation additionally demands that every activity that may affect an area of conservation concern (industry, mineral extraction, agriculture, and animal rearing) be backed up by a study of the impact (Massa et al., 2021). Its implementation mechanisms consist of three legislative laws (Decrees N 95 - 531-PM, 95 - 678-PM, and 95 - 678-PM) and three general laws (Decrees N 86 - 230, 96 - 237-PM, and 96 - 238-PM) (Beckline et al., 2022).

Forests Management Prospects in Cameroon

The Cameroonian forest industry is experiencing extensive organizational and legal modifications, every one of which is following several regional and international agreements under which Cameroonian is a signatory (Adewumi et al., 2022). Alongside them is the Biodiversity Protocol, which took effect on June 14, 1992. This has led to a series of acts that have drastically amended legislation controlling the whole forestry industry, and a Department of Conservation and Forestry was established in 1992 (decree n 92/069 of April 9, 1992) (Zekeng et al., 2021). Unlike the previous Department of Agriculture Investigation, the recently established College of Research on Agriculture for Reconstruction (decree n 96/050 of March 12, 1996) places a greater priority on reforestation and ecological studies (Sroufe, 2017).

To conserve flora and wildlife, the government has established several preserves. Apart from the approximately fifteen finished preserves having a total projected area of approximately 19,017 km2, there are also around thirteen more PAs in various phases of development encompassing an approximated surface area of 6660 km2 (Hohenlohe et al., 2020). In addition, the country has around 11 national parks spanning 18,069 km2, along with various sanctuary grounds comprising approximately 948 km2 (Ninan and Inoue, 2013). Around 56% of those designated regions are in humid tropical regions, including 30% around the tropical forest savannah and 7% in the mountainous regions (Lescuyer, 2012).

The National Zoning Plan also serves as an overview of the structuring, direction, and utilization of biodiversity in the south wooded region (Folke et al., 2005). The National Zoning Plan has

55% thick forests, 33% forested areas, and 12% terrain, wherein trees don't constitute significant flora. Throughout 2006 and 2011, they rose by 3% to 163,000 km2, constituting about 35% of the overall national land area, exceeding the 30% objective set by the 1994 Forests Regulation (Escobedo et al., 2011). The National Zoning Plan had 11,000 km2 of forest in 2011; 90% of the area was public forests, as seen in Figure 3 (Nesha et al., 2021).

Following the emergence of local initiative techniques in agricultural growth and conservation of forests in the middle of Africa in the early 1990s, ideas such as participation and engagement of local communities in forest management have been gradually adopted (Arts et al., 2017). The main focus in Cameroon is on communities, as seen in Figure 3.

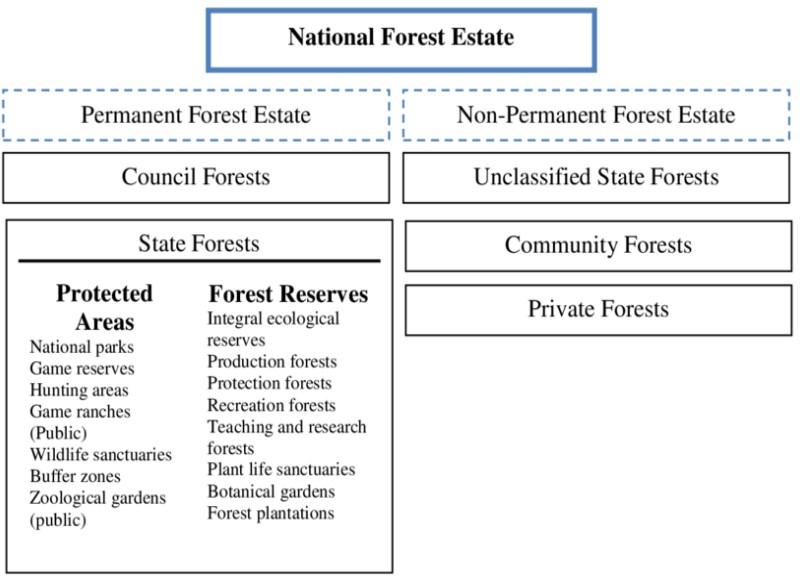

Figure 3. Cameroon's Forest Policy and Zoning (Essougong et al., 2019)

Cameroon's forestry strategy and zoning system. Forests Regulation 94/01, enacted on January 20, 1994, mentioned in Fokeng et al. (2020). Cooperation in the conservation of forests emerged primarily as a result of its approval of the Rio Earth Summit's agreements in 1992 (Lemenkova, 2020). Emphasize how the passage of a new forests law in 1994 granting communities at large a legal claim to operate forests has supported collaborative forestry tendencies in remote regions of Cameroon (Tchoumbou et al., 2020).

Cameroon's Forest Preservation Faces Some Challenges

The Minister of Forests and Wildlife (MINFOF) manages the forest resources sector in partnership alongside the Ministries of Environments and Natural Preservation and Sustainability (MINEPDED) as well as other centralized functions among the local and regional stages (Hein et al., 2018). The forests and biodiversity legal requirements are incorporated in forests legislation N 94 - January 01 January 20, 1994, and provide the regulatory structure that assists the execution of the National Forests Strategy Plans. The legislation's legal requirements regarding the laying of prominence in Cameroon's policy and strategic plan for managing its forests (Bitondo, 2000).

However, forest preservation initiatives are being revitalized as a result of these forest regulations, and outcomes have been less encouraging. Other than advances in forest accessibility of knowledge, forest regulatory changes have yet to be developed (Keenan & Williams, 2018). As a result, activities, including forest materials preservation and oversight strategy, are frequently distributed beginning at the start (Levin, 1985).

This absence of an organized strategy in the forest industry has hindered timber's long-term viability, particularly because governments have been unable to make investments in the technological and management abilities and employees required for the maintenance and preservation of the nation's forests (Ahenkan and Boon, 2011). Furthermore, the drawbacks and disadvantages of present techniques for managing forests do not give a venue or a chance to enable indigenous peoples to communicate their concerns about the woods. This is mainly because the forestry ministry's development programs are unstable, ineffective, and unable to solve the fundamental issues (Gann et al., 2019).

The previous instances show that preservation of the environment initiatives across Africa overall, and Cameroon in particular, have typically been accorded poor importance in comparison to the food supply, wellness, academic achievement, development of roads, and possibly sport (Chakrabarty, 2009). Despite the strain of greater challenges, future demands and properly planned investments for conservation administration are sometimes disregarded. It’s a sign of poor governance in most African nations, resulting in often contributing to the downfall of forests and other environmental resources. Further, woodland loss and other natural losses of resources (Steenwerth et al., 2014). At the same time, it promotes greater interest and revenue generation from forestry extraction of resources.

Initiatives that increase the engagement of indigenous individuals along with other participants, including those that assure appropriate forest preservation, are frequently inadequate (Savedoff, 2018). The foreseeable hazard is the degradation of these precious

woodlands, which has an impact on their preservation as well as the lives of nearby forested populations (Dolan & Riegel, 1996).

Conclusion

According to the current investigation, Cameroon has vast forest reserves, extending more than forty per cent of the nation. Furthermore, like elsewhere in the tropics, numerous indigenous peoples dwell both inside and near the forested areas, which is where their daily lives rely. This dependency is mainly dependent on traditional farming as well as forest resources collecting as its primary means of revenue. Notwithstanding all of this, the state will require a wide range of electoral, forest management, and economic perspectives to fulfil its tree preservation goals, make decisions on policies, and make efforts to mitigate the effects of adverse environmental circumstances. As a result, effective Cameroonian forest preservation planning and oversight ought to incorporate a broad spectrum of politics, forests, economics, technology, and collaboration among stakeholders across multiple phases of the biodiversity protection procedure.

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CHAPTER VI

Determination of In Vitro Antagonistic Effects of Poplar Vinegar against Some Fungal Pathogens

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INTRUDUCTION

Worldwide, plant diseases caused by fungal pathogens account for 65% of all plant diseases and lead to significant yield losses (Ferraz et al., 2019). Fungal diseases cause 20% of the losses during the pre-harvest period and 10% of post-harvest losses (Fisher et al., 2018), with total global losses estimated at $40 billion (Syed Ab Rahman et al., 2018). Fungal pathogens are considered the

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primary causes of both pre- and post-harvest losses in crops. Given the changing weather conditions due to climate change, reducing these losses is critical to achieving global food security goals (Aulakh and Regmi, 2013; Zhang et al., 2020).

One of the biggest challenges encountered before harvest is soil-borne diseases, which are considered significant limiting factors for agricultural production. Soil-borne plant pathogens such as *Rhizoctonia* spp., *Fusarium* spp., *Verticillium* spp., *Sclerotinia* spp., *Pythium* spp., and *Phytophthora* spp. have been reported to cause yield losses of 50-75% in various crops, including wheat, cotton, maize, vegetables, fruits, and ornamental plants (Panth et al., 2020). Among these diseases, *Sclerotinia sclerotiorum* (Lib.) de Bary is one of the most destructive and virulent plant pathogens in the world. This fungus is found globally, including in temperate, tropical, and arid regions, and is known for causing white rot disease. Due to the non-host specificity of *S. sclerotiorum*, it can infect over 400 plant species, leading to significant crop losses (Boland and Hall, 1987; Hossain et al., 2023). For example, annual losses in the United States due to *S. sclerotiorum* have exceeded $200 million (Bolton et al., 2006). In addition to the pathogens encountered before harvest, combating the most important fungal pathogens causing post-harvest losses is also a key issue. One such pathogen, *Botrytis cinerea*, ranks second among the top 10 fungal organisms causing the greatest economic losses worldwide. It has become a significant problem for agriculture and the food industry due to its ability to infect various hosts, adapt to diverse environmental conditions, and its rapid mycelial growth rates (Choquer et al., 2007). Both pre and post-harvest, the primary method used to control decay in most crop

groups is the application of synthetic fungicides (Dukare et al., 2019). However, the use of these substances is increasingly being restricted due to their negative impacts on fungal resistance, as well as their adverse effects on human and animal health and the environment (O'Brien, 2017). These concerns have led to a preference for more effective and environmentally friendly methods, resulting in increased research on these topics (Dukare et al., 2019; Syed Ab Rahman et al., 2018). Recently, biochar-based agricultural and forestry residues, particularly those aimed at reducing greenhouse gas emissions such as carbon dioxide, energy production, and environmental protection, have become widely used in agriculture (Ayaz et al., 2019). With the growing demand for biochar in recent years, the amount of lignocellulosic biomass pyrolysis liquid produced during biochar preparation has also increased. Biomass pyrolysis liquids, commonly known as wood vinegar, have become a popular research topic (Li et al., 2019; Zhang et al., 2019). WV is a complex mixture containing more than 200 water-soluble compounds, of which 80-90% is water. These compounds include nitrogen, phenols, organic acids, sugar derivatives, alcohols, and esters (Zheng et al., 2018; Grewal et al., 2018). The chemical composition of WV is determined by the pyrolysis rate, temperature, and the raw materials used (Xue, 2022). As a natural agricultural product, WV is increasingly recognized and valued for its various properties, including not polluting the environment, having no toxic effects on humans or animals, improving soil structure, promoting plant growth, enhancing fruit taste and quality, and serving as an alternative to synthetic pesticides. Its usage is expanding in agriculture, forestry, animal husbandry, and

other sectors (Gao et al., 2020; Ofoe, 2022; Bouket, 2022). WV is used to combat plant diseases, and it is predicted that different concentrations of WV may significantly affect field diseases (Wang, 2013; Oramahi, 2013; Velmurugan, 2009; Liu, 2021; Zhou, 2024).

The poplar tree is used in the production of wood pulp and paper, lumber, veneer, plywood, composite panels, structural composite lumber, containers, pallets, furniture parts, and matchsticks (Balatinecz et al., 2001). In the past, the bark of the poplar tree was used to extract salicylates, which are precursors to aspirin. However, today, aspirin is produced using the Kolbe–Schmitt process with sodium phenolate, petroleum-based benzene, and CO_2 (Norn et al., 2009; Luo et al., 2016). Recently, studies on the use of WV, obtained from the pyrolysis of poplar tree residues and forest waste, in agriculture have gained attention. For instance, poplar vinegar was found to be distinctly acidic, with a pH of 2.24, due to its high organic acid content (42.3%). The main components of poplar vinegar in the same study were reported to be carboxylic acids, esters, aldehydes, and ketones (Ríos-Reina et al., 2017).

In an agricultural study examining the effects of poplar vinegar on seed germination in pepper and tomato plants, it was found that, compared to the control, low concentrations of poplar vinegar significantly increased root length in pepper. However, this increase became insignificant when the concentration reached 0.02%. For tomatoes, an increasing trend in both root and shoot lengths was observed (Luo et al., 2019). In another study, the herbicidal effects of WV obtained from poplar, pine, and forest waste were investigated, yielding successful results (Aguirre et al., 2020).

This research aims to investigate the antifungal effects of poplar wood vinegar (PWV) against both pre-harvest (*S. sclerotiorum*) and post-harvest (*Botrytis cinerea*) fungal diseases from various perspectives.

METHOD

1. Pathogens and Wood Vinegar

In the experiment, phytopathogenic fungi (*B. cinerea* and *S. sclerotiorum*), which were previously obtained from our studies and subjected to pathogenicity tests, were used. Potato Dextrose Agar (PDA) medium was chosen for propagating the pathogens and assessing their antimicrobial effects.

The poplar wood vinegar used in the experiment was obtained by gasifying the wood parts of poplar (*Populus nigra, P. alba*) in the pyrolysis unit at the S.U. Çumra Vocational School of Applied Sciences. The smoke produced during this process was condensed by cooling it with water, and the tar fraction that precipitated from the liquid was then separated for further use.

2. Determination of In Vitro Activity of Poplar Wood Vinegar

The effect of poplar wood vinegar on inhibiting the mycelial growth of *B. cinerea* and *S. sclerotiorum* was tested at concentrations of 0.2 mL, 0.5 mL, and 0.7 mL. The wood vinegar was directly added to autoclaved (121°C for 20 minutes) Potato Dextrose Agar (PDA) medium, which had been cooled to 45°C, and poured into sterile Petri dishes to solidify. Circular discs (5 mm in diameter) from 7-10-day-old pathogen cultures were placed in the center of the Petri

dishes and incubated at 27°C. For the control group, PDA medium without WV was used to cultivate pathogens. Three replicates were performed for each treatment, and the experiment was repeated twice. Once maximum growth was observed in the control Petri dishes, mycelial growth was measured, and the inhibition percentage (R) was calculated using the formula:

$$R = [(C - B) / C] \times 100$$

According to this:

C= radial growth in the control group,

B = radial growth in the treatment group.

3. Statistical Analysis

The data were analyzed using one-way ANOVA with SPSS statistical software (SPSS Inc., version 17.0), and differences between doses were evaluated using the Tukey test ($p \leq 0.05$).

CONCLUSION and DISCUSSION

The study found that the application of PWV at the tested concentrations significantly reduced the mycelial growth of *B. cinerea* and *S. sclerotiorum* compared to the control group. Data marked with the same letter in each column, as determined by the Tukey test ($P \leq 0.05$), did not show any significant differences (Figure 1).

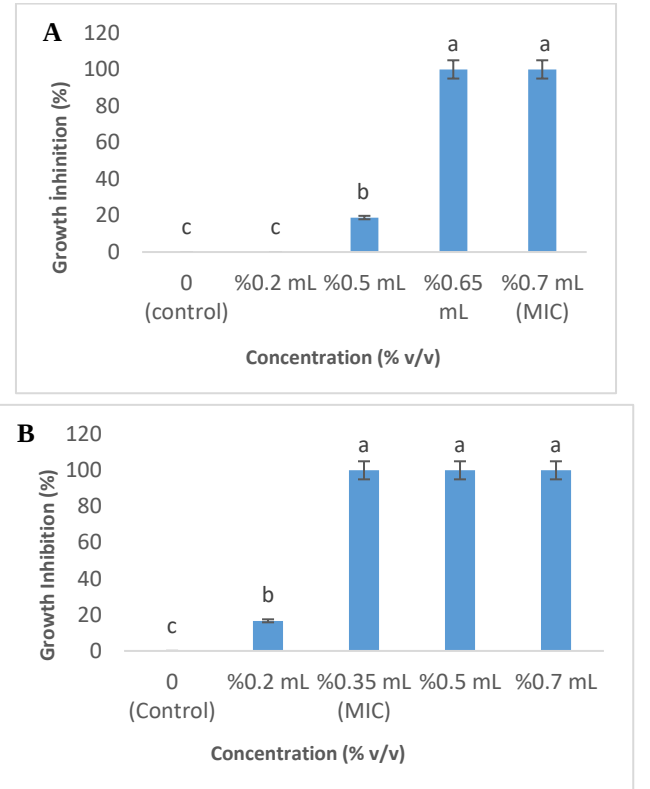

Figure 1. *Mycelial growth inhibition (%) of B. cinerea (A) and S. sclerotiorum (B) in vitro at increasing concentrations of poplar wood vinegar.*

The effect of different application doses and the percentage inhibition on *B. cinerea* is shown in Figure 1 (A). At the low dose (0.2 mL), no inhibition of mycelial growth was observed. At the medium dose (0.5 mL), mycelial growth decreased (70.3 mm), resulting in an 18.88% inhibition. This suggests that the dose partially inhibited growth but did not provide complete control. At higher doses (0.65 mL and 0.7 mL), mycelial growth was completely

halted, with a 100% inhibition observed. Overall, the 0.65 mL concentration was considered the effective minimum inhibitory concentration (MIC) for complete inhibition of growth.

The effect of different doses of WV on the mycelial growth (mm) and percentage inhibition of *S. sclerotiorum* is shown in Figure 1 (B). The 0.2 mL low dose exhibited an inhibition close to that of the control group (16.66%), while the 0.35 mL, 0.5 mL, and 0.7 mL concentrations were identified as effective doses, resulting in complete inhibition of mycelial growth. Additionally, 0.35 mL was determined to be the minimum inhibitory concentration (MIC).

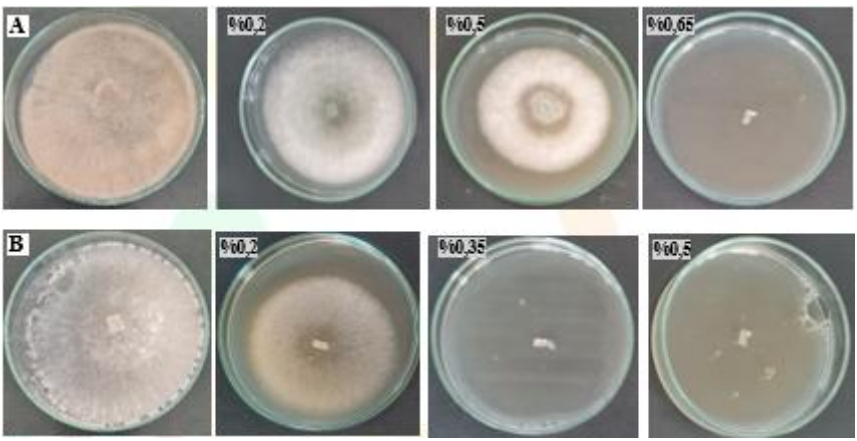

Figure 2. *Inhibitory effect of different doses (mL) of poplar wood vinegar on the mycelial growth of B. cinerea (A) and S. sclerotiorum (B) (Control).*

In Figure 2, the inhibition percentages for different application doses are shown, with a significant increase in inhibition rates as the dose increases.

DISCUSSION

Wood vinegar, a natural product, is not only easily degradable but also contains antimicrobial acids and phenolic compounds (Oramahi et al., 2018). In the composition of PWV, 54 organic compounds have been identified, with phenols and their derivatives accounting for 43.19%, organic acids for 26.97%, ketones for 10.53%, and esters for 3.85% (Zhu et al., 2021). Numerous studies have demonstrated that these compounds in WV exhibit antifungal activity. Research has shown that organic acids and phenolic compounds cause damage to pathogen cell membranes, leading to lipid dissolution and the natural degradation of proteins (Bridgewater, 2004; Hwang et al., 2005; Nurhayati et al., 2005; Jung, 2007; Chukeatirote and Jenjai, 2018; Liu et al., 2020; Faisal et al., 2022). The use of WV, either alone or in combination with pesticides, has proven highly effective in disease control and is widely utilized (Jaiswal et al., 2019; Desvita et al., 2022).

Wood vinegar exhibits a broad antifungal effect and can effectively inhibit fungal species such as *Pythium*, *Penicillium*, *Rhizobium*, *Sclerotinia*, and *Fusarium* (Zhu et al., 2021). Studies have shown that WV inhibits fungal growth by slowing down cell division, with phenolic compounds playing a critical role in this effect. Moreover, the inhibitory activity increases as the concentration of WV rises (Wei et al., 2008; Qin et al., 2010; Zhang et al., 2016; Gao et al., 2020). In a study examining the effects of various wood vinegar concentrations on *Alternaria panax* and *Botrytis cinerea*, it was found that doses of 3.0% or higher completely (100%) stopped the growth of *A. panax*, while a 2.25% dose reduced mycelial growth by 70.68%. For *B. cinerea*, when the

concentration of WV reached 2.25% or higher, mycelial growth was completely (100%) inhibited (Li et al., 2014). Hagner et al. (2010) reported that WV significantly inhibited soil-borne diseases such as *Rhizoctonia*, *Sclerotinia*, and *Fusarium.*

In our study, compared to the control, poplar wood vinegar at a dose of 0.65 mL completely (100%) inhibited *B. cinerea*, while a lower dose of 0.35 mL completely stopped (100%) mycelial growth of *S. sclerotiorum* (Figure 3). A separate study with PWV also confirmed its ability to reduce disease incidence caused by *Sclerotinia sclerotiorum* and *Peronospora parasitica* in canola seeds (Zhu et al., 2021).

The results of this study demonstrate that PWV has significant potential as a natural antifungal agent for sustainable agriculture. Further in vitro and field trials are needed to determine the full effectiveness of poplar WV in controlling plant diseases. Additionally, the use of wood vinegar offers an economic and environmentally friendly method for converting agricultural waste into valuable products, benefiting the pyrolysis industry as well.

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CHAPTER VII

Cnidaria Filumu Özellikleri ve Karadeniz'deki Medüz Üyeleri

Zekiye BİRİNCİ ÖZDEMİR[1]

Giriş

Küresel ısınma, antropojenik etkiler ve birçok doğa olayı okyanus ve denizel ekosistemlerde değişimleri beraberinde getirmektedir. Son 50 yıllık periyodda Avrupa deniz ekosistemlerinde farklılıklar görülmüştür (Beore ve Miils, 1999, Fountes ve ark., 2011) Özellikle pelajik ekosistemlerde jelimsi organizmaların arttığı hatta baskın grup haline geldikleri tespit edilmiştir. Azak denizi, Hazar denizi,

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Baltık denizi gibi birçok denizde jelimsi makrozooplankton gruplarının artması o ekosistemdeki zooplankton miktarının azalması, bazı balık türlerinde azalma ve de ekosistemdeki diğer türlerin etkilenmesi sorunlarını beraberinde getirmiştir (Beore ve Mills, 1999, Mutlu, 2001, Bat ve ark., 2007). Ülkemizi çevreleyen ve ülke ekonomisinde katkısı yüksek olan Karadeniz ekosistemi için de aynı senaryo kendini göstermiştir. 1960'lı yıllardan itibaren Avrupa'da hızlanan sanayileşme sonucu yükselen miktarda atıkların, Karadeniz'e boşalan akarsuların kirlilik yükünü taşıması, ticari avcılık yapan teknelerin teknolojik gelişimi ve avlama kapasitelerinin artması gibi faktörlerin yanında son olarak iklimsel değişimler Karadeniz ekosisteminin doğal dengesini bozmuştur. Dengesi bozulan ekosistemde jelimsi organizmalar baskın duruma gelmiştir (Bat ve ark., 2007; Gücü, 2002, Özdemir ve ark., 2014, Birinci Özdemir ve ark., 2019). Karadeniz ülkemiz denizlerinde ticari balıkçılık açısından yeri önemli bir denizimizdir. Önceki yıllarda yaşanılan olumsuzluklarla birlikte, sonrasında Karadeniz'de jelimsi makrozooplankton miktarının artışı ile balıkçılık miktarı oldukça fazla düşmüştür. Denizel ekosistemlerde bu derece etkili jelimsi makrozooplankton türleri ile ilgili bilimsel araştırmalar artmıştır. Tüm ekosistemi etkileyebilen ve ciddi sonuçlara neden olabilen jelimsi makrozooplankton grupları Karadeniz'de Cnidaria ve Ctenophora filumları ile temsil edilmektedir. Bu çalışmada Cnidaria filumu özelliklerı ve Karadeniz'deki türleri hakkında detaylı bilgi verilmiştir.

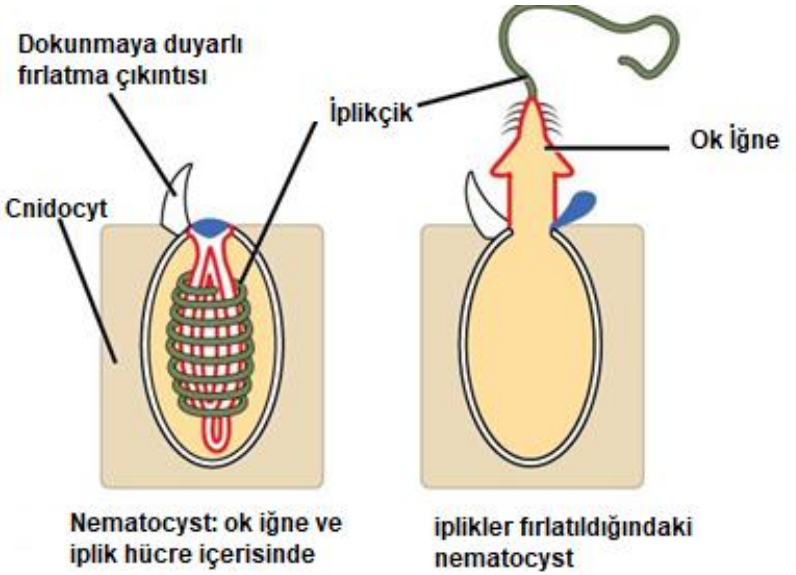
1. Filum: Cnidaria

Cnidaria (Coelenterata), bu filumun tüm üyelerinde bulunan, cnidocyte veya nematocyst olarak bilinen yakıcı hücrelerin varlığından adını alır. Genellikle iki yetişkin formu vardır, Polipoid (veya hidroid) formu, tübüler olup genellikle bir substrata sabitlenerek yaşamını sürdürür (sesil). Meduzoid formlar, çoğu

durumda serbestçe yüzme yeteneğine sahip, düz veya şemsiye şeklindedirler.

Cnidaria filumu denizşakayıkları, mercanlar, denizanası, tatlı su hidrası ve fizalya gibi 10.000'i aşkın tür içerir. Serbest ya da sesil olarak bulunan basit radial simetrili metazoa grubudur. Endoderm ve ekdodermden oluşan iki tabaka ve arasına yerleşmiş jelatimsi tabakaya (mesoglea) sahiptir. Bütün coelentaratlar (knidliler) radial ve biradial simetrili olmalarına rağmen bir tek gastrovosküler adı verilen boşluğa sahiptir. Ağız ve anüs görevi gören tek bir açıklığa sahiplerdir. Genelde sinir sistemi çok ilkel olup sadece sinir hücreleri ağı vardır. Hayat evreleri nesil değişmesi olan metageneze sahiptir. Mesoglea cansız olmasına rağmen, embriyonik ekdodermden türemiş canlı hücreleri kapsar. Bütün knidlilerin ağız çevresinde tentakülleri vardır ve tek açıklıkları mide sistemidir (gastrosöl).

Cnidaria üyelerinin en önemli özelliği knid adı verilen ve yakıcı madde içeren hücrelerin bulunmasıdır. Knid içeren bu hücrelere knidoblast adı verilir (Zhong, 1988). Bütün knidliler interstitial hücrelerce oluşturulan nematositlerle donatılmıştır. Nematosit, bu filumun üyelerinde tektir ve hücre içindeki diğer küçük organellerden oluşur. Nematosit kapsül, kapak ve ipten oluşmuştur. Nematosit uyarıcı bir etki aldığında kapak açılarak ipler fırlatılarak hemen boşaltılır. Boşaltılmamış nematosit kapsülleri spiral, oval, armut şeklinde vb. olmaktadır (Şekil 1) (Pechenic, 1995).



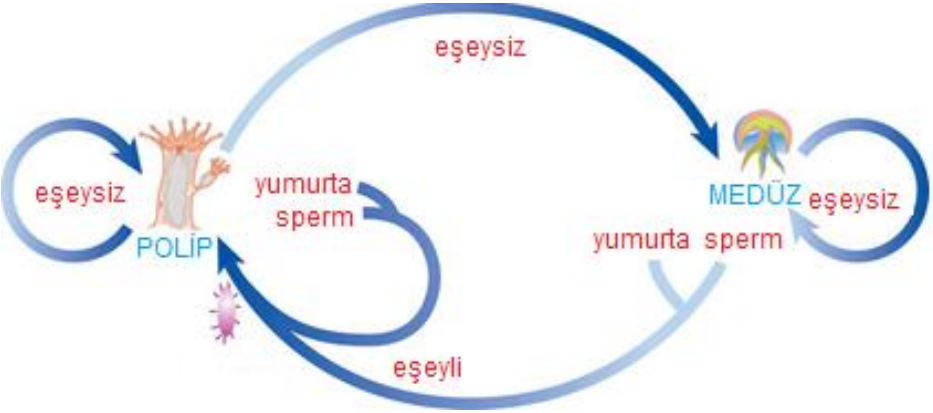
Şekil 1. Cnidaria üyelerinde nematosit yapısı (Anonim, 2004a'dan uyarlanmıştır)

Nematositler küçük objelerin etrafını sarmak, yüzeylere yapışmak, yüzeyi delmek ya da zararlı protein toksinlerini salgılamak için özelleşmiş olabilir. Nematositlerin görevi besin toplama, kısmen savunma ve harekettir. Bütün türler özellikle beslenme tentakülleri bakımından zengindir. Nematositlerin fonksiyonel önemi onların bireysel büyüklüğünden ziyade vücut yüzeyindeki her mm^2 de büyük miktarlarda bulunmasındadır (Zhong, 1988; Pechenic, 1995).

Cnidaria Filumu Üreme ve Larval Aşamaları

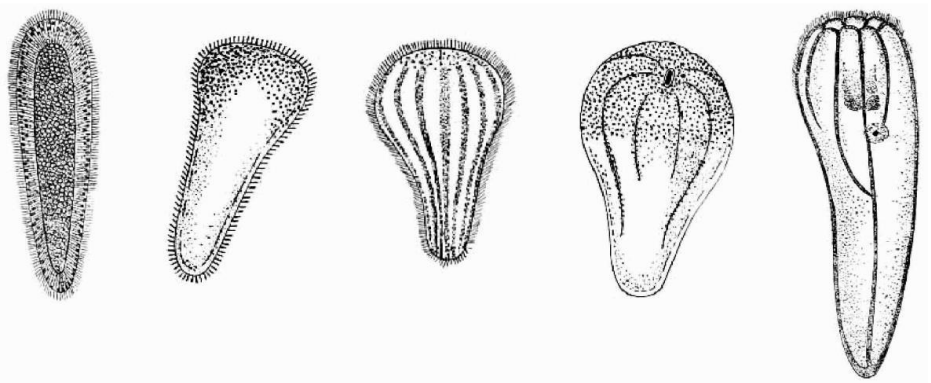
Bazı cnidaria üyelerinin, yaşam döngülerinde sadece bir form olarak bulunurken, diğerleri her iki formu da gösterebilirler. Çoğu, eşeyli ve eşeysiz aşamalar arasında geçiş yapar ve üreme

stratejilerinde birçok varyasyon mevcuttur. Ancak cnidariaların tipik erken larval aşaması planula larvasıdır. Üreme, olgunlaşan gametlerin gastrik cepler içine dökülmesi ile olur ve buradan ağız yoluyla dışarı atılırlar. Yumurtaların çatlaması gastrik ceplerde başlar. Embriyolar ağızdan serbest bırakılır ve oral kollarda kuluçka işlemi gerçekleşir. Burada gelişimini tamamlayan larva (planula) ergin bireyden ayrılır. Planula larvası kısa bir süre serbest yüzdükten sonra kendisini sert bir zemine tespit eder. Bazen de larvalar dışarı bırakılmayıp daha ileri bir aşamaya kadar organizmanın içinde gelişebilir (Convey, 2012).



Şekil 2. Cnidaria filmu yaşam döngüsü (Anonim, 2024b'den uyarlanmıştır)

Planulalar, siller (silia) ile kaplıdır ve uçta bir terminal silli yumağa sahip olabilirler. Vücudu tüp şeklindedir, ağız ve anüs işini gören tek bir açıklık vardır. Düz, küresel, silindirik veya armut şeklindedirler ve hepsinin merkezi bir boşluğu yoktur. Planktonla beslenen planulalar (planktotrophic), ağız geliştirebilir ve zemine yerleşimden önce yumurtadan beslenenlere (lecithotrophic) göre planktonda daha uzun süre kalırlar. Anthozoa, en büyük planulalara sahip grup olup çoğunlukla planktotrofiktir (Convey, 2012).



Şekil 3. Planula çeşitleri (Hyman, 1940)

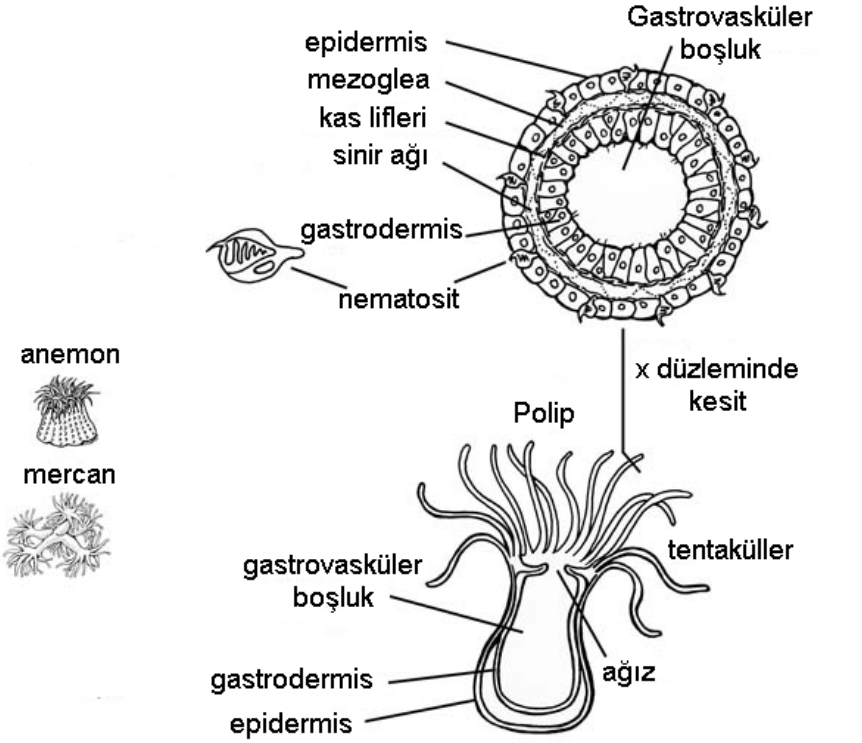
Medüz formu serbest olarak denizlerin pelajik bölgelerinde yaşamlarını sürdürürler. Vücut genellikle şemsiye şeklinde, şeffaf, jelimsi ve peltemsi bir yapıdadır. Medüzlere jelimsi vücut yapısını veren mesoglea tabakasıdır. Medüz formları savunma ve beslenme için avlanma sırasında kullanılan tentaküllere sahiptir. Medüz formlarının *Craspedacusta* türleri dışındaki tüm türleri denizeldir. Pelajik yaşam sürdürerek serbest yüzerler. Vücutlarının %95-%97'si sudan oluşmaktadır. Medüzler çok sayıda türe sahip olmakla birlikte, dünya okyanuslarında ve denizlerinde geniş yayılım göstermektedirler (Bat, & ark., 2008; Convey, 2012).

Cnidaria filumu Anthozoa, Scyphozoa ve Hydrozoa olmak üzere 3 sınıfda incelenir:

1.1. Sınıf :Anthozoa

Anthozoa, "çiçek hayvanları" anlamına gelir ve bu gruba mercanlar, deniz gülleri, deniz anemonları gibi gruplar dahildir. Anthozoa, 10 takım ve binlerce türden oluşmaktadır. Anthozoanlar, vücutlarının dış kısmında yumuşak vücut dokularını destekleyip korumak için ölü bir madde salgılayabilir. Renkler kırmızı, pembe ve mor ile sarı, mavi ve turuncu arasında değişebilir. Bazıları sadece

birkaç inç boyunda iken, diğerleri birkaç feet yüksekliğe kadar büyüyebilir (Anonim, 2024d).



Şekil 4. Anthazoa sınıfı üyelerinin genel görünümü (Anonim, 2024c'den uyarlanmıştır).

Yetişkin anthozoalar, polipoid bir şekle sahiptir ve medüz formları yoktur. Anthozoan planulaları bir süre planktonda kalabilir ve tentaküller gelişmeden önce planula olarak zemine yerleşebilir ya da planktonda iken tentakül tomurcukları gelişebilir. Ardından tentaküller oluşarak, küçük bir deniz anemonuna benzeyen bir yapıya bürünebilirler. Tentaküllerin birleştiği boşlukta ağız bulunur.

Vazo şeklini andıran alt vücut yapısı gostrodermis, epidermis ve gastrovasküler boşluktan oluşmuştur (Şekil 4).

Tentakülleri olan pelajik deniz anemon larvaları, tentaküllerin sayısı ve sıraları, gastro-vasküler boşluğu ayıran bölümlerin sayısı gibi özelliklere bağlı olarak sınıflandırılırlar.

1.2. Sınıf : Scyphozoa

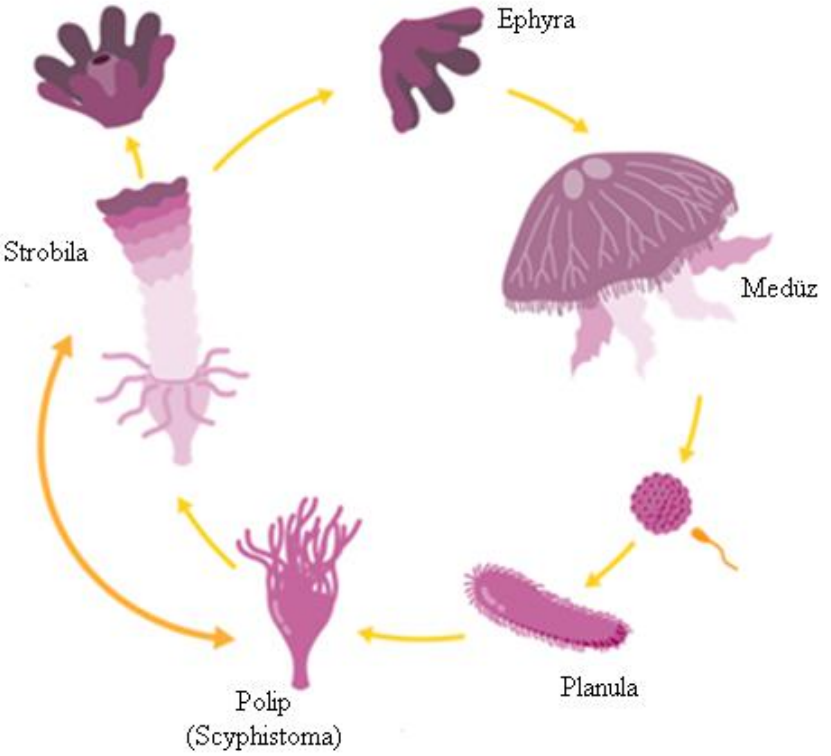
Scyphozoalar, genellikle "denizanası" kelimesiyle eşleştirilen organizmalardır. Tüm grup üyeleri denizlerde yaşayan, sapsız şemsiye şeklinde canlılardır. Birçoğu saydam, mavi, pembe renktedir. Hem polip hem medüz formu bulunur. Erginleri ise medüz halinde olup su yüzeyine yakın ve serbest halde yüzerler. Hayat devrelerinde medüz formu dominanttır (Convey, 2012).

Yetişkin scyphozoalar, genellikle yaz aylarında yaygın olarak bulunurlar ve üreme sonrası sonbahar sonunda kaybolmaya eğilimlidirler. Bu dönemde ölü bireylerin çoğu kıyıya vurmakta veya deniz tabanına (bentik) bölgeye inmektedir. Ancak bazıları, kış boyunca derin sularda veya korunaklı alanlarda hayatta kalabilmektedir.

Scyphozoa Ephyra Gelişimi ve Morfolojisi

Çoğu scyphozoa medüzü, tipik Cnidaria planula larvalarına dönüşen gametler üretir (Şekil 5.). Planulalar, kayalık gibi uygun bir substrata tutunarak, deniz anemonuna benzeyen scyphistoma adı verilen bir polip aşamasına dönüşür. Scyphistoma, yeni polipoid bireyler oluşturarak sayısını artırabilir. Sonrasında strobilasyon (bölünme) adı verilen bir tomurcuklanma süreci oluşur. Bu oluşum üst üste, kat kat açılan bir çiçek görünümündedir. Strabilasyon sonucu gelişen ephyra (genç medüz) strobiladan ayrılarak yüzmeye başlar. Serbest kalan ephyra birkaç taneden birçok sayıya kadar

üretilip serbest bırakılabilir (Şekil 5). Besin bulunabilirliği ve sıcaklık, strobilasyonu düzenleyen ana faktörler olarak görünmektedir. Bu grupta yetişkin medüzler tarafından üretilen gametlerden doğrudan bir gelişim göstererek, planula aşamasından ephyra'ya ve ardından kademeli olarak bir yetişkin medüze dönüşür. Bu nedenle yaşam döngüsü tamamen pelajiktir (Convey, 2012).



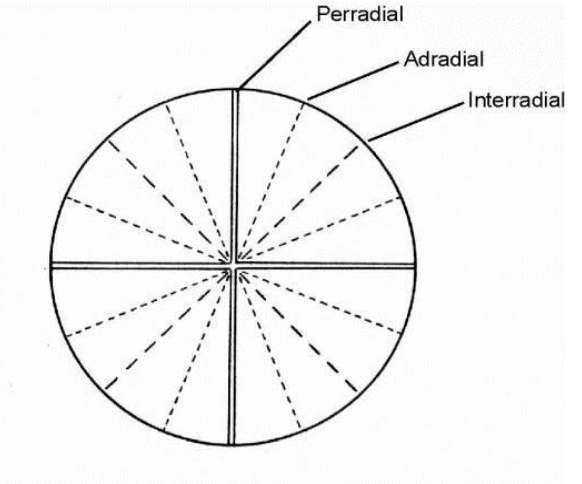
Şekil 5. Scyphozoa Ephyra Gelişimi (Anonim, 2024e'den uyarlanmıştır)

Bir yıldan daha az sürede olgunluğa erişir. Gonadlar dışında erginin özelliklerinin çoğu var olup dikkatli bakıldığında görülebilir.

Genç bireyde ağız sapı, ağız, gastrik filamentler ve duyu organı bulunur. Gelişmiş solenteron dış hattı, mide ve üç tip radial kanal görülebilmektedir

Ephyra ve juvenil bireylerin sayıları genellikle Mart-Nisan ve Eylül-Ekim aylarında zirve yapar (Bat & ark., 2008, Birinci Özdemir, 2011). Tipik olarak, merkezi bir disk bulunan, düz ve ince yapılıdırlar ve bu diskin içinde mide boşluğu yer alır. Ephyra başlangıcında sekiz radyal lob bulunur ve her lobda çiftler halinde terminal lapetler vardır. Mide boşluğu, ephyra'nın uçlarına, merkezden dışa doğru yayılan gastro-vasküler kanallar aracılığıyla bağlanır, bu kanallar lobların içinde ve ayrıca loblar arasındaki girintilerin tabanına da uzanır. Loblara uzanan kanallar, uç kısımlarındaki girintilere marjinal duyusal organlar olan rhopalia bulunduğundan, rhopalial kanallar olarak adlandırılır (Convey, 2012). Ephyra'ya ait daha detaylı bilgi *Aurelia aurita* ve *Rhizostoma pulmo* türlerinin açıklanmasında detaylandırılacaktır.

Rhopalia, bir kanalın küçük bir kanalının bağlandığı, boş içi olan, çomak şeklinde yapılardır. İçlerinde, sinir dokusu ve bazen de ocelli (basit göz-sensör) olarak adlandırılan katı bir terminal statosist taşırlar. Statositler yönelim ve ışığa duyarlı denge organı olarak görev yapmaktadır. Tanımlayıcı amaçlarla, rhopalial kanallar, yönelim eksenlerine bağlı olarak interradial veya perradial olarak adlandırılır (Şekil 6).



Şekil 6. Radial kanal alt isimlerndirmlerinin gösterimi (Russell, 1953).

Loblar arasındaki sekiz daha kısa kanal rhopalia içermez ve bunlar adradial veya tentacular kanallar olarak adlandırılır, bu bölgelerde ileriki aşamada marginal tentaküller gelişmektedir. Sekiz tentakül her zaman aynı anda ortaya çıkmaz. Tentaküller şemsiyenin hemen kenarından veya şemsiye altından çıkar ve tentakül kanalları genişleyerek mide keselerini oluşturur. Bu durum türlere göre farklılık göstermektedir, örneğin *Rhizostoma pulmo* türünde tentakül gelişmez, yetişkin *Chrysaora hysoscella* 24 tentaküle sahipken, *Aurelia aurita* tamamen farklı bir tentakül düzenlemesine sahiptir. İleri aşamalarda, gastro-vasküler kanal sistemi oldukça karmaşık hale gelmekte ve bir ağ şeklini almaktadır (Convey, 2012).

Merkezi mide, manubriumun ortasında bulunan ağız yoluyla dışarıya açılır. Mide içinde dört interradial grup halinde düzenlenmiş gastrik filamentler adı verilen küçük dokunaçlar görülmektedir. Bu filamentler, mide içindeki besinlerin sindirilmesinde görev yapmaktadır. Başlangıçta bazı türlerde eksik olabilir, ephyra

büyüdükçe sayıları artar. Şemsiye dış yüzeyi (exumbrella) düz olabilir, ancak bazı ephyra'lar, nematosit içeren kabarık noktacıklar geliştirir (Nelson, 2020).

Karadeniz'de Cnidaria filumu üyelerinden *Rhizostoma pulmo, Aurelia aurita*, (Zhong, 1988) yaygın olarak görülmektedir. *Chrysaora hysosella* (Öztürk ve Topaloğlu, 2009) 2007 yılından sonra Batı Karadeniz'de tespit edilmiş ancak sonrasında geniş yayılım göstermemiştir. Bu nedenle bu çalışma içerisinde *A. aurita* ve *R. pulmo* türleri ayrıntılı olarak açıklanmıştır.

***Aurelia aurita* (Linnaeus, 1758)**

Aurelia aurita sistematiği aşağıdaki gibidir.

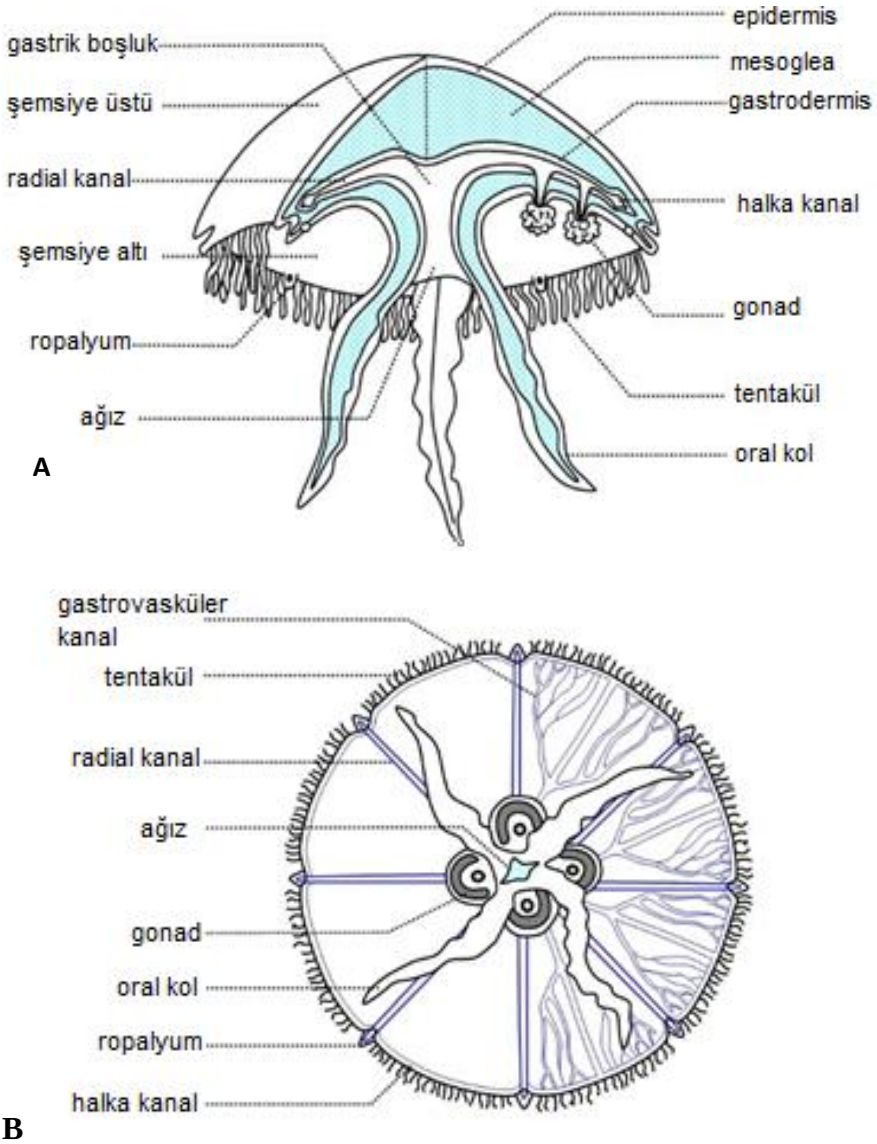
Filum	: Cnidaria
Sınıf	: Scyphozoa
Takım	: Semaeostomeae
Aile	: Ulmaridae
Cins	: Aurelia
Tür	**:** *Aurelia aurita* (Linne, 1758)

Cnidaria filumu üyesi *A. aurita* tür dünya denizlerinde dağılım göstermekte ve kıyısal sularda daha yaygın olarak görülmektedir (Zhong, 1998; Bat & ark., 2008; Mutlu, 2001). Genellikle sıcak tropikal kıyısal sularda ve ılıman sularda yaşamlarını devam ettirirler. Geniş sıcaklık töleransı bulunan bu organizmalar 6 - 31°C değişen sularda yaşamlarını sürdürebilirler (Bat & ark., 2008). *A. aurita* populasyonu polip tipleri için uygun substrata sahip kıyısal sular ve haliçlerde, medüz formları ise küçük, sığ, kapalı veya yarı kapalı sistemlerde daha fazla bulunmaktadır (Lucas, 1996; Mutlu, 2001, Bat & ark., 2009, Birinci Özdemir & ark., 2019). Bu organizma türünde medüz formu baskın olarak

görülür. Vücudu şemsiye şeklinde ve peltemsi bir yapıdadır. Medüzlere jelimsi vücut yapısını veren mesoglea bu grupda incedir. Savunma ve beslenme için kullanılan tentaküllere sahiptir (Convey, 2012).

Genellikle denizlerin yüzey sularında bulunan ve oldukça saydam görünüşü olan bir organizmadır (Şekil 7A,B). Hareketi sırasında genişleyip, küçülebilen dış yüzeye exumbrella (şemsiye üstü), aynı şekilde açılıp kapanma özelliği olan iç yüzeye de subumbrella (şemsiye altı) denir. Yetişkin bir birey sekiz basit marjinal lob, sekiz duyusal organ ve dört uzun oral kola sahiptir (Şekil 7A). Lobların kenarlarında yakıcı hücreler içeren çok sayıda ince ve küçük tentaküller (siller) vardır (Şekil 7A,B) (Pechenic, 1995).

Alt şemsiyenin merkezinde kısa bir manubrium (ağız sapı) uzanır, oral yüzeyin merkezine bağlanmıştır. Ağız sapının ortasından 4 ağız kolu ve kare şeklinde bir ağız açıklığı vardır. Kollar serbest olarak su içinde uzanır. Kollar üzerindeki yakıcı hücreler sudaki küçük canlılara (plankton) çarparak sersemletir-felce uğratıp vücuda alınmasını sağlar. Ağız midenin merkezine açılır. Ağız çevresinde at nalına benzer 4 gastrik cep (sindirim ve beslenmede kullanılan organ) bulunur (Şekil 7B). Her bir oral (ağız) kol, yüzeyi iki dalgalı şeride benzer uzunlamasına silli solungaç oyukları meydana getirir. Dört oral kolun oyukları ağızda birleşir, oyukların merkezleri küçük dallı tentaküllere ayrılırlar. Tentaküller besinin yakalanmasında görev yapar ve ağıza götürülmesinde yardımcıdır. Ağız kolları merkezden etrafa doğru ağ şeklinde yayılım gösterir (Şekil 7B.) (Convey, 2012, Anonim, 2024f).



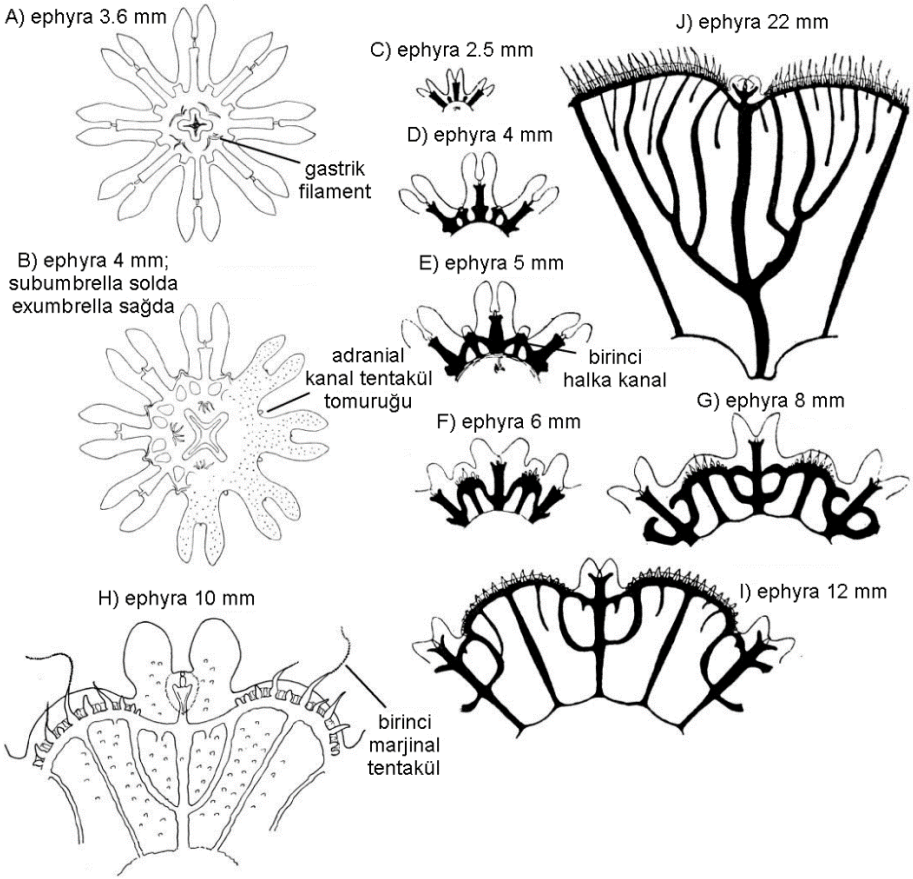
Şekil 7. A. aurita şematik görünümü A: yandan görünümü B: alttan (Anonim, 2024f'den uyarlanmıştır).

Türün abarol yüzeyindeki mukus salgısı besinlerin vücut üzerine yapışmasını sağlar. Besinlerin ağza transferi mukusun epidermal sillerden çanın merkezine hareket ettirilmesi ve de dallanmış oyuklardaki sillerin hareketi ile gerçekleştirir. (Bat & ark., 2008, Riisgard, 2022).

Aurelia aurita Ephyra Gelişimi

Aurelia aurita türünde ephyra'lar, yaklaşık 1.5-4.5 mm çapında serbest bırakılır. Bu büyüklükte marjinal lapetlerin uçları oldukça ince ve sivridir. Gastrik filament sıfır ile iki arasında bulunur. Başlangıçta, perradial ve interradial rhopalial kanalların uçları kare şeklindedir. Bazen hafifçe loblu olup, adradial kanallar sadece kare uçlu kısa tomurcuklar halindedir. Halka ve radyal kaslar belirgin durumdadır (Şekil 8A, E) (Convey, 2012, Anonim, 2024f).

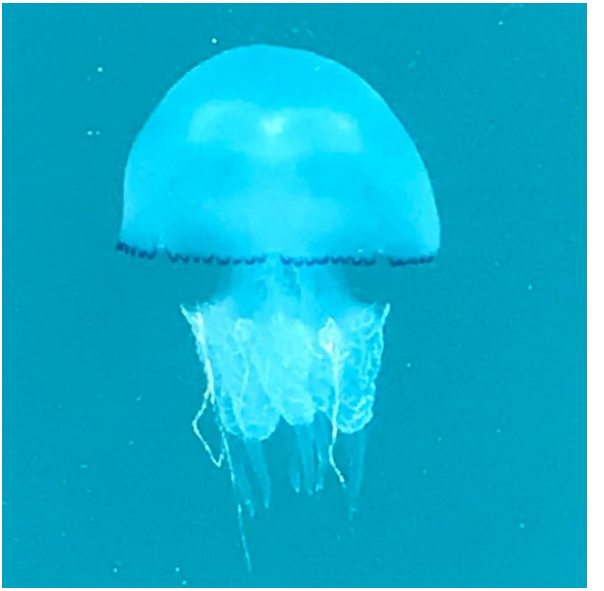
Ephyra boyutu 2.0-2.5 mm olduğunda marjinal tentaküller veya tentakül tomurcukları yoktur. Her bölümde *üç* gastrik filament ve marginal lapet benzeri yapılar görülmeye başlar. Ephyra ~4.0 mm boyutlarına ulaştığında, perradial ve interradial kanalların tabanlarında ve adradial kanalların yanlarında çıkıntılar gelişir (Şekil 8B, D). Bu aşamada her grup için yaklaşık altı ila sekiz gastrik filament bulunur. Ephyra 5-6 mm çapında olduğunda, her adradial kanaldan yanlara doğru kanallar gelişir ve düz rhopalial *k*anallarla birleşerek birincil halka kanalını oluşturur (Şekil 8E-F). Bu, yetişkin *Aurelia*'da bulunan oldukça karmaşık dallanmış gastro-vasküler sistemin ilk görünüşüdür. Küçük tentaküller, oral dudakların kenarlarında görünür. Her lob arasında marginal tentaküllerin sayısı artar ve ~8 mm boyutuna ulaşıldığında, her birincil marginal tentakülün iki yanında beş ila altı tentaküle ulaşır (Şekil 8G, H), bu da bir grupta 10-12 tentakül yapar. Boyut arttıkça ephyra ergin medüze dönüşür, kanal sistemi giderek daha karmaşık hale gelir (Şekil 8I, J).



Şekil 8. Aurelia aurita ephyra gelişimi (Convey 2012'den uyarlanmıştır)

Rhizostoma pulmo **(Macri, 1778)**

Rhizostoma pulmo tropikal ve ılıman denizlerde yaşam süren scyphzoan grubu üyesidir. Kubbe şeklinde bir şemsiyesi olup, çapı 50-60 cm'ye kadar ulaşabilir Şeklinden dolayı varil deniz anası, deniz ciğeri gibi isimler ile anılır (Şekil 9).



Şekil 9 Rhizostoma pulmo (orijinal fotoğraf)

Rhizostoma pulmo sistematiği aşağıdaki gibidir.

Filum	: Cnidaria
Sınıf	: Scyphozoa
Takım	: Rhizostomae
Aile	: Rhizostomatidae
Cins	: Rhizostoma
Tür	: *Rhizostoma pulmo* (Macri, 1778)

Ergin bireylerin marginal tentakülleri yoktur. Tuzluluk ve sıcaklık koşullarındaki değişimlere yüksek tolerans gösterir ve besin bakımından zengin alanlarda yaygın olarak bulunur. Akdeniz havzasında, Marmara Denizi ve Karadeniz'de yaygın olarak bulunan bir türdür (Mutlu,2001, Fountes & ark., 2011).

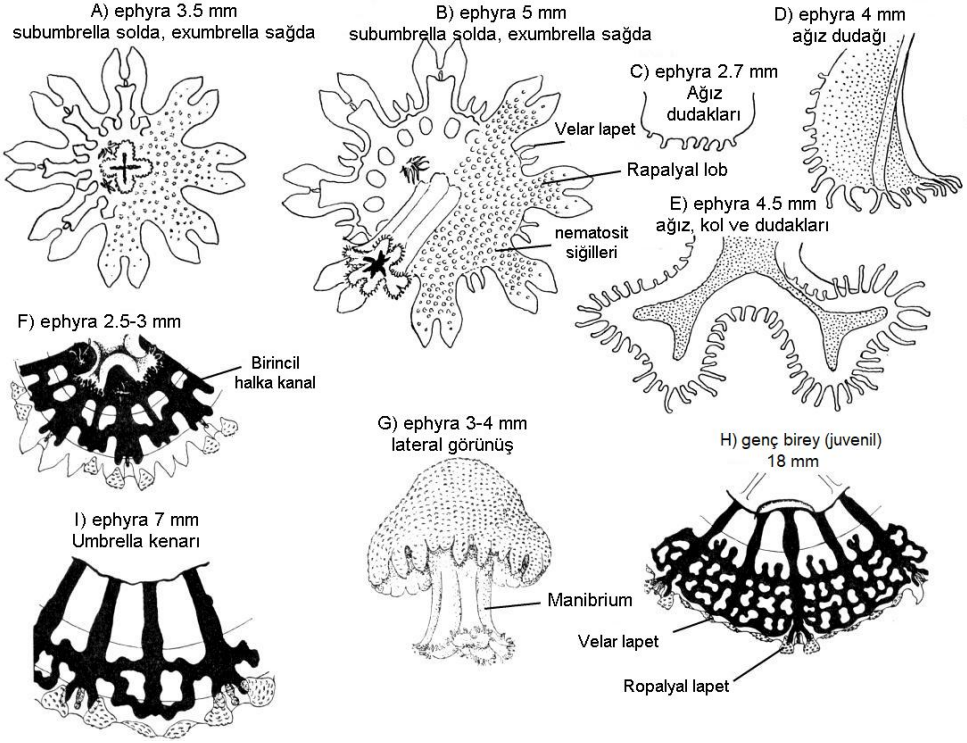
Ergin bir Rhizostoma medüzünün, merkezinde manibrium ve bu kısımdan uzanan 8 adradial dallı oral kol bulunur. Kollar üzerinde çok sayıda ağız mevcuttur (Fountes & ark., 2011). Ağıza ait tentaküllerı birleştiğinden ağız dar ve dışarıya pek çok kanalla açıktır. Bundan dolayı bu medüz büyük avları yutamaz, fakat mide dışındaki dudak tentaküllerı arasında besini sindirerek absorbe eder (Convey, 2012). Genellikle mavi renkli olan şemsiyenin kenarında menekşe renginde çok sayıda küçük lopçuklar yer alır (Demirsoy, 1982).

Şemsiye çevresizindeki her boğumda, rhopalial lapetlerle ayrılmış on marginal lapet bulunur, bu lapetler velar lapet olarak adlandırılır. *Rhizostoma pulmo*'nun toplam 80 lapeti vardır. Bu türde mezogloea serttir. Şemsiye dışında organizmaya granüler bir doku veren yakıcı yapıda küçük noktacıklar taşır. Her biri turuncu renkli statolith taşıyan ancak ocelli içermeyen 8 rhopalia'ya sahiptir. Rhopalium'un üstünde üçgen silli exumbrella duyusal çukuru ve alt yüzeyinde subumbrella silli duyusal çukuru mevcuttur ((Fountes & ark., 2011, Convey, 2012).

Rhizostoma pulmo Ephyra Gelişimi

Bu türde yeni serbest bırakılan ephyra'lar, ~2.7-6.0 mm çapındadır. Ephyra 2.7 mm boyutlarında iken, oral dudakların kenarlarında küçük tentaküller görünmeye başlar (Convey, 2012) (Şekil 10C). Dallanmış marginal lapetler dıştan daha yuvarlak, içten ise daha keskin şekillidir (Şekil 10A, B), ancak şekil değişkendir. Her bölmede iki-üç gastrik filament ve oldukça uzun bir manubrium vardır (Şekil 10G). Rhopalial kanallar, uçları yuvarlak, hafifçe çatallanmış bir yapıdadır. Adradrial kanallar *A. aurita* ephyra'sına benzer olarak kısa, uçları kör ve sivrilmiş şekildedir. Birincil halka kanal, ephyra yaklaşık 3 mm'ye ulaştığında adradial kanalların rhopalial kanallarla birleşmesiyle oluşur (Şekil 10F). 5 mm boyutlarındaki bir bireyde, birincil halka kanalı tamamen oluşmuş,

manubrium oldukça uzun ve bölünmüştür. Her bölmede 11-12 gastrik filament bulunmaktadır (Şekil 10B). Rhopalial loblar arasındaki yarıkta şemsiye kenarında ilk velar lappet çifti oluşmuş ve eksumbrella nematosit siğilleriyle kaplanmıştır. 7 mm boyutlarındaki bir bireyde (Şekil 10I), marginal velar lapetler açıkça ayrılmış ve ilk marginal halka kanalları gelişme gösterir. Ephyra yaklaşık 18 mm boyutlarına geldiğinde (Şekil 10H), halka kanalın her çeyrek dairesinde dört yuvarlak velar lapet oluşur. Marjinal kanal hiç gelişmez ve kanal ağı oldukça karmaşık yapıdadır (Convey, 2012).



Şekil 10. Rhizostoma pulmo ephyra gelişimi (Convey 2012'den uyarlanmıştır.

1.3.Sınıf Hydrozoa

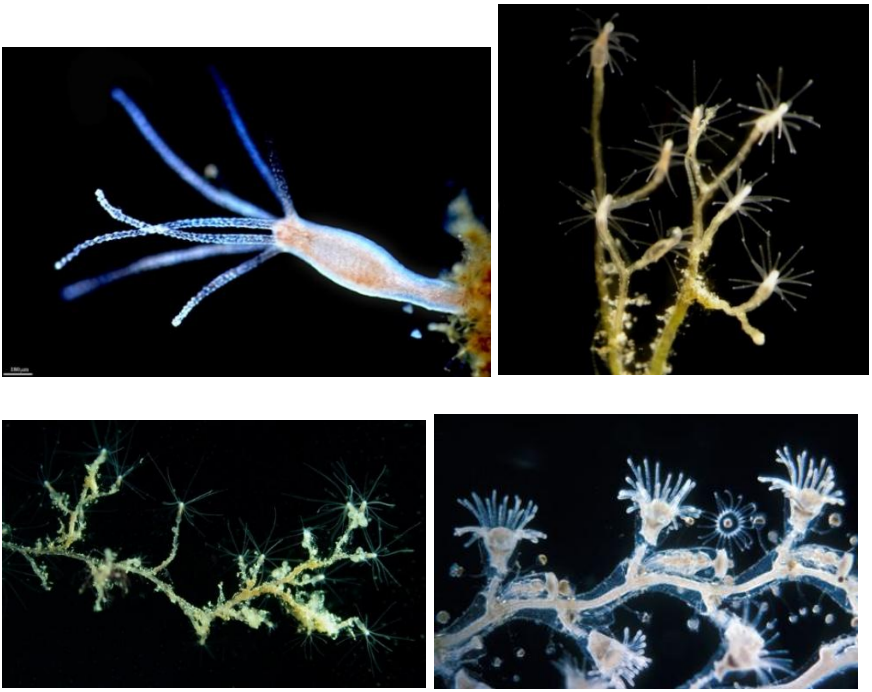
Hydrozoa, tüm dünya okyanusları ve denizleri boyunca hem bentos hem de planktonda yaygın olarak bulunur. Neritik yaşam sürdüren bu grubun bilinen yaklaşık on bin canlı türü vardır. Temel yaşam döngüleri, tomurcuklanarak büyüyen ve bazı durumlarda tomurcuklanmayla ilgili bir süreçle bireysel planktonik medüzler üreten bentik modüler polip kolonilerinden oluşur (Boero & Mills, 1999).

Hydrozoa Gelişimi ve Morfolojisi

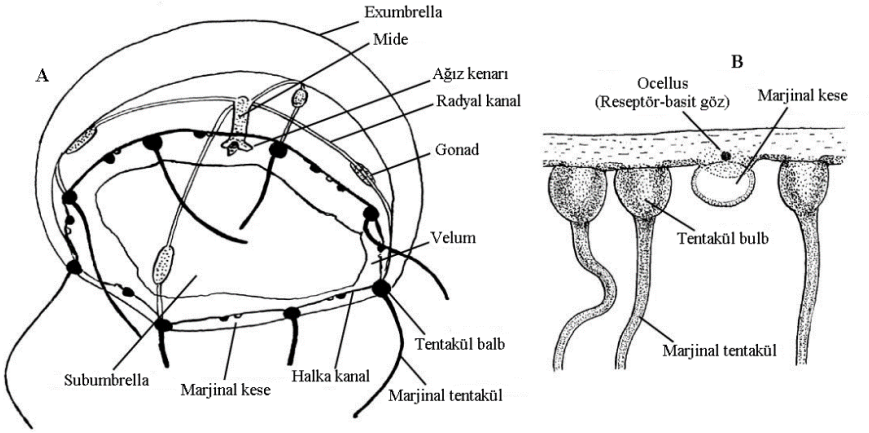
Hydrozoa **(**Siphonophorae grubu hariç**)** türleri ya tekil (yalnız) olup ya da koloniler oluşturur ve yaşam döngüleri yalnızca polipoid, yalnızca medusoid ya da her iki evreyi de içerebilir. Tipik olarak, medusoid evreler, kayalara, kabuklara, deniz yosunlarına vb. bağlı olan poliplerden (Şekil 11) aseksüel olarak tomurcuklanarak meydana gelir. Serbest yüzebilen medusoid evreler genellikle ayrı cinsiyetlere sahiptir ve olgunlaştıklarında gametlerini denize bırakırlar. Döllenmiş yumurtadan serbest yüzebilen planula larvası gelişir, bu larva yerleşir ve yeni bir polip olarak büyür. Ancak bazı üyeler, dipte sabit olarak yaşayan bir evreye sahip değildir; tamamen planktonik bir yaşam döngüsüne sahiptirler, diğerleri ise medusoid evresine sahip değildir.

Bir hydrozoa medüzün genel yapısı Şekil 12'de verilmiştir. Mide ve gonadlar subumbrella (alt iç) yüzeyinde yer alır. Radyal kanallar, mideden yayılarak, şemsiye kenarını çevreleyen bir halka kanala bağlanır. Şemsiye kenarında ise türüne bağlı olarak değişen sayılarda marginal tentaküller bulunur. Ayrıca, duyusal organlar da mevcut olabilir. Subumbrella boşluğunun açıklığı etrafında, türlere göre genişliği değişen, kaviteyi kısmen kapatan ve yüzme jeti türünü belirleyen, raf benzeri bir velum bulunur. Medüz türleri, şemsiye şekilleri ve jelatin kalınlıklarında çeşitli farklılıklar gösterir;

tamamen düz olanlardan çan şeklinde olanlara kadar değişebilir, bazen apikal çıkıntılar da bulunabilir (Convey, 2012)



Şekil 11. Hydrozoa polip örnekleri A)Hydra vulgaris B)Cordylophora caspia C)Bougainvilla muscus C)Obelia sp. (Anonim, 2024g,h,ı)



Şekil. 11. Hydrozoa medüzünün genel yapısı (Convey, 2012'den uyarlanmıştır).

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