AGRICULTURAL PRIORITIES

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PREFACE

A sustainable agricultural sector is becoming increasingly necessary as a result of climate change. Determining priority research fields is essential for the sustainable development of agriculture because there are still knowledge gaps and a need for technologies that assist farmers in the sustainability transition. Cross-cutting strategic agricultural priorities include combating climate change through climate smart agriculture, forestry, and clean energy, advancing racial justice, equity, opportunity, and rural prosperity, developing more and better market opportunities, and addressing food and nutrition insecurity. On a planet with limited resources and in a climate that is changing, more food needs to be produced sustainably. The 'digitalization of agriculture' may be able to offer fresh answers to these difficult problems as a result of the development of technologies, computing capacity, and analytics. Science has a responsibility to provide evidence for and assist the design and usage of digital technologies in order to achieve these positive results and prevent unforeseen consequences. The question of whether agriculture can enhance human nutrition is controversial. Integrating beneficial plant microbiomes—those that promote plant growth, nutrient usage effectiveness, abiotic stress tolerance, and disease resistance—into agricultural production is one strategy to help achieve these objectives. Understanding and controlling plant-microbiome interactions in the context of contemporary agricultural systems will necessitate a massive effort by academic researchers, industrial researchers, and farmers.

CHAPTER I

FIRST DETECTION OF THE EFFECT OF CLIMATE CHANGE ON NATURAL SPECIES IN RANGELANDS: DETERMINATION OF HABITAT REQUIREMENTS AND PHENOLOGICAL PERIODS OF *AGROPYRON CRISTATUM* (L.) GAERTN. SUBSP. *PECTINATUM* (M. BIEB.) TZVELEV, *ARTEMISIA SCOPARIA* WALDST. & KIT., *BASSIA SCOPARIA* (L.) A.J. SCOTT

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1.INTRODUCTION

Integrating data on natural disasters such as floods and floods with the forest inventory and monitoring system, and creating an early warning system integrated with the land monitoring system for the purpose of determining and monitoring the effects of climate change on biodiversity and ecosystem services are included in national climate change action plans (Bozoglu, 2018).

In the evaluations made by the Gravity Recovery and Climate Experiment Monitoring (GRACE-FO) satellites; Since July 2020, almost all provinces in Turkiye have experienced below-average rainfall almost every month. It was determined that from October to December, rainfall across the country was 48 percent lower than the 1981-2010 average, and as of January 11, 2021, shallow groundwater storage remained below critical values.

When rainfall and groundwater resources were examined between 1948 and 2010, it was observed that the rainfall regime changed (Anonymous, 2021). As a result of all these changes and adaptation processes, biodiversity, which is of great importance for human life, is in danger. A disaster as big as climate change is the destruction of biodiversity. Biodiversity collectively describes the millions of unique living organisms that inhabit the Earth and the interactions between them. Biodiversity, which represents a vital element for the sustainability of life, is constantly under threat. More than 60% of the species and habitats protected under the EU Habitats Directive have been found to have unfavorable conservation status. This has and will have fundamental consequences for our society, our economy and our human health (Garcia-Lozano, 2018, Torca et al., 2019; Delbosc et al., 2021; Anonymous, 2022).

For the continuation of biodiversity; In order to alleviate the negative effects of environment and climate change, increase the economic and ecological returns of rangelands, reduce poverty, provide sustainable pasture use and new opportunities for environmental factors, rangelands should be given more importance in developing countries (Lipper et al., 2010). Specific adaptation options need to be identified to maintain the agro-ecosystems on which farmers' livelihoods depend and to increase the resilience of vulnerable smallholders to the undesirable effects of social-ecological change (Kmoch et al., 2018). This is possible by determining how biodiversity and environmental factors are perceived and used by people (Cevher, 2023).

In particular, it is necessary to determine the goods and services provided by biological diversity and to determine the value of these services in ecological, economic and socio-cultural processes. Combining ecological processes and economic processes under the same roof, within the scope of sustainable economic policies, will form the basis of future action plans. Today, such studies are increasing in many countries and in various branches of science. Our biodiversity is not only food, feed and raw materials, but also natural carbon storage biological environments. Likewise, the raw materials of many of the agricultural industrial products are of vegetable origin, and they are used in clothing, ornaments, various dyes, etc.

Agricultural biodiversity is especially important for the development of varieties with thousands of different genetic features. In addition, the biotechnological manipulations of genetic material and the resulting goods and services processes have great economic value (Demir, 2009; Ashaboğlu, 2012; Demir, 2019).

Another important contribution of biological diversity to economic processes is its potential for use as pharmaceutical raw materials. People globally need or use medicines derived from plants to live a healthy life. 25% of prescription drugs sold in Europe are ephedrine, ergomatine, etc. derived from plants. It contains active raw materials (Erdem, 2004), and between 20 thousand and 70 thousand plants are used in traditional medicine or as pharmaceutical raw materials.

It has been determined that the market value of plants used for medicinal purposes is 5 billion $/year (Pearce and Puroshothaman 1993; Simpson et al., 1996; Clapp, and Crook, 2002; Toksoy et al., 2003). In 1985, it was determined that 16 of the 5000 plants grown in the USA had potential medical use value, and the value of each of the 16 plants was 203 billion dollars and the total value for 16 plants was 3248 billion dollars (Fransworth and Soejarto, 1985).

In another study, it is estimated that the prescription value of 40 plants in the USA is $11.7 billion, the value for each plant is $290 million on average, and the contribution of each plant to the life scale is $6 billion (Principe, 1989; Kumar, 2004). These figures reached a total of 500 billion dollars in 2015 (OECD, 2019).

Due to the diversity of its geographical structure, Turkiye creates different ecosystems and habitats and allows different plant species to emerge in different ways. For this reason, our country has a rich collection of endemics and biodiversity. 3708 of approximately 12000 plant species living in Turkiye are endemic and live only in Turkiye in the world (Güner et al., 2012). While biodiversity conservation efforts are rapidly gaining importance in the world, it is observed that this issue is not at the top of the priority list in developing countries such as Türkiye (Altındal and Akgün, 2015).

Industrialization and urbanization, as well as climate factors, threaten our biodiversity in Turkiye and the world (Niksarlı, 2015). While unsustainable land use causes people, plants and animals to be exposed to challenges arising from climate change, it also risks issues such as food security and human health. Human interventions and land management practices are other factors that trigger the degradation of habitats (Şen and Öztopal, 2017; ÇMUSEP, 2019; Beşen, 2021; Budak, 2022; Aydin, 2023).

Renewable energy resources, which are also closely related to industrialization, require planning by taking into account their effects on climate change and the sustainability of ecosystem services that increase resistance to climate change (Turan and Bayraktar, 2020).

This will also be possible by developing new technologies such as artificial intelligence that can develop innovative solutions such as separation of waste at the source, recycling practices and circular water use, by considering surface water, groundwater and rainwater potentials together in new water resources development plans.

Developing solutions to water-related problems requires understanding the common challenges and behavior of the aquatic ecosystem, ranging from the local to the global level. (Yıldız and Özgüler, 2020). Temperature is one of the most determining factors of climate. Vegetables with low temperature requirements, high temperatures cause flowering and fruit formation in the vegetation to change in harvest time and decrease in quality (Kim, 2008; Radwan et al, 2023).

In some regions of Korea, an Asian country, the locations of orchards have changed, shifting to the north. Phenological development (flowering, maturity, seed periods) is a concept closely related to the economic rent in crop productivity due to the presence of vegetation (Audu et al., 2013; Kim et al, 2004; Kim, 2008; 2009; 2012).

In this study, habitat requirements, phenological periods, period lengths and physical characteristics of species with high economic value for our biodiversity were investigated in order to ensure their sustainability under the influence of climate change. These features have been recorded and identified for the first time.

2.MATERIALS AND METHODS

2.1. Materials

In the study, three plants that were in the medicinal aromatic plant class and had economic value as fodder were selected as materials. The plants are listed below and their characteristics are explained.

1. L Agropyron Cristatum. Gaertn. subsp. pectinatum (M. Bieb.) *Tzvelev var. pectinatum*:

It is a meadow plant belonging to the Poaceae family. It is one of the three grassland species growing within the borders of Türkiye. Distribution in Turkey: Thrace (Istranca Section), Eastern Black Sea Section, Y. Sakarya, O. Kızılırmak and Konya Sections, Y. Fırat, Erzurum-Kars and Y. Murat-Van Sections (Güner et al., 2012).

It is a species that can adapt to many different ecosystems in Turkey. It is one of the most durable forage plant species in pastures. It is found in the natural vegetation of steppe pastures. It is a cool climate grass plant that is included in natural species mixtures in lawn production. In this respect, it has great economic importance. It is one of the important species, especially for the evaluation of saline and alkaline soils. It is one of the alternative species that can be produced in fallow areas (Acar et al, 2020).

It is also one of the showy natural grass family members that can be used in landscaping applications in xeric areas (Özyavuz and Çorbacı, 2017). Medicinally, in some regions, all plant parts are used in the treatment of hemorrhoids and diabetes.

There are publications in the Artvin region where the rhizomes are used as a diuretic and laxative (Gürhan and Ezer, 2004; Sarıkaya et al, 2010; Cesur and Yüksel, 2018; Eminağaoğlu, 2005).

2. Artemisia scoparia Waldst. & Kit.:

It is a perennial herbaceous species belonging to the Daisyaceae (Asteraceae) family. Distribution in Türkiye: Çatalca-Kocaeli and Ergene Sections; B. and O. Black Sea Sections; Central Anatolian Section; Central Anatolia Region, Y. Fırat, Y. Murat-Van and Hakkari Sections; O. Fırat Department (Güner et al., 2012).

The genus *Artemisia scoparia* is generally used in the literature with the Turkish Scientific Names of Yavşan or Wormwood (Güner et al., 2012).

It is an anti-erosion and drought-adaptive species. The genus Artemisia is represented by about 500 species in the world. 27 species grow naturally in Turkiye (Güner et al., 2012; Kürşad et al., 2018).

Some species of *Artemisia* genus form plant associations in xerophytic and eroded areas in Central Anatolia. They spread remarkably in an important part of the floristic composition (Geven et al., 2015).

Some species of *Artemisia* are used medicinally as an appetite stimulant, antipyretic, strengthening agent and dewormer. Studies have found that their species exhibit a wide range of bioactivity (antifungal, anticancer, antioxidant, antimicrobial and insecticidal, etc.). In addition, "Artemycin" used in the treatment of malaria is an alkaloid obtained from the plant. Essential oils obtained from the above-ground parts of the plant are used in the perfume and cosmetics industry (Coşge and Şenkal 2017).

3. Bassia scoparia (L.) A.J.Scott (synonym = former name *Kochia scoparia*) :

It is a perennial herbaceous plant known as *Kochia* (old synonym name). It has been transferred to the genus *Bassia scoparia* through molecular studies and phylogenetic classification studies carried out in recent years. It is a member of the Amaranthaceae family. Three species of this genus are naturally distributed in Turkiye (Güner et al., 2012). Distribution in Türkiye: W. Black Sea Region; Y. Sakarya, O. Kızılırmak and Konya Departments; Y. Fırat Department (Güner et al., 2012). It is a branched perennial herbaceous species that can grow up to 20-150 cm tall. They can spread up to 1200 m above sea level, on the edge of waste areas and cultural areas. It has a body that turns from green to bright red at the end of the vegetation period. It grows in regions connected to Europe and Asia in the world. Plant form varies in species growing near cultural areas where conventional agriculture is carried out (Davis, 1967).

In North America, the predictable feature of the emergence period of the vegetative part of the *Bassia scoparia* plant in spring has been found to have the potential to be used in weed control studies (Schwinghamer & Acker, 2008). It is a typical halophyte plant.

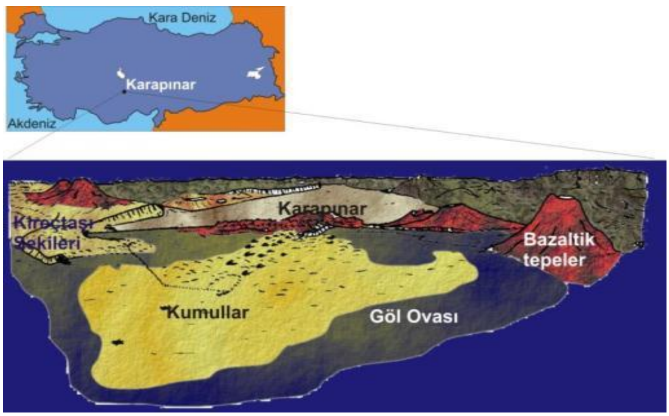
The continuation of the vegetation period of the plant in late summer and autumn is very important in terms of competition with other plants (Khan et al, 2001). *Bassia scoparia*, which is resistant to salinity, makes areas with salt water and arid soil in desert ecosystems suitable as pasture, and can also be used as animal feed in emergency situations in the livestock industry (Nabati et al., 2011). It has been determined that the *bassia scoparia* species is grown in some regions of Turkiye for the production of "Brooms" (Ertuğ et al., 2004).

Phytochemicals of the plant as a plant affecting blood sugar were determined and samples collected from Northern, Central and Eastern Anatolia were examined. Obtained phytochemicals; Momordin IC vs its 2'-O-Beta-D-glucopyranoside (Saponins) (Hazer and Hamamcıoğlu, 2017). Figure 1. Konya Karapınar Protected Area (Şimşekli, 2012)

The soil texture is sandy-loam in the surface soil, and sandy-clayey-loam as you go down. Soils are rich in lime and potassium, but poor in organic matter

1.2. Research Area Description and Soil Properties

Karapınar district of Konya province is located between 37°42' North latitude and 33°33' East longitude. The distance to the city center is 102 km. The average altitude of the district above sea level is 1,026 meters. The soils in Karapınar are generally of alluvial origin, formed on old lake deposits. Soils are mostly defined as Inceptisol and Entisol orders according to soil classification (Soil Survey Staff, 1999).



The soil texture is sandy-loam in the surface soil, and sandy-clayey-loam as you go down. Soils are rich in lime and potassium, but poor in organic matter and phosphorus. The water retention capacity of the soil is low and the infiltration rate is 6.8 cm/h. The soil structure prevents rainfall from being retained in the soil. The limited amount of rainfall moves away from the profile by capillary and infiltration due to high evaporation.

2.Methods

2.1. Phenological Period and Crown Volumes (Above-Soil Part) Calculations

The observations made in the study started in 2018 and continued for four years in 2018-2021. The flowering period defines the period when the flower of the plant is observed, and the maturity period defines the period when the fruit is observed. In some plants, fruit formation directly corresponds to the seed period, and maturity and seed period are given in the same date range. In some plants, seeds are formed after a certain period of time after fruit formation. Seed formation is also noted in these plants.

As a physical feature, the crown volumes of the plants were measured. These periods were taken into account when calculating crown volumes. Crown volumes of plants in the field according to their phenological stages were calculated according to Sternberg and Shoshany (2001). Soil and plant samples and height and width measurements were taken at two stages of the plants (flowering and maturity - seed).

The crown volumes of the plants whose height measurements were taken were calculated with the help of the following empirical equations (Sternberg and Shoshany, 2001).

In equations;

r= crown radius,

h= crown height (cm) expresses.

Table 2. Crown shapes of plants and empirical equations for volume calculation

Plants	**Plant crown shapes**	**Formula**
Agropyron cristatum subsp. *pectinatum*	Cylindrical	$A = \pi r^2 h$
Artemisia scoparia	Semicircle	$A = \frac{4}{3}\pi r^2 h$
Bassia scoparia	Cone	$A = \frac{1}{3}\pi r^2 h$

2.2. Determination of Habitat Requirements (Climate Requirements) of Plants

Individual habitat requirements (climate requirements) of the studied plants were determined. Examination; In this study, the phenological periods were observed, the beginning of the period, the length of the period and the dates when the phenological stages ended.

While determining the climate requirements of plants, the annual, monthly, daily and hourly maximum minimum average of the climate data obtained from the General Directorate of Meteorology was used for each climate parameter. An effort was made to interpret as many parameters as possible in order to reveal the change in the climate components of the vegetation.

Each climate parameter was examined and evaluated separately for each plant for 4 years, covering the project period. Evaluation; The date ranges in which the phenological stages were observed (by considering the 40 days forward and backward dates on the time line) were expanded and all the extreme and average (max-average-min) values of all climate data were evaluated.

Each of the plants was examined separately each year throughout the monitored period. Accordingly, the climate requirements of the flower, maturity and seed stages were determined.

3.RESULTS AND DISCUSSION

Agropyron cristatum subsp. observed in the pasture in Konya Karapınar protected area. Field observations of pectinatum, Artemisia scoparia and Bassia scoparia were recorded with photographs and arranged according to their periods.

1. Agropyron cristatum (L.) *Gaertn. subsp. pectinatum* (M.Bieb.) *Tzvelev var. pectinatum*:

Figure 1. *Agropyron cristatum subsp. pectinatum var. pectinatum* - Grassland weed - Flower -Fruit and Seed Period

Agropyron cristatum; 1st year (2018); Flowering started in the last week of June, and the full bloom date is mid-July. The end of the flowering period was recorded as the end of July.

Flowering period is 25 days, maturity period is 53 days. The total phenological period is 78 days and all phases have been completed in this period. In general, it is possible to say that the green period is during the flowering period and the beginning of the maturity process. In the first year, flower formation and blooming took time.

It was determined that the crown volume was 1.69 m^3 during the flowering period and 1.44 m^3 during the maturity period. It has been observed that the plants dry out, shrink in volume and cover rates decrease during the maturity and seed stages. 2nd year (2019); The flower was seen in early July and the process lasted 38 days. The maturity period was observed in the second week of October, after 58 days. The total phenological period was recorded as 96 days, and seed formation took up to two weeks.

The highest crown volume values were recorded in this period, with 2.86 m^3 of flowers, 2.42 m^3 of maturity and an average height of 1.48m. It was also observed that there was a 16% loss in crown volume between periods. The period with the longest crown volume and phenological period was recorded as 2019.

3rd year (2020); Flowering started at the beginning of June and the end of the flowering period was observed at the end of July. The exact date when the flower can be observed is the middle of July. Seeds were observed in the second week of October. Flowering period is 35 days, maturity period is 62 days. The total phenological period duration is 97 days and it has completed its phenological stages in this period. This year the flowering period has been shortened and the ripening period has been considerably extended. During the four years monitored, the longest maturity period was recorded in Year 3. Again, the seed formation process took a month this year. This process has increased by 100% compared to previous years.

4th year (2021); The flowering period decreased to 14 days and the flowering period was determined at the end of May. The maturity period was observed at the end of July and the seed period was observed in the first week of August. The maturity period lasted 56 days, and the total phenological period decreased to 70 days. The earliest flower was seen in 2021, and its shortest presence in the area was this year.

The crown volume was measured at 2.67 m^3 flower, 2.26 m^3 maturity stage, the volume decreased compared to previous years with the shorter flowering period. The crown volume showed its lowest values this year, the crown volume was not developed enough because the flower period was not long enough and remained undersized.

It has been observed that the less development in crown volume during the flowering period, the more loss there is in the maturity period over 4 years. *Agropyron cristatum* is one of the plants that responds most sensitively to the changes in the climate parameters examined. The highest population was detected in the area in 2019. The presence of *Agropyron cristatum* in an area and the fluctuations in the volume, amount and dimensions of its presence in the vegetation can be accepted as an indicator of a variability in the climatic components of that region. In this sense, it could be used as an indicator or control plant.

Agropyron cristatum habitat requirements for the onset of phenological stages in a 4-year period: Minimum air temperature for the flowering period: 10-15 ^oC, aboveground temperature at the beginning of flowering 10 ^oC, min aboveground temperature during flower formation 8.5-10 ^oC; 20 cm root depth 25-26 ^oC; humidity 45-55%; wind speed 1.5-3.5 m/s; *Agropyron cristatum* experiences its flowering period under 20-26 mm average rainfall conditions.

The lowest air temperature for the maturity period is 15-16 ^oC; min above ground temperature 16-17 ^oC, 20 cm root depth temperature 24-26 ^oC, humidity 40 -47%, wind 1.2-2.2 m/s; 20 mm rainfall conditions have been determined as the climate requirement of the plant.

Climatic requirements for seed formation: min. air temperature: 10-12 oC, surface temperature -9;-2-12 ^oC; soil root depth temperature 21-23 ^oC; humidity: 40-47%; rainfall 1.3-13 mm wind speed: can go up to 1.4 m/s.

Agropyron cristatum skipped the process of creating seeds quickly in 2018. It is thought that the reason for this is that the soil root depth and air temperature suddenly drop to 10 ^{o}C and persist. In 2019, it received 20 mm of rainfall during the maturity period and temperatures were high, thus seed formation slowed down and its duration was extended by 1 month. Since the temperatures dropped to - values in the same period in 2020, it could not tolerate the humidity and this process decreased to 15 days.

For flower initiation, plant root depth can be recommended for at least 25 ^{o}C, 10-11 ^{o}C in lowest temperature conditions and at least 20 mm rainfall. It has been observed that they do not grow very tall in open areas in the area, and that they grow mostly on hillsides and under trees where there is no wind. Wind in the work area can reach up to 4.9 m/s. Since *Agropyron cristatum* mostly covers the soil under trees and shrubs, it is predicted that the adaptation process will develop better in an area where the wind is cut off. Therefore, it is not a plant that can be recommended as a windbreak.

2. Artemisia scoparia Waldst. & Kit.

Figure 2. *Artemisia scoparia* - - Flower-Fruit-Seed Stage

Artemisia scoparia; 1st year (2018); The flower period was seen in the third week of September and this period lasted 38 days. The maturity period was observed in mid-July and lasted 20 days. The total phenological period duration was recorded as 58 days. The seed was seen in mid-November.

2nd year (2019); The beginning of the flowering period was detected at the beginning of August, but after 38 days, the flowers showed wilting/falling before seeds were formed, and volume shrinkage and drying were observed at the beginning of November. These two periods were recorded as 28 days and 38 days, and the phenological stages were completed in 58 days in total. No flowers or seeds have formed on the plant. In general, there has been a decrease in the population in the area this year.

3rd year (2020); The flowering period was again observed in the second week of September and this period lasted 35 days. The maturity period was observed in mid-October and lasted 3 days. Seed was observed in the third week of October. The total phenological period duration was recorded as 38 days. Compared to the first year, phenological stages started three weeks earlier and the length of the processes was halved compared to the previous year. The year 2020 was recorded as the fastest seed formation.

Year 4 (2021); The flower period shifted to the last week of May and lasted 56 days. The maturity period continued in mid-July and lasted 24 days. The seed period extends until mid-October. Total phenological period duration was recorded as 80 days. The durations of phenological periods were similar to 2019 and lasted approximately the same length. The years in which the largest population spread in the area are 2019 and 2021.

It was determined that the 1st year crown volume was 254.34 m^3 at flower and 100.30 m^3 at maturity. It was determined that the 2nd year crown volume was 278.63 m^3 at flower and 136.98 m^3 at maturity. It was determined that the 3rd year crown volume was 334.93 m^3 at flower and 114.88 m^3at maturity. The highest crown volume was detected this year. It was determined that the 4th year crown volume was 387.20 m^3 at flower and 123.40 m^3 at maturity. The lowest volumes of four years were detected in the last two years. It reached the highest volume in the first year, and a decrease in plant volume was observed in the following years.

When the four-year period is examined, although the vegetative parts were very developed in 2019, the generative parts were not developed and the volume increased to the previous year, it existed in the vegetation for a long time, remained green, but could not produce seeds. 2019 Vegetation Observations:

Depending on the temperature and the amount and type of rainfall, irregularities and delays were observed in the flowering, maturity (fruit) and seed times of the plants. In the *Artemisia scoparia* species, fruits and seeds have not been formed and have not completed their phenological period.

Artemisia scoparia ; Habitat requirements (climate requirements) required for the start of phenological stages in a 4-year period: The lowest air temperature for the flowering period: 8-11 ^{o}C, the above-ground temperature at the beginning of flowering is 10 ^{o}C, the lowest above-ground temperature for flower formation is 8.5-10 ^{o}C; 20 cm root depth 22-25 ^{o}C; humidity 45-55%; wind speed 1.5-3.5 m/s; *Artemisia scoparia* experiences its flowering period under 10-20 mm average rainfall conditions. The lowest air temperature for the maturity period is -4-3 ^{o}C; the lowest above-ground temperature is 7-8.5 ^{o}C, 20 cm root depth temperature is 11-15 ^{o}C, humidity 70-88%, wind 1.2-2.2 m/s; 17 mm rainfall conditions were determined as the climate requirement of the plant. Climatic requirements for seed formation: minimum air temperature: -4-10 ^{o}C above ground temperature 5-6,5 ^{o}C; soil root depth temperature 4-11 ^{o}C; humidity: 55-65%; rainfall 13 mm wind speed: 4,7 m / s can be up to.

Artemisia scoparia ; Flowers and seeds did not open in 2019 and dried before completing their phenological stages. Although the averages of other climate parameters are similar and within the same ranges in the periods expected to bloom in 2019 compared to the periods in other observed years, the plant received excessive rainfall in the area during these periods. In addition, in 2019, the fluctuations in daily and hourly climate data were examined and it was observed that there were sudden decreases in air temperature, surface temperature, wind and humidity values, and that the temperature difference, especially in hourly and daily air temperature values, increased up to 6^{o}C.

The observed periods of 2020 received little rainfall (4.8 mm), and after the flower period, the temperatures suddenly dropped, the wind speed decreased and the humidity increased. In this condition, the fastest seed formation was observed and reached the highest population and volume values in 2020, the driest year. It has been observed that the vegetation period is shortened and it passes from fruit to seed very quickly when it receives a lot of rainfall after entering the flower period.

3. *Bassia scoparia (synonym=formerly Kochia scoparia) – Fireball:*

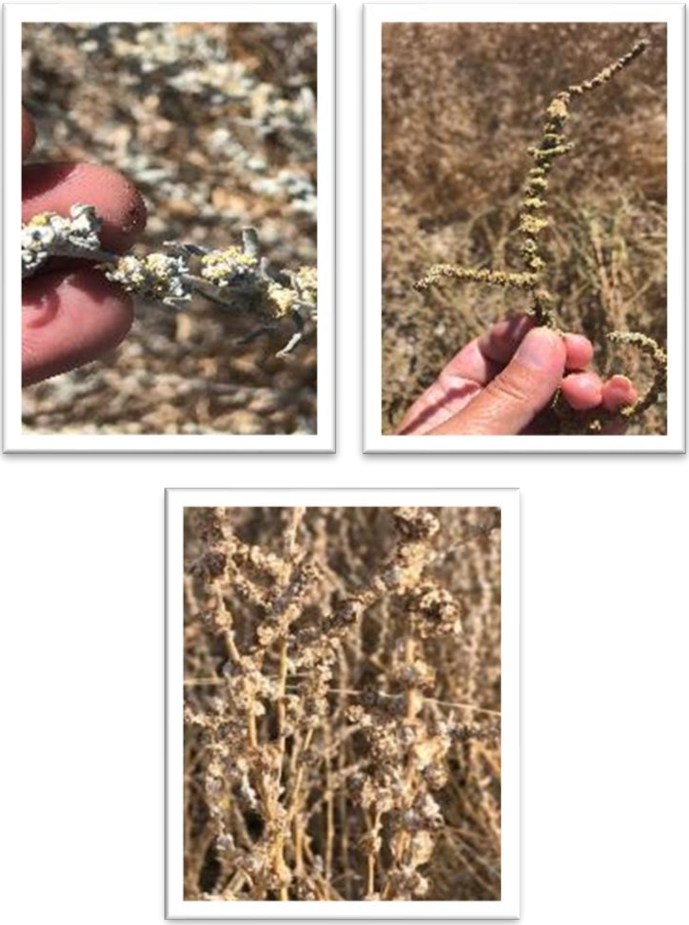


Figure 3. *Bassia scoparia* - - Flower - Fruit - Seed Period

Bassia scoparia; 1st year (2018); The flowering period was observed in the third week of July and this period lasted 73 days. The maturity period was observed at the end of October and lasted 20 days. The total phenological period length was recorded as 93 days.

2nd year (2019); The flowering period was observed in the last week of August and this period lasted 28 days. The maturity period was observed at the end of September and lasted 59 days. The total phenological period duration was recorded as 87 days. Seeds were observed in the second week of November.

The phenological period duration was shortened by one week compared to the previous year.

3rd year (2020); The flowering period was observed at the end of September and this period lasted 40 days. The maturity period was observed at the end of October and lasted 4 days. Seed was again observed at the end of October. The total phenological period duration was recorded as 44 days. Compared to the first year, the phenological stages started about 1 month later and the length of the processes was halved compared to the previous year.

Year 4 (2021); The flower period shifted to the last week of May and lasted 56 days. The maturity period continued until the end of July and lasted 14 days. The seed period was observed at the end of October. The total phenological period duration was recorded as 70 days. The duration of the phenological stages was the longest in the first year, 2020. There was a sharp decline, and in 2021, it lasted more than two months again. This year, the population in the area increased again.

It was determined that the 1st year crown volume was 49.04 m^3 at flower and 33.35 m^3 at maturity. It was determined that the 2nd year crown volume was 48.04 m3 at flower and 31.35 m^3 at maturity. It was determined that the 3rd year crown volume was 34.04 m^3 at flower and 18.64 m^3 at maturity. The highest crown volume was detected this year. It was determined that the 4th year crown volume was 53.80 m^3 at flower and 42.30 m^3 at maturity. The lowest volumes of four years were detected in the last two years. It reached the highest volume in the first year, and a decrease in plant volume was observed in the following years.

Bassia scoparia Habitat requirements (climate requirements) for the beginning of the phenological stages in a 4-year period: Minimum air temperature for the flowering period: 11-15 ^oC, aboveground temperature at the beginning of flowering 10 ^oC, flower formation above ground temperature at the lowest low temperature 8-12 ^oC; 20 cm root depth 24.5-25 ^oC; humidity 45-55%; wind speed 1.5-4.8 m/s; *Bassia scoparia* experiences the flowering period in average rainfall conditions of 15-25 mm.

The lowest air temperature for the maturity period is 8-12 ^{o}C; the lowest above-ground temperature is 7-8.5 ^{o}C, 20 cm root depth temperature is 7-12 ^{o}C, humidity 45-78%, wind 1.2-3.9 m/s; Rainfall conditions of 1-10 mm were determined as the climate requirement of the plant. Climatic requirements for seed formation: minimum air temperature: -6-10 ^{o}C above-ground temperature 5-6,5 ^{o}C; soil root depth temperature 4-11 oC; humidity: 55-65%; rainfall 13 mm, wind speed: 2,5 m / s can be up to.

A four-year period was examined and, as with other plants, the specific climate requirements of the plant were examined. It has been observed that *Bassia scoparia* blooms after receiving at least 45 mm of rainfall in the area and after a dry period of 35-40 days.

In the other three years, flowers formed under parallel climatic conditions, and the period for maturity and seed formation was long. Unlike other years, when it bloomed in low temperatures and dry conditions in (2020), it was observed that it rapidly started seed formation when these climatic conditions lasted at least 25-30 days. Thus, he could not develop much. The lowest flower period temperatures were observed in 2020. In 2021, it rained after the flower and the temperatures did not fall below zero for a long time. It then received no rainfall and adapted to hot and dry conditions. Thus, the highest volume values were observed this year. Its development remained small during the periods when it received the most precipitation. It has been observed that it can keep its existence long and its volume high in hot and dry conditions.

In the years when *Bassia scoparia* received a lot of precipitation in all phenological periods, its vegetative part remained green for a long time, but its development was adversely affected. An increase in the population of the area was also observed in arid conditions. In 2020, the rainy season has shifted forward, the flowering period has been delayed, and the vegetation period has shortened. The reason for this is; It is thought that the sudden decrease in root depth and above-ground temperatures and the continuity of this situation. This year, the soil temperature dropped to 10 ^{o}C and showed continuity.

4.CONCLUSION AND RECOMMENDATIONS

It was concluded that the *Agropyron cristatum* plant could not close the gap in the need for temperature with the increase in the amount of moisture, at least the root depth should be higher than 0 ^{o}C. Considering all the data; It is thought that the *Artemisia scoparia* plant has not completed its phenological stages due to excessive rainfall as well as sudden increases in temperature differences. A decrease in volume or a shortening of the phenological phases of some other plants in low rainfall or dry conditions has also been observed before. However, when *Artemisia scoparia* received a lot of precipitation (more than 25 mm), it was observed that it did not experience the stages in its productivity or phenology instead of earliness, it completely withered and did not participate in the vegetation. Thus, it has been observed that it is better adapted to arid conditions, unlike other arid plants.

When the climate data examined and the responses of the studied species to changing climate conditions are examined; It has been concluded that *Bassia scoparia* is suitable for flowering in the 5th and 6th months and receiving little rainfall after flowering until maturity, i.e. fruit formation, for its population to increase in the vegetation, for the development of its vegetative parts, to exist in the area for a long time and to remain green. Determining the habitat requirements of plants in order for their phenological phases to be long in the pasture is of great importance in directing the plant composition in the pasture, animal welfare, and the industries where they are used as raw materials in the medicinal aromatic plants class due to the active substances they contain. Depending on the habitat requirements of the plants, the increase or decrease of the population within the vegetation in the area and the duration of their stay green have also changed. However, period lengths have been lengthened or shortened by climatic conditions. The extension of phenological periods creates the coverage rate and duration of the soil. This is of great importance in terms of grazing time of pastures, the high nutritional value of green grass for animals, and also soil protection, especially in areas where populations of arid climate plants such as *Agropyron cristatum subsp pectinatum*, *Artemisia scoparia* and *Bassia scoparia* are seen.

Agropyron cristatum and *Bassia scoparia* are mostly found among shrubs and trees in the area. Therefore, its population is spreading among woody plants that serve as windbreaks. However, the spread of the population of *Artemisia scoparia* in open areas has been evaluated as a result of its need for more sun exposure than the other two plants and its ability to be more resistant to wind erosion. Thus, *Artemisia scoparia* plant can be recommended in areas with high sunshine duration, arid areas and exposed to wind erosion.

Such studies should increasingly continue for the sustainability of agricultural production and agriculture-based sectors and industries under changing climatic conditions in the world and in Turkıye.

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CHAPTER II

AN OVERVIEW OF *IN VIVO* AND *IN VITRO* GENOTOXICITY TESTS IN EUKARYOTES

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INTRODUCTION

Genotoxicity is a genetic term that refers to the situation where a substance that has a destructive effect on DNA and RNA, which is the genetic material of the cell, and thus affects the integrity of the cell, causes mutations in the gene, chromosome and genome. Genotoxins are mutagens that can cause genotoxicity, causing damage to DNA or chromosomal material and thus mutation. These genotoxins can be chemicals as well as factors such as rays and radiation. Genetic toxicology is a branch of science that studies agents or substances that can damage the DNA and chromosomes of the cell. It is often stated that genotoxicity is confused with mutagenicity. All mutagens are genotoxic, but not all genotoxic substances are mutagenic (De Flora and Izzotti, 2007). Genotoxicity tests are tests used to determine the effects of these genotoxic substances. The main purpose of these tests is to identify and announce substances that may have mutagenic and carcinogenic effects in humans in a short time.

Genotoxic substances are divided into 3 groups according to their mechanism of action (Izquierdo-Vega et al., 2017);

a) Carcinogens and cancer-causing substances

b) Mutagens or substances that cause mutations

c) Teratogens or substances that cause birth defects

Today, people have problems such as the proliferation of synthetic substances, the close contact of these substances and nutrients, the intensive and uncontrolled use of pesticides in agricultural areas, the pollution of agricultural areas, streams, lakes and seas with waste materials, the use of mobile phones and smart devices, which have entered our lives due to technological advances. People are exposed to many substances, more or less, directly or indirectly, every day, knowingly or unknowingly, due to exposure to radiation and rays as a result of excessive use of tools. Therefore, it is of great importance to understand the genotoxic effects of such substances.

Damage to the genetic material in somatic cells in eukaryotic organisms may cause effects such as cancer, cardiovascular diseases, premature aging, while damage to the genetic material in the germ cells results in infertility, genetic disorders (cystic fibrosis, sickle cell anemia, hemophilia, etc.), multifactorial diseases (diabetes, cleft palate-cleft lip, schizophrenia, etc.) and hereditary mutations may occur. These mutations can take any form; may include duplication, inversion or deletion of genetic information. These mutations can cause a variety of problems in living things, from a wide variety of diseases to cancer. One of the best ways to control damage from mutagens and carcinogens is to identify the substance or chemical i.e. antimutagens/anticlastogens. Genotoxicity tests are used for this purpose.

Importance of genotoxicity tests

Genotoxicity assessment is an essential component of the safety assessment of drugs, industrial chemicals, pesticides, biocides, food additives, cosmetic additives, in other words, any substance in the context of international legislation for human protection. Genotoxicity studies can be defined as various in vitro and in vivo tests designed to identify any substance or compound that may directly or indirectly cause damage to genetic material by various mechanisms. *İn vitro* and *in vivo* genotoxicity tests, which were developed to detect compounds that cause damage to genetic material, are used as an aid in measuring the carcinogenic potential of chemicals under development, characterizing the genetic effect spectrum and interpreting toxicity and carcinogenicity test results, and assessing risk for humans and animals.

Genotoxicity tests

Many in vitro and in vivo tests have been developed to detect DNA damage or its biological consequences in prokaryotic (eg bacterial) or eukaryotic (eg mammalian, avian or yeast) cells (URL 1). *Salmonella* in genotoxicity tests with prokaryotes *Typhimurium*, *Escherichia coli* and *Bacillus subtilis* are the most commonly used bacteria. The Ames test is the most widely used genotoxicity test with bacteria (Zeiger, 2019). Genotoxicity tests in eukaryotes vary widely. These tests are divided into *in viv*o and *in vitro*. In addition to this distinction, tests performed in eukaryotes are also classified according to their performance in germ cells and somatic cells. However, when it is difficult to perform these tests in germ cells, genotoxicity tests performed on somatic cells are preferred. Since the studies show that the data obtained from the somatic cells are also compatible with the data obtained from the germ cells, it is accepted that the results obtained as a result of the somatic tests are also valid for the germ cells.

Genotoxicity tests on somatic cells are primarily performed *in vitro*. *İn vitro* genotoxicity assays enable simple, robust, short-term and cost-effective detection of targeted toxicity and underlying mechanisms. However, in some cases, the results obtained from these tests may not be sufficient. In this case, the same substance may also need to be tested *in vivo*.

In vitro genotoxicity tests are performed using different cell systems. The data obtained as a result of these tests help to understand the mechanisms of toxicity. İn vitro genotoxicity tests using somatic cells are divided into two groups as indicator and direct mutagenicity tests. The results obtained as a result of the indicator tests are not directly associated with the mutation, but still show the presence of a genotoxic effect. The most commonly used indicator tests are the sister chromatid exchange test (SCE), the unscheduled DNA test (UDS) and the comet test. Human peripheral blood cells, V79 cell (male Chinese hamster lung tissue cell), CHO cell (Chinese hamster ovary cell), rat hepatocytes are the most frequently used cells in these tests. Chromosome aberration test (CA), micronucleus test (MN), randomly replicated polymorphic DNA test (RAPD), thymidine kinase gene mutation test, hypoxanthine phosphoribosyl transferase gene mutation test can be counted among direct mutagenicity tests. In these tests, human peripheral blood cells, V79 cells, CHO cells, mouse lymphoma cells, and fibroblasts are used (Ünal and Yüzbaşıoğlu, 2022).

In vivo genotoxicity tests are tests performed when results from *in vitro* tests are inconclusive. These tests are complementary tests. These tests, which are performed using different living cells, are grouped as indicator and direct mutagenicity tests, as in *in vitro* tests. The point to be considered in these tests is to determine whether the test material used reaches the target in the cell to which it is applied. For this purpose, mitotic index analysis is performed on the living creature. The decrease in the mitotic index indicates that the investigated substance has reached the cell. *In vivo* genotoxicity tests include sister chromatid exchange test and comet test, which are used as indicator tests. Direct mutagenicity tests are chromosome aberration test, micronucleus test and gene mutation test. In these tests, as in in vitro tests, different cell groups are used.

The point to be considered in both *in vitro* and *in vivo* tests is to determine the carcinogenic effects as well as the genotoxic effects of the chemicals whose effects are investigated. Although the indicators among these tests show that the chemical is mutagenic, the results alone may not be sufficient and may need to be supported by direct tests.

In vitro and in vivo genotoxicity tests in eukaryotes

a. Sister Chromatid Exchange Test (SCE)

Sister chromatid exchange (SCE) test is a short-term test used to detect reciprocal DNA exchange between two sister chromatids of a duplicated chromosome. With the PPE test, mutagenic compounds that form DNA attachments or interact with DNA replication are detected. This test has an important place in investigating the mutagenic and carcinogenic effects of various agents, especially the structural changes in chromosomes.

SCE in cells exposed to substances known to be mutagenic and carcinogenic, and in various inherited diseases characterized by chromosomal fragility and susceptibility. There is a linear relationship between increased SCE frequency and tumor formation. It has been determined that there is a relationship. SCEs represent the exchange of DNA replication products at apparently homologous loci. This test can be performed in vitro as well as in vivo using animal models such as mice, rats and hamsters. In in vitro assays, cell cultures are exposed to test chemicals and allowed to grow in the presence of bromodeoxyuridine (BrdU). The cells are then arrested in the metaphase stage of mitosis. Preparations are stained and metaphase cells are analyzed for their SCE using a microscope. While this test method can be easily performed in in vitro studies, it is not a preferred method in in vivo studies because too much BrdU needs to be injected into the living thing and this causes negative effects *in vivo* (Güner, 2014; Ünal and Yüzbaşıoğlu, 2022). The SCE test is a preferred test in the investigation of potential genotoxicity because it can be applied both *in vitro* and *in vivo*, is a complementary test, and can be used together with other genotoxic tests.

b. Unscheduled DNA testing

It is a short-term genotoxicity test used to identify substances that cause DNA damage and repair. With this test, DNA repair mechanisms that occur in all stages of replication except the DNA synthesis phase can be determined. Living cells are needed in this method, and rat liver cells are the most preferred cells. This test, which can be used both *in vivo* and *in vitro*, is especially preferred to determine the carcinogenic effect of chemicals. However, since cancer development occurs as a result of many steps and long processes, this test alone is not sufficient and must be supported by other genotoxicity tests (OECD, 1997).

c. Comet test

In recent years, the comet test or single-cell gel electrophoresis (SCGE) has become one of the standard methods used to assess DNA damage, with applications in genotoxicity testing, human biomonitoring, and molecular epidemiology, echogenotoxicology, and basic research. It has been made a systematic test with the guide published by the OECD in 2016 and has become preferred by many scientists with its practicality, sensitivity, versatility and economic nature (OECD, 2016, Test No. 48). Today, it is widely used to investigate the genotoxic effects of many chemicals such as environmental pollution, pesticide effects, food additives, heavy metals and nanoparticles, ranging from bacteria to humans. This test is one of the short-term tests used in preclinical experimental therapeutic studies and clinical studies to determine possible risks that may arise, in human epidemiology studies, to investigate the antigenotoxic, antimutagenic, anticarcinogenic properties of various substances *in vitro* or *in vivo*. Since agents with genotoxic effects mostly cause single strand breaks in DNA, the comet test has an important place in detecting DNA damage. The basic principle of the comet method is to determine the effects of genotoxic and cytotoxic agents, which occur for chemical and physical reasons, on living cells by examining the DNA of the cells one by one. Generally, DNA in nuclei isolated from living tissues is fixed in a thin agarose gel and run in an electrophoretic medium. If the damage caused by the action of genotoxic agents is not repaired, breaks occur in the single or double strands of DNA, and these broken pieces migrate at different rates in the electrophoretic environment since they have different molecular weights. When DNA molecules are stained with DNA- specific dyes such as ethidium bromide and examined under a fluorescent microscope, the method was named "Comet Assay", which means "comet" in English, since these broken DNAs form images of varying degrees from circular form to comet-like form, depending on the degree of damage (Ostling and Johanson, 1984). The comet test has been widely used in vivo and in vitro for the determination of genotoxic effect and the investigation of antigenotoxic effect in human, animal and plant cells, from molecular epidemiology to genetic toxicology, due to its easy applicability, rapid results in a small number of cells and being a sensitive test. It is a test that will be preferred by scientists for years due to its usability.

d. Chromosome aberration (CA) test

Chromosome aberration test is one of the oldest test methods used to determine the toxicological risks of chemical or physical agents on the living genome or to investigate the causes of developmental disorders that occur with birth. Today, it is widely used in genotoxic studies because it reflects the obtained results objectively, can be used with other tests, and is easy to apply. The test preparations obtained after the application of the test are evaluated under the microscope and the result is reached. In this respect, it is a time-consuming test. Abnormalities in the structure or number of chromosomes by various mechanisms can be lethal to the cell during the cell cycle following their initial formation, and sometimes cause non-fatal changes in the chromosome structure. These changes can occur in both somatic cells and germ cells. And depending on the cell in which it occurs, it can lead to important problems that can lead to cancer. Chromosome aberration test, especially performed under in vitro conditions, has an important place in determining the effects of newly developed and marketed compounds such as pesticides, nanoparticles and food additives, especially drugs, on the health of humans and other living things. This test, which is frequently used in epidemiological studies and accepted as a biomarker with a decisive role in the diagnosis of early cancer risk, can be performed *in vivo* or *in vitro*. In the *in vitro* chromosome aberration test, cultured mammalian cells are used as well as plant cells. If the data obtained as a result of the *in vitro* test show that the agent used has a positive effect, *in vivo* mutagenicity tests should be performed or the material should be considered mutagenic. In the CA test method, it is the experimental unit cell. Therefore, the clastogenicity of the tested chemical is evaluated by calculating the percentage of cells with abnormality. Chromosome aberrations can occur structurally and/or numerically. Structural chromosomal aberrations can be divided into two main classes: chromosomal-type aberrations involving both chromatids of a chromosome and chromatid-type aberrations containing only one of the two chromatids. Some of the agents used cause chromosome type abnormalities such as dicentric chromosome, inversion, ring chromosome in the G_0 or G_1 stage of the cell cycle (ie before replication), while they cause chromatid type abnormalities such as breaks and gaps in the synthesis or G_2 stage. Most chemical mutagens are clastogens as they act at the synthesis stage and therefore cause chromatid type aberrations. Numerical chromosome aberrations include polyploidy, hypodiploidy, and hyperdiploidy. Chromosome aberration test is one of the tests that will continue to be used for years, since significant results are obtained in a short time and these results have a great acceptance in terms of genotoxicity.

e. Micronucleus test (MN)

Micronucleus test, which is one of the most preferred and used tests among short-term genotoxicity tests, is accepted as a fast and reliable test for detecting mutagenic and aneugenic effects. Since it allows both in vitro and in vivo application, it is successfully performed in different cell types. It is easily detected in cells in interphase and easily examined under a light microscope, making it a frequently preferred test in genotoxic studies. Micronuclei are defined as formations that arise during mitosis of the cell, are not included in the main nucleus, and originate from whole chromosomes or acentric chromosome fragments (Vanparys et al., 1990). With this formation, they are usually caused by deficiencies in genes controlling the cell cycle, defects in the mitotic spindle, kinetochore or other parts of the mitotic apparatus, and chromosomal damage. The increase in the number of MN is considered as an indirect indicator of numerical and structural chromosomal irregularities caused by various agents in cells. Agents stimulating aneuploidy cause centromere division errors and dysfunction in spindle fibers. Clastogens, on the other hand, contribute to the formation of MN by forming chromosome breaks. Therefore, the detection of an increase in the number of MN in cells is accepted as an indicator of genomic instability in somatic cells (Şekeroğlu and Atlı-Şekeroğlu, 2011). Although all MN types are based on micronucleus frequency analysis, they differ in the cells and protocols used. The cytokinesis-aborted micronucleus test is the most popular micronucleus test. This test uses a wide variety of cell types. In this test, which can be performed in vitro and in vivo, cytokinesis must be stopped since the micronucleus can be seen after cell division (Fenech and Morley 1985; Fenech, 2000). Cytochalasin B, which is used for this purpose, does not prevent karyokinesis but prevents cytokinesis and allows the detection of micronuclei in the cell. The mammalian erythrocyte micronucleus test was first performed on immature erythrocytes obtained from bone marrow of young mice and rats (Von Ledebur and Schmid, 1973). This *in vivo* test is generally used to determine whether the tested compound causes chromosomal damage by analyzing erythrocytes in the bone marrow and/or peripheral blood cells (Krishna and Hayashi, 2000). Cheek epithelium micronucleus test is a test that has attracted great interest in recent years. This test is preferred to study how genotoxic factors affect organisms by inhalation. It is expected that the test will become a standard cytogenetic test in the coming years due to its sensitivity and the advantage of application compared to other micronucleus test types (Assiri et al., 2020). Micronucleus test is widely used and accepted as a reliable test because it provides risk assessment as well as identification of substances that may have genotoxic effects, is well standardized, and molecular and genetic mechanisms leading to micronuclei formation are well known.

f. Randomly replicated polymorphic DNA test (RAPD)

Evaluation of the genotoxic effect on DNA is a situation preferred by scientists because it gives precise results in a short time. Therefore, the use of DNA-based techniques to detect changes in DNA sequences is becoming more common day by day. DNA sequences are directly affected by the effects of many possible genotoxic substances such as UV or X-rays, heavy metals, arsenic, food additives. For this reason, one of the most frequently used methods to determine these changes and mutations by looking at the sequence and structure of DNA is PCR (Polymerase Chain Reaction) based Randomly Amplified Polymorphic DNA (RAPD) (Martins et al., 2005; Enan, 2006; Liu et al., 2007). In this method, it is one of the most reliable tests used to detect DNA damage, as proliferation stops after the effect of the genotoxic substance. Changes in RAPD profiles following genotoxic treatment are detected by analyzing the variation between band intensities between exposed and unexposed individuals (Cenkci et al., 2010). It is a sensitive, economical, fast and applicable technique for a large number of samples. In addition, the fact that it can be applied to any sample and that it can be applied without prior knowledge of the nucleotide sequence allows the widespread use of this technique.

g. Thymidine kinase (TK) gene mutation test

The Thymidine Kinase (TK) gene is located on autosomal chromosomes in mammals such as humans, mice and rats. The enzyme, which is the product of the TK gene, is an enzyme that works in the recovery pathway of nucleotides. In this analysis, mutant cells that lose the function of the TK gene under the influence of the applied test chemical gain resistance to the cytotoxic effects of trifluorootimidine (TFT), a pyrimidine analog that inhibits cellular metabolism and stops the next cell division. Thus, mutant cells proliferate in TFT-containing growth medium and are selected from non-mutant heterozygotes containing TK enzyme, which cannot grow in TFT-containing medium. The autosomal and heterozygous nature of the TK gene allows detection of cells lacking the Tk enzyme following mutation. This deficiency is caused by genetic events such as gene mutations (point mutations, frameshifts, small deletions, etc...) and chromosomal events (large deletions, chromosomal rearrangements, and mitotic recombination) that affect the TK gene (OECD TG 490, 2016; Yüzbaşıoğlu et al., 2016). This test, which is similar to the Ames test in terms of its basic approach, is used to detect forward mutations that provide resistance to a toxic chemical, unlike back mutations. This test allows widespread use of the test because of the determination of the effects of mutagens that can cause point mutations, deletions and/or mitotic recombinations and its applicability to different cell types.

h. Hypoxanthine phosphoribosyl transferase gene mutation test

The HPRT gene forward mutation test is based on the principle of selecting mutant cells for the enzyme HPRT, an enzyme required for purine biosynthesis. Mutant cells are selected in the medium containing 6-thioguanine (6-TG), a toxic nucleoside analog, and the test is performed by looking at the colony frequency. DNA base pair changes are highly reflective of genetic changes such as large or small deletions, inversions, and heterologous chromosome recombinations (Albertini, 2001). This test, which was developed in Chinese hamster ovarian cells, was revised over time and explained in detail in the OECD 476 guideline (OECD TG 476, 2016). Mutant cells deficient in HPRT enzyme activity in the HPRT test are resistant to the cytotoxic effects of the purine analog 6-thioguanine (TG). Therefore, mutant cells can proliferate in the presence of TG, whereas normal cells containing the enzyme Hprt (in the HPRT test) do not. Cytotoxicity is calculated by relative survival. Due to the non-autosomal location of the HPRT gene, the types of mutations detected in this analysis are point mutations, including base pair changes from small insertions and deletions, and frameshift mutations. Because the HPRT gene is found only on the X chromosome of humans and rodents, only one copy of this gene is active in each cell. Therefore, a mutation occurring in only one active HPRT locus results in the absence of a functional HPRT enzyme in a cell (Albertini, 2001; OECD TG 476, 2016).

CONCLUSION

In recent years, the number of genetic defects, genetic diseases and cancer cases has increased significantly. Although the causes of such defects and diseases are attributed to spontaneous mutations, continuous exposure in our environment. The effects of external physical and chemical agents that we are exposed to are too great to be ignored. In addition to these, genotoxicity tests should be performed for candidate drugs in the drug development process. Therefore, it is necessary to evaluate mutagens in terms of genotoxicity and to identify those with serious genotoxic risks. Expanding and developing the use of short-term genotoxicity tests that can be applied *in vitro* and *in vivo*, aiming to take precautions required. With the widespread use of these tests, it will be possible to predetermine the genetic response of individuals to any chemical agent, to detect predisposed individuals and to take necessary precautions by screening diseases such as metabolism disorders and cancer without clinical symptoms. The results obtained by genotoxicity tests in the development of drug active ingredients are important in terms of showing whether candidate drugs cause changes in human genetic material. Therefore, dissemination of genotoxicity tests in medical and drug development research is of great importance in terms of increasing human health and quality of life.

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CHAPTER III

PERFORMANCE OF SOME TURFGRASS SPECIES SOWN PURE AND MIXED IN TURKEY

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1.INTRODUCTION

Factors such as a rapid increase in population, unplanned urbanization, and industrial development have caused the widespread destruction of turfgrass in Turkey. However, as a result of this urbanization, especially in metropolitan areas, the importance of turfgrass has increased due to the desire for green areas, more attention being paid to landscaping, and the need for the public to spend more time in parks and garden areas. Turfgrass is now required for summer and winter living areas, in large housing estates with many residences, on football pitches and golf courses, around hotels and workplaces, in parks and roadside landscaping—in short, in all areas of public life. In this context, lawns, which people are in direct contact with in their daily lives, at home or at work, constitute the cornerstones of the urban green fabric along well-organized roads, around squares, and in pedestrian zones in urban spaces (Uzun, 1989). As mentioned above, the problems caused by rapid, irregular, and unplanned urbanization in parallel with population growth, as well as problems such as noise and traffic, adversely affect people's physical and mental health. This situation increases their sensitivity toward green areas in cities and strengthens their environmental awareness. The World Health Organization (2010),has stated that the per-capita green area in a city should be at least 9 m^2, while 10–15 m^2 is considered ideal. While the average green area per capita in developed countries is around 20 m^2, it varies between 1 and 9 m^2 in Turkey (Kırdar, 2013). Furthermore, WHO recommends an ideal green area of 50 m^2 per person (Morar et al. ,2014) These areas are not only visually appealing, but also have important ecological functions in terms of holding rainwater and soil in place and hosting many insects and burrowing creatures. Grass areas are defined as green areas, usually established from plants in the Poaceae family, that cover the soil surface, grow densely, have a homogeneous appearance, and are kept short by continuous mowing (Orçun, 1979). Cereals, which have the ability to form tufts, stolons, and rhizomes, are widely used in erosion control and green-area facilities. Understanding the ecological conditions these cereals thrive under is very important in establishing a resilient green area. In general, in our observations of turfed areas, the wrong species and mixtures tend not to have been successful and, at this point, we need to gather sufficient information to make better choices of species by examining the performance of turf plants regionally. According to Glab et al. (2020), turfgrass quality is commonly evaluated based on its functional characteristics and aesthetic value—that is, density, uniformity, texture, smoothness, ground cover, and color. Patton and Boyd (2007) found that cool-climate turfgrasses have the best turf quality in spring and fall, while turf quality decreases in summer. They identified *Festuca arundinacea*, which has a coarse texture compared to other cool-climate wheatgrasses, as being more resistant to heat and drought than other cool-climate grass species, so it has been more widely used than other cool-climate species and gives the best results in summer. Arslan and Orak (2011) recommended investigating certain wheatgrass species and mixtures of these. Tamkoç et al. (2012) found that perennial grass populations were greener in the spring, but the scale values were lower in the observations made in other seasons. In addition, the populations with high green characteristics in the spring in the first year maintained these characteristics in the second year.

In this study, we aimed to determine the characteristics and performance of the most suitable species of pure- and mixed-sown turfgrass for establishing in Tekirdağ, Turkey and under similar ecological conditions elsewhere.

2.MATERIALS AND METHODS

This study was conducted in the Sultanköy neighborhood of the Marmara Ereğlisi district of Tekirdağ province, Turkey, at the intersection of 41º01'35.5"N and 27º59'49.4"E, and at an altitude of 10 m. The study was conducted in 2013–2014. Sixty plots, each 2 x 1 m = 2 m^2 with three replications, were formed based on a randomized block experimental design. After the plots had been mown, fertilization was applied at a rate of 4 kg of pure nitrogen per decare. In the autumn, before winter, a compound fertilizer was applied at a rate of 15 kg per decare.

Perennial grass (*Lolium perenne* L.) Temprano, meadow bunch grass (*Poa pratensis* L.) Evora, red fescue (*Festuca rubra*) Relevant, and reed fescue (*F. arundinacea*) Meandre were selected as the study species. Based on Avcıoğlu (1997), we used 12.5 g of *Festuca* seeds, 40 g of *L. perenne* seeds, and 8 g of *P. pratensis* seeds per m^2.

The soil properties of the study area were neutral, with a pH of 7.35. There was a medium amount of organic matter (2.63%). The nitrogen content was low (0.13%), whereas the phosphorus (48 ppm) and potassium (474.23 ppm) contents were sufficient. The nitrogen deficiency in the soil was dealt with by nitrogen fertilization in certain periods to meet the nitrogen needs of the plants (Anonymous, 2013).

The total precipitation at the site was 471.7 mm in 2013 and 756.5 mm in 2014, the long-term average being 589 mm. The average temperature in 2013 was 15.4ºC and 15.5ºC in 2014. The average long-term temperature was 14ºC (Anonymous, 2018) (Figure 1).

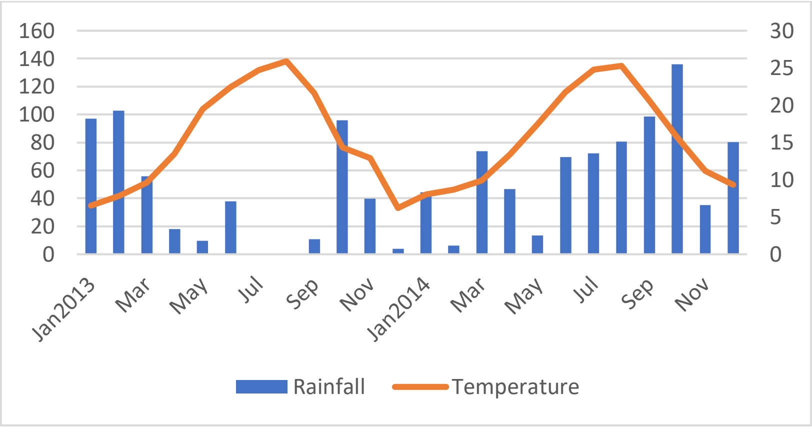

Figure 1. Monthly rainfall (mm) and mean temperature (^{0}C) in the experimental areas

Several observations were made during one vegetation period, based on the technical instructions of the Ministry of Agriculture and Forestry of the Republic of Turkey for the measurement of agricultural values (Anonymous, 2001). These included:

Plot cover speed (days)—the number of days between the sowing date and the date when 75% of the plot was completely covered with plants (Anonymous, 2001);

Weed rate (scale, 1–5)–in the second year, after the last mowing at the end of the vegetation period, the rate of weeds in the plot was observed and evaluated (1 = very high, 3 = moderate, 5 = no weeds);

General appearance (scale, 1–9)–the plot was observed each season and the general characteristics of each grass, its uniformity, color, texture, vigor, weeds, diseases, and pests, were evaluated (1 = very bad, 3 = bad, 5 = medium, 7 = good, 9 = very good) following Mehall et al. (1983) and Sills and Carrow (1983);

Winter hardiness (scale, 1–9)–observations were made at the end of February, before the beginning of spring growth (1 = very bad, all plants dead, 3 = bad, 50% of plants dead, 5 = medium, entire plot yellowed, 7 = good, less than 50% of the plot yellowed, 9 = very good, no yellowing of the plot);

Tiller number (scale, 1–5)–immediately after the second mowing in spring, the frequency of tillings in the plant tissue was examined and evaluated (1 = very sparse, 3 = moderate, 5 = very frequent), baaed on Anonymous (2001);

Leaf color (scale, 1–9)–observations were made in spring, summer, autumn, and winter and in the middle of each month to obtain the characteristic leaf color of each season (1 = yellow, 3 = light yellow-green, 5 = green, 7 = dark green, 9 = very dark green). Statistical evaluation of the data was performed using SPSS v. 15.0 for Windows software.

3.RESULTS AND DISCUSSION

Figure 2. General appearance of the field after the emergence of the grass seeds in the study plots.

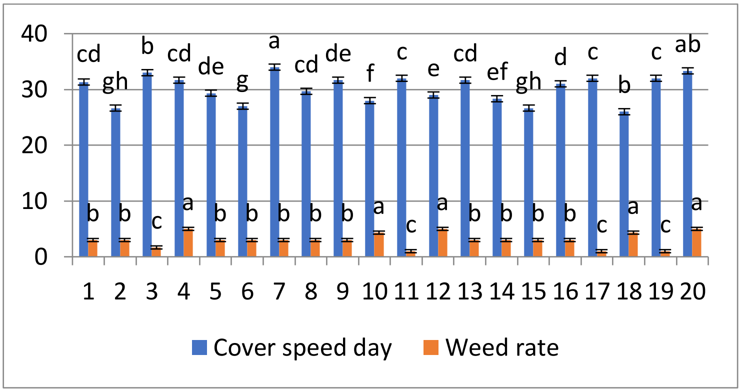

Figure 3. Plot cover speed (days) and weed rate (scale, 1–5)

1.%80 *F.rubra* + %20 *F. arun.* ,2. %80 *L.perenne* + %20 *P.pratensis,3.*%80 *P.pratensis* + %20 *F. arun.* 4. %80 *F. arun.* + %20 *L. perenne,5.* %35 *F. rubra* + %25 *L. perenne* + %15 *P. pratensis* + %25 *F. arun.* 6. %10 *F. rubra* + %40 *L. perenne* + %35 *P. pratensis* + %15 *F. arun.* 7. %25 *F. rubra* + %5 *L. perenne* + %40 *P. pratensis* + %30 *F. arun.,* 8. %25 *F. rubra* + %25 *L. perenne* + %25 *P. pratensis* + %25 *F. arun.* 9. %60 *F. rubra* + %30 *L. perenne* + %10 *P. pratensis, 10.* %70 *L. perenne* + %15 *P. pratensis* + %15 *F. arun.,* 11. %15 *F. rubra* + %15 *L. perenne* + %70 *P. pratensis, 12.* %15 *L. perenne* + %15 *P. pratensis* + %70 *F. arun.,* 13. %10 *F. rubra* + %10 *L. perenne* + %20 *P. pratensis* + %60 *F. arun.,14.* %30 *F. rubra* + %30 *L. perenne* + %30 *P. pratensis* + %10 *F. arun.,* 15. %20 *F. rubra* + %60 *L. perenne* + %10 *P. pratensis* + %10 *F. arun.,16.* %10 *F. rubra* + %10 *L. perenne* + %50 *P. pratensis* + %30 *F. arun.* ,17. %100 *F. rubra, 18.* %100 *L. perenne,19.* %100 *P. pratensis, 20.* %100 *F. arun* .Data presented are estimated mean values, where LSD is the least significant difference at the 0.05 significance level. Error bars correspond to the estimated common standart error of the mean values.

In evaluating the species in terms of plot cover speed rate in pure and mixture plantings, 25% *F. rubra* + 5% *L. perenne* + 40% *P. pratensis* + 30% *F. arundinacea* had the lowest coverage rate, at 34.0 days, and pure *L. perenne* had the highest coverage rate, at 26.0 days. The second fastest number of days to cover (26.66 days) was obtained with the mixture containing L. perenne (80% *L. perenne* + 20% *P. pratensis*) and %20 *F. rubra* + %60 *L. perenne* + %10 *P. pratensis* + %10 *F. arun.,* (Figure 3). The ecological conditions of the region can be a factor in plant performance. Oral and Açıkgöz (1999), Zorer (2003), all found that mixtures with a high percentage of *L. perenne* produced the highest coverage rate, whereas Zorer (2003) reported that mixtures with a high percentage of *Agrostis* sp. and *Festuca* sp. gave the lowest coverage rates.

For the weed rate scale, the plots planted with pure *F. arundinacea* (5.00:no weeds) and with a high mixture ratio (80% *F. arundinacea* + 20% *L. perenne*) scored the highest and fell into the same statistical group as the pure *L. perenne* plots (4.33:no weeds). The plots with 70% *P. pratensis* + 15% *L. perenne* + 15% *F. rubra* and pure *P. pratensis* and *F. rubra* scored the lowest (1.00: very high weeds). The difference between the mixtures was found to be statistically significant (P<0.05) (Figure 3). The low resistance of *Poa* species to weeds has previously been reported by Arslan et al. (2020), and this finding was confirmed in our study. In our research, it has been observed that *L. perenne* established rapidly in grass mixtures and thus also minimized weed growth.

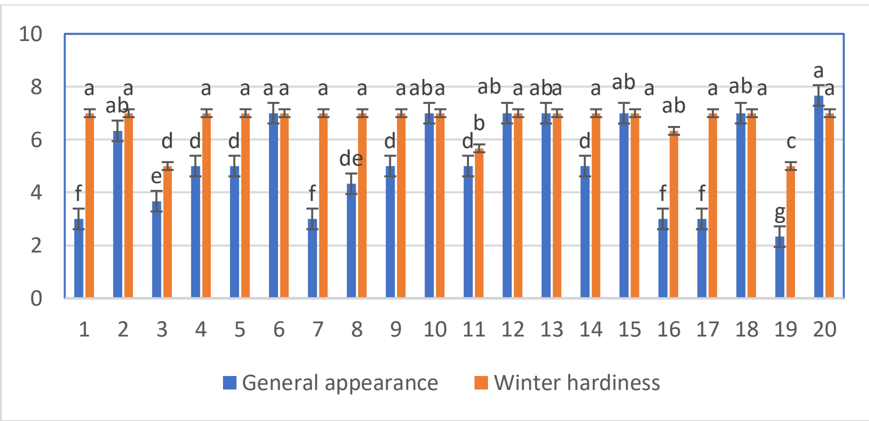

Figure 4. General appearence (scale, 1–10) and winter hardiness (scale, 1–10) of the difference turf species/mixtures

1.%80 *F.rubra* + %20 *F. arun.* ,2. %80 *L.perenne* + %20 *P.pratensis,3.*%80 *P.pratensis* + %20 *F. arun.* 4. %80 *F. arun.* + %20 *L. perenne,5.* %35 *F. rubra* + %25 *L. perenne* + %15 *P. pratensis* + %25 *F. arun.* 6. %10 *F. rubra* + %40 *L. perenne* + %35 *P. pratensis* + %15 *F. arun.* 7. %25 *F. rubra* + %5 *L. perenne* + %40 *P. pratensis* + %30 *F. arun.,* 8. %25 *F. rubra* + %25 *L. perenne* + %25 *P. pratensis* + %25 *F. arun.* 9. %60 *F. rubra* + %30 *L. perenne* + %10 *P. pratensis, 10.* %70 *L. perenne* + %15 *P. pratensis* + %15 *F. arun.,* 11. %15 *F. rubra* + %15 *L. perenne* + %70 *P. pratensis, 12.* %15 *L. perenne* + %15 *P. pratensis* + %70 *F. arun.*, 13. %10 *F. rubra* + %10 *L. perenne* + %20 *P. pratensis* + %60 *F. arun.,14.* %30 *F. rubra* + %30 *L. perenne* + %30 *P. pratensis* + %10 *F. arun.*, 15. %20 *F. rubra* + %60 *L. perenne* + %10 *P. pratensis* + %10 *F. arun.,16.* %10 *F. rubra* + %10 *L. perenne* + %50 *P. pratensis* + %30 *F. arun.* ,17. %100 *F. rubra, 18.* %100 *L. perenne,19.* %100 *P. pratensis, 20.* %100 *F. arun* .Data presented are estimated mean values, where LSD is the least significant difference at the 0.05 significance level. Error bars correspond to the estimated common standart error of the mean values.

In terms of general appearance (grass characteristics, uniformity, color, texture, vigor, weed, disease, and pest control), it was observed that pure *F. arundinacea* did not harbor weeds because it covered the ground very well, forming a dense texture. Although *F. arundinacea* is a C3 plant, it can grow like C4 plants in hot and arid conditions, as a result of which, the areas in which it is being used as a sustainable turf is rapidly expanding (Kır et al., 2010; Salman et al., 2011). *Festuca arundinacea* was also dark in color, had the highest weed control, and thus received the highest score (7.67) (Figure 4). Perennial ryegrass (*L. perenne*) has good shade tolerance, but does not perform as well in Oklahoma as tall fescue and Kentucky bluegrass due to disease, heat, and drought stress. Creeping red fescue (*F. rubra*) has excellent shade tolerance, but does not survive well during summer heat, often developing diseases, especially in the more humid Oklahoma counties (Moss et al. 2017).

The plots with pure *F. rubra*, *F. arundinacea*, and *L. perenne* had high winter hardiness (7.00), whereas the plots with pure *P. pratensis* had the lowest hardiness (5.00). *Poa pratensis* had the lowest winter hardiness compared with the other species, both when sown pure and in mixtures; as the proportion of *P. pratensis* in the mixture decreased, the winter hardiness of the plot increased. The difference between the mixtures was found to be statistically significant ($P<0.05$) (Figure 4). *L. perenne* and *F. arundinaceae* species scored high for winter hardiness (Özaydın et al., 2021).

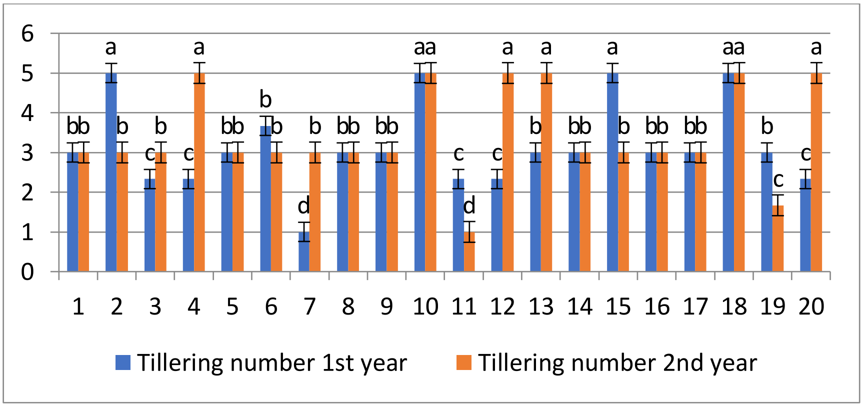

Figure 5. Tillering number scale, first and second years

1.%80 *F.rubra* + %20 *F. arun.* ,2. %80 *L.perenne* + %20 *P.pratensis,3.*%80 *P.pratensis* + %20 *F. arun.* 4. %80 *F. arun.* + %20 *L. perenne,5.* %35 *F. rubra* + %25 *L. perenne* + %15 *P. pratensis* + %25 *F. arun.* 6. %10 *F. rubra* + %40 *L. perenne* + %35 *P. pratensis* + %15 *F. arun.* 7. %25 *F. rubra* + %5 *L. perenne* + %40 *P. pratensis* + %30 *F. arun.,* 8. %25 *F. rubra* + %25 *L. perenne* + %25 *P. pratensis* + %25 *F. arun.* 9. %60 *F. rubra* + %30 *L. perenne* + %10 *P. pratensis, 10.* %70 *L. perenne* + %15 *P. pratensis* + %15 *F. arun.,* 11. %15 *F. rubra* + %15 *L. perenne* + %70 *P. pratensis, 12.* %15 *L. perenne* + %15 *P. pratensis* + %70 *F. arun.,* 13. %10 *F. rubra* + %10 *L. perenne* + %20 *P. pratensis* + %60 *F. arun.,14.* %30 *F. rubra* + %30 *L. perenne* + %30 *P. pratensis* + %10 *F. arun.,* 15. %20 *F. rubra* + %60 *L. perenne* + %10 *P. pratensis* + %10 *F. arun.,16.* %10 *F. rubra* + %10 *L. perenne* + %50 *P. pratensis* + %30 *F. arun.* ,17. %100 *F. rubra, 18.* %100 *L. perenne,19.* %100 *P. pratensis, 20.* %100 *F. arun* .Data presented are estimated mean values, where LSD is the least significant difference at the 0.05 significance level. Error bars correspond to the estimated common standart error of the mean values.

The number of tillers scale was evaluated per pure and mixed planting of each species and the tillering number scale was found to be the highest in the plots with pure *L. perenne* (5.00) and where its mixture ratio was high in the first year of the study, but with *L. perenne* showing good tillering performance in both years. In the pure *P. pratensis* plot, the number of tillers scale was moderate (3.00) in the first year and low (1.67) in the second year, and it had a low number of tillers and was sparse in mixed plots where it was the main component. While the number of tillers scale of *F. arundinacea* was low (2.33) in the first year, this increased (5.00) in the second year to form a dense grass cover. In terms of coverage rate, *F. arundinacea* was slow to develop in the first year, but then showed a good performance in tillering and coverage (Figure 5). In the second year, *F. arundinacea* had the highest tiller number scale in both its pure and high mixture forms. The effect of higher rainfall in the second year may also have had an effect.

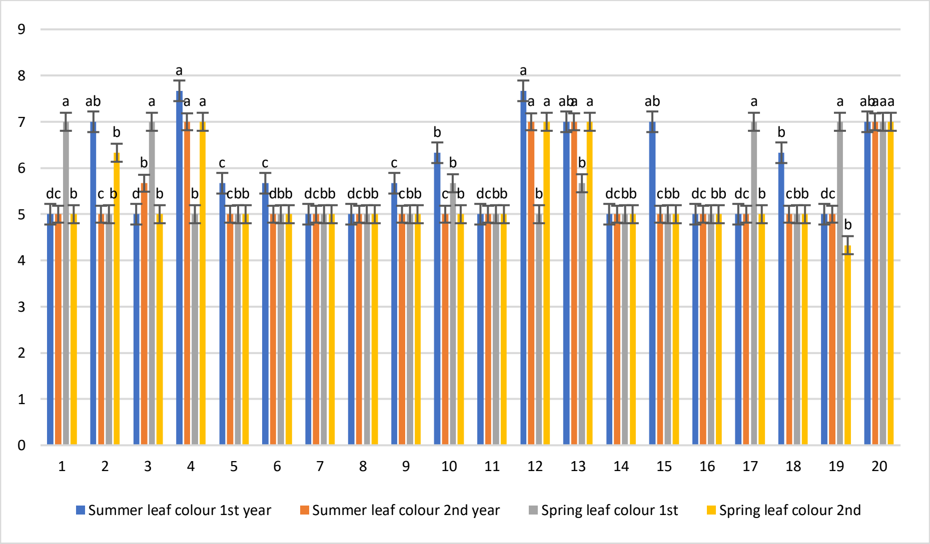

Figure 6. Leaf color, summer and spring

1.%80 *F.rubra* + %20 *F. arun.* ,2. %80 *L.perenne* + %20 *P.pratensis,3.*%80 *P.pratensis* + %20 *F. arun.* 4. %80 *F. arun.* + %20 *L. perenne,5.* %35 *F. rubra* + %25 *L. perenne* + %15 *P. pratensis* + %25 *F. arun.* 6. %10 *F. rubra* + %40 *L. perenne* + %35 *P. pratensis* + %15 *F. arun.* 7. %25 *F. rubra* + %5 *L. perenne* + %40 *P. pratensis* + %30 *F. arun.,* 8. %25 *F. rubra* + %25 *L. perenne* + %25 *P. pratensis* + %25 *F. arun.* 9. %60 *F. rubra* + %30 *L. perenne* + %10 *P. pratensis, 10.* %70 *L. perenne* + %15 *P. pratensis* + %15 *F. arun.,* 11. %15 *F. rubra* + %15 *L. perenne* + %70 *P. pratensis, 12.* %15 *L. perenne* + %15 *P. pratensis* + %70 *F. arun.,* 13. %10 *F. rubra* + %10 *L. perenne* + %20 *P. pratensis* + %60 *F. arun.,14.* %30 *F. rubra* + %30 *L. perenne* + %30 *P. pratensis* + %10 *F. arun.,* 15. %20 *F. rubra* + %60 *L. perenne* + %10 *P. pratensis* + %10 *F. arun.,16.* %10 *F. rubra* + %10 *L. perenne* + %50 *P. pratensis* + %30 *F. arun.* ,17. %100 *F. rubra, 18.* %100 *L. perenne,19.* %100 *P. pratensis, 20.* %100 *F. arun* .Data presented are estimated mean values, where LSD is the least significant difference at the 0.05 significance level. Error bars correspond to the estimated common standart error of the mean values.

Color is often evaluated in turfgrass experiments. The color of turfgrass is influenced by the species and variety, the soil properties, including water and nutrient availability, weather and light conditions, and the presence of disease (Glab et al., 2020). We observed that *L. perenne* was lighter in color than the other species, the other species being darker and close in color tone to each other. Aslan and Çakmakçı (2004) found that *L. perenne*, *F. rubra*, and *F. arundinacea* showed good performance in terms of color, with *L. perenne* having the highest value (8.0) in mixtures where it was in high proportion (Oral and Açıkgöz 1999; Arslan et al., 2020). Arslan et al. (2020) found the color variation to distinctively depend on the season for all the species we studied.

4.CONCLUSIONS

In evaluating the species based on general appearance, winter hardiness, and weed rate, *F. arundinacea* was found to be better than the other species in the pure plots and in the mixed plots where it was dominant. In addition to knowing which species are best to include in turfgrass mixtures and in what proportion for green areas, it is equally important to understand what the turfgrass will be used for in each situation. We suggest that a high ratio of *L. perenne* be included in mixtures where the characteristics of fine structure, light color, and rapid coverage are preferred, whereas a high ratio of *F. arundinacea* should be used in areas where weed control, a high coverage rate, and dark color are important. We found that pure sowings of *F. rubra* and *P. pratensis* did not give the desired performance in terms of the criteria tested for, given the ecological conditions of the region, and they would be more appropriate planted in mixtures.

Based on our observations, the best mixtures and ratios for creating a green area in Tekirdağ (or anywhere under similar ecological conditions) are:

1) %70 *L.perenne* - %15 *P. pratensis* – %15 *F. arundinacea*

2)%70 *F. arundinacea* - %15 *P. pratensis* - %15 *L.perenne*

3) %80 *F. arundinacea* - %20 *L.perenne*

4)%60 *F. arundinacea* - %20 *P. pratensis* - %10 *L.perenne* - %10 *F. rubra*

*This article is based on Murat Koçak's master's thesis. It was supervised by Prof. Dr. Canan ŞEN.

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CHAPTER IV

A REVIEW ON THE RELATIONSHIP BETWEEN PASTURE BIODIVERSITY AND MEAT AND MILK QUALITY OF GRAZING LIVESTOCK

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1.INTRODUCTION

Turkey is a unique country owing to its rich plant species diversity. According to "Flora of Turkey and The East Aegean Islands", Turkey has 1251 genera belonging to 174 families and more than 12,000 species and subspecies taxa (subspecies and varieties) (Davis 1965-1985). The European continent has about 12,000 plant taxa, and pastures are home to this rich flora. The composition of plant species in pastures is called botanical composition, the proportion of different plant species, and it is possible to evaluate the botanical composition in pastures based on species or families. Botanical composition varies depending on many factors, including soil structure, slope degree, groundwater status, climate, grazing management type, and grazing animal species. Therefore, each pasture shows a unique botanical composition structure consisting of different species. As a result, the variation in botanical composition leads to beneficial differences in the nutritional status of the animals grazing these pastures. In addition, such nutritional differences become more apparent as the animals graze selectively. Good quality pastures are also those areas where the most economical roughage need is met. For this reason, Turkey's livestock sector depends on pastures and benefits from these areas.

Grazing on a high herbage yielding pasture is a cheaper source of feed compared to more expensive concentrate feeds. According to Dillon et al. (2005), milk production costs are reduced by 2.5 cent per liter for every 10% increase in the proportion of grazed grass in Ireland. Besides, in pasture-based livestock breeding systems, grazing areas with rich plant composition and different plant families help animals grow healthier.

Sometimes, an animal product, such as meat, cheese, yogurt, or ice cream produced in a specific region can differ from those made in other areas. Such a product can gain consumers' appreciation concerning its processing technology and features, such as taste and aroma. Over time, this different and more preferred product will be distinguished geographically according to the factors contributing to its differentiation. One of these factors is the relationship between animal products and pasture species diversity, and it is vital to quantify the effect of endemic plant species of a region or the species that make up the botanical composition on pasture species diversity. Soycan Onenc et al. (2015)

reported that meat quality of sheep is affected by breed, vegetation and feeding practices. It has been revealed that the botanical composition of the pasture has significant effects on meat and milk composition (fatty acid; carotenoids) in pasture-based feeding systems of livestock (Collomb et al., 2002; Prache, 2005; Elgersma et al., 2006; Noziere et al., 2006; Sickel et al., 2014; Weddernburn et al., 2020; Kearns et al., 2023).

This review aims to examine the studies revealing the relationship between plant species diversity and meat and milk composition obtained from pasture-based animal feeding systems and to draw attention to the need for such studies in Turkey's pastures and animal husbandry, which have a rich biodiversity.

2.REVIEW AND DISCUSSION

2.1.Pasture-Based Nutrition and Fatty Acid Composition

Fresh forages are an important natural source of vitamins and fatty acids (FA) in ruminant diets, and their concentrations in forage species also determine the quality of animal-derived foods, such as dairy and meat products (Elgersma et al., 2013). Thus, to improve the biodiversity and sustainability of ruminant feeding systems, there is a move towards grazing on botanically diverse pastures (BDP), which contain a range of different plant species. This poses an opportunity to combine a range of plant species that can provide unique dietary (FA), antioxidants and secondary metabolite compounds compared to individual species over the full grazing year. Despite the potential of BDP, very little research has been conducted into whether grazing animals on BDP can improve the meat composition. Most studies have compared animals grazing on perennial ryegrass monocultures or two-species pastures (Kearns et al., 2023).

The health of livestock, humans, and ecosystems is tied to plant diversity and the associated phytochemical richness across landscapes. Health is enhanced when livestock forage on phytochemically rich landscapes. However, it is reduced when livestock graze on simple mixtures or monoculture pastures or consume high-grain rations in feedlots. Similarly, it is also significantly reduced for people who eat highly processed diets (Provenze et al., 2019). For example, it was reported by Elgersma et al. (2003) and Moloney (2008) that

FAs, which are beneficial for human health, are highly concentrated in dairy and meat products originating from pasture rich in botanical composition. Circumstantial evidence also supports the hypothesis that the phytochemical richness of herbivore diets enhances the biochemical richness of meat and dairy, which is linked with human and environmental health (Provenze et al., 2019). Furthermore, among many roles they play in health, phytochemicals in herbivore diets protect meat and dairy from protein oxidation and lipid peroxidation that cause low-grade systemic inflammation implicated in human heart disease and cancer. Nevertheless, epidemiological and ecological studies critical of red meat consumption do not discriminate among meats from livestock fed high-grain rations as opposed to livestock foraging on landscapes of increasing phytochemical richness (Provenze et al., 2019).

It can thus be said that there is a relationship between the pasture-based nutrition of animals, the plant species composition of the pasture, and the nutrient content and quality of animal products. Specifically, pasture feeding has important effects on the sensory properties of dairy and meat products, as grazing on pasture leads to the formation of specific compounds with aromatic and functional properties (Prache et al., 2005). Many studies reveal that the quality and flavor of animal products grazing on pasture are unique (Bérodier, 1997; Monnet et al., 2000; Luciano et al., 2011; Ponnampalam et al., 2017; Kearns et al., 2023). Even more, many of these compounds also hold health benefits as they exert an antioxidant effect, preventing oxidative degradation of unsaturated FAs and cholesterol, helping to reduce the risk of cardiovascular disease and tumors, and increasing the shelf life of dairy and meat products. These compounds can also be used as biomarkers for the traceability of animal nutrition on pasture (Prache et al., 2005).

Regarding the feeding system, cows can be fed either indoors in a feedlot on a diet of mixed ration or, in areas with temperate climates, such as Ireland and New Zealand, the feeding regime of dairy and beef herds is almost entirely pasture-based. Animal feeding regimes and herd management practices are linked to differences in organoleptic and nutritional quality attributes of milk, dairy, and meat or beef products, with pasture-based feeding systems being associated with superior-quality produce (Stanton et al., 2021). Consumers generally perceive milk and meat products from animals raised on free-range grazing as healthier than produce derived from intensive indoor feeding systems where animals are fed typical indoor rations and concentrates. However, while research has demonstrated differences in milk and meat quality of different feeding systems, especially regarding FAs, data on the impact of dairy and meat products produced from different feeding systems on human health are limited (Stanton et al., 2021).

To better understand the role of FAs in the quality of meat products, it is important to revise the types of FAs. The two primary essential FAs are linoleic acid and a-linolenic acid. Polyunsaturated FAs (PUFAs) are involved in forming hormone-like compounds and are divided into omega-6 (co-6) and omega-3 (to-3) (Newton, 1997). Unsaturated linolenic acid(C18:3) is a characteristic fatty acid of feed lipids (Wood et al., 1999). Linoleic acid (C18:2), linolenic acid (GLNA, C18:3), and arachidonic acid (ARA, C20:4) are the most critical o j-6 PUFAs and are generally found in plants. The known d-3 PUFAs are a-linolenic acid (ALNA, C18:3) and its metabolites eicosapentaenoic acid (EPA, C20:5) and docosahexaenoic acid (DHA, C22:6) (Bayizit 2003). Fish, fish oils, and some vegetable oils are rich sources of essential FAs. Many studies have positively correlated essential FAs with reduced cardiovascular morbidity and mortality, infant development, cancer prevention, optimal brain and vision functioning, arthritis, hypertension, diabetes mellitus, and neurological or neuropsychiatric disorders (Kaur et al., 2014).

Considering this, meat and dairy products from pasture-grazing animals are perhaps best known for their nutritional differences in FA content and composition. Compared to products from grain-fed systems, meat products from pasture-fed animals contain less fat and higher proportions of more beneficial fats such as α-linolenic acid, the building blocks of omega-3 essential fatty acids (Wood and Enser, 1997; Wood et al., 2008). Additionally, compared with grass/clover/maize silage, cows grazing grass/clover pasture have been found to produce milk 70% higher in beneficial omega-3 FAs, which increased by an additional 15% when grazing more diverse pasture (Loza et al., 2023). Likewise, Lourenço et al. (2007) reported that grazing forage with different botanical compositions caused the difference in FA composition in the longissimus muscle and subcutaneous fat of sheep. Those results demonstrated that forage nutrition may be an essential effector for changing the meat quality and contents of AA and FA in the muscle and adipose tissues during the different grazing periods. Different nutritional systems thus evidently affect the composition of muscle FAs, and the FA composition of meat also plays a vital role in the flavor (Elmore et al., 2000).

Furthermore, Witkowska et al. (2008) found that there was a significant positive correlation between FA concentrations of wheatgrasses and different nitrogen doses and nitrogen contents C16:0, C18:2, and C18:3. In another study, Díaz et al. (2002, 2005) reported that lambs fed with concentrate showed a lower percentage of C18:0 and higher C18:2 than lambs fed on pasture. Spanish lambs showed the highest proportion of C18:2 and the lowest C18:0. In contrast, Uruguayan and German lambs had the highest percentage of C16:0. The proportions of C18:3 and C20:5 were higher with grass-fed lambs (mainly Uruguayan) compared with those reared intensively using concentrates (Spanish and German lambs). These differences in FA composition could be principally related to differences in the feeding production system (grass or concentrate). In other research, Sanudo et al. (2000) compared English lambs grazing on a natural pasture with Spanish lambs receiving concentrated feed. They found that English lambs had higher levels of stearic acid, linolenic acid, and long-chain PU n-3 but lower levels of linoleic acid and long-chain PU n-6 than Spanish lambs. Panelists gave higher scores to British lamb (with a high level of 18:3) and lower scores to Spanish lamb (with a high level of 18:2) for odor and flavor intensity. Linolenic acid oxidation products have been associated with species-related meat flavors (Marmer et al., 1984).

Meat from grass-consuming ruminants is protected from oxidation by antioxidants in the grass (Wood et al., 1999). Young and Baumeister (1999) stated that linolenic acid plays a crucial role in determining meat aroma and suggested that one of the compounds responsible for the pastoral odor in grazing cattle is 4-heptenal, a product of linolenic acid oxidation. The eating quality (e.g., flavor and texture) of meat and dairy products from pasture-fed animals is generally perceived positively by consumers. The FA composition of meat and milk products from pasture-fed animals differs from those of concentrate-fed animals in their production system, giving meat and milk, butter, cheeses, and fats yellow and developing sour flavors.

In milk, several studies have shown that different types of pastures (cultivated v. natural) produce substantial differences in the milk FA profile (Coppa et al., 2015a, Prache et al 2020). Coppa et al., (2015b) investigated the effect of grass phenology on the fatty acid (FA) composition of milk and its interaction with the proportion of fresh grass in cow diets under controlled conditions and they reported that the forage FA profile largely varies with pasture phenological stage, botanical composition, and grazing management. According to Collomb et al. (2002), certain plant species have been positively correlated with higher PUFA in milk. However, it is not so easy to prove the direct effect of plant species on the chemical composition of milk, especially regarding the FA profile of milk fat. It is thus clear that many factors influence the FA profile.

Conjugated linoleic acid (CLA) has been indicated as one of the most beneficial FAs for human health (Pariza, 2004). Levels of CLA in milk and dairy products are of particular nutritional interest since the primary sources of CLA for humans are dairy and meat products from ruminant animals, with dairy contributing up to 70% of total CLA intake (Lawson et al., 2001; Wahle et al., 2004; Avilez et al., 2013). Having ruminants graze on natural and/or improved pastures can also produce a high CLA content in raw milk (Gómez-Cortés et al., 2009; Avilez et al., 2012), and the CLA content of milk also increases when cows are offered grass as grazing (Lawson et al., 2001). Elgersma et al. (2006) add that cows grazing fresh grass on pastures with a high herbage allowance produce milk with the highest concentration of omega-6 PUFAs. Kelly et al. (1998) also reported that changing cows from indoor feeding to pasturing showed a quick response in the CLA content of milk. On the other hand, a lower CLA content has been observed in cows grazing mature pastures, possibly due to the declining quantity and quality of the herbage (Lock and Garnsworthy, 2003; Ward et al., 2003; Avilez et al., 2012).

Milk and meat from cattle grazing grassland, particularly botanically diverse pastures, have higher concentrations of FAs and antioxidants that benefit human health. As mentioned, the grazing system affects the FA composition of milk. However, more research is required to explain the effects of botanical composition or forage conservation on milk quality. In addition, primary milk producers should focus on improving milk quality because they can obtain particular benefits from the higher market value at the end of the food value chain (Stypinski, 2011).

According to Alothman et al. (2019), pasture feeding has been shown to increase concentrations of various beneficial nutrients in milk, including vaccenic acid, CLA, ß-carotene, and α-linolenic acid. Such changes affect the nutritional composition and the sensory characteristics of dairy products produced from milk. The feeding system has also been demonstrated to impact milk's functional properties, color, and textural properties. Therefore, the impact of the feeding system on cow milk's composition and processability has been an active area of research, through which various potential biomarkers of pasture feeding have been identified. Future work to develop robust methods for verifying pasture-derived dairy products will be important as grass-fed dairy products become more prominent on shop shelves. Grains feed are rich in linoleic acid (C18:2), but lower in linolenic acid (C18:3). Meadows, however, are rich in linolenic acid, but poor in linoleic acid. Therefore, the amount of CLA in meats of farm animals fed with rations high in grain proportion is lower than those grazing at meadows and pastures. In other words, the source of high CLA amount in the meat of ruminants grazing at meadows is linolenic acid (Önenç and Özdogan 2022).

Furthermore, studies by Morand-Fehr et al. (2007) have also shown that indoor feeding systems with a very high level of intensification, rich in maize silage, and concentrated feed with low forage-to-concentrate ratios may reduce the quality of milk and cheese, producing a low fat content, low smoothness of cheese, and a granular paste. Accordingly, the farmer must find a management balance by choosing a level of intensification likely not to damage the quality of milk intended for cheese-making. Equally important, farmers must select farming and feeding systems following trade conditions, consumer demands, and socio-economic conditions in the future. If they can access markets where commercialization of high-quality and high-price cheeses is possible, they will have to define systems that allow optimization of quality parameters, even by limiting milk production. Developing countries may even play a role in such markets if they are positioned to commercialize their products with good sanitary quality.

In another study, Dierking et al. (2010) found that the FA composition of the distinctive pasture types did not influence the intramuscular fat composition in beef steers. This may be due to the low polyphenol oxidase (PPO) in the red clover (RC) treatment; perhaps the percentage of red clover in this study was inadequate in increasing the PUFA of the intramuscular fat. The duration of the experiment also may not have been long enough to allow the accumulation of PUFA that would typically be seen in an animal consuming only a forage diet.

The pasture type may impact the FA profiles of meat, but different studies have obtained varying results. For example, Ramírez-Retamal et al. (2014) grazed sheep on pastures with two different botanical compositions: natural pasture and rangeland. The animals fed on naturalized pastures had higher percentages of monounsaturated FA (MUFA) and lower PUFA than lambs fed on rangeland pastures. In addition, lambs fed on rangeland pastures showed higher percentages of n-6 and n-3. Whittington et al. (2006) reported that meat from lambs grazed on heather (dominant species: *Calluna vulgaris, Vaccinium myrtillus,* and *Deschampsia flexuosa*) and mooreland (dominant species: *Festuca ovina, D. flexuosa,* and *Nardus stricta*) had significantly higher n-6, C22:6, and n-3 PUFAs compared to sheep grazed on perennial ryegrass. However, Marley et al. (2018) reported no significant difference in FA ratio in cattle grazing perennial grass or perennial grass/dandelion. Also, in research by Sickel et al. (2014) on the effects of vegetation and grazing preferences on the quality of alpine dairy products, the results of the statistical modeling indicated that the different plant groups on the rangelands were significantly correlated to specific chemical components in the milk. The omega-3 FA C18:3 and β-carotene were both positively related to herbs.

2.2.Pasture Biodiversity

Pasture productivity increases with pasture improvement and management. In a study conducted in a pasture in Tekirdağ, Altın et al.(2010) reported an average herbage yield of 1665 kg/da from plots with nitrogen fertilizer application and 845 kg/da from plots without fertilizer. Fertilizing primarily effects botanical composition and canopy cover of a rangeland. With fertilizing, botanical composition was determined to increase rates of Fabaceae and Poaceae and reduce the rates of other families in transect and point-frame measurements in the fertilized area. Fertilization significantly increased the production and intake of grass. According to Salcedo and Bonet, (2014) the content of C18:2 and C18:3 compared to the control N 0 pasture was 7.3%-23% higher for N 84 and 23-30% with N 168 , while ingestion of C18:3 increased by 31% in N 84 and 47% in N 168 . Linolenic intake from pasture was 31 and 47% higher than control for N 84 and N 168 , respectively

Changes in plant compositions will also cause differences in the composition of the feed produced, such as protein, fatty acids carotenoids. For this reason, we should ask the question of what kind of botanical composition we want in the pasture according to animal feeding and animal feed preferences. Then we should determine pasture improvement practices such as seeding, irrigation, weed control, and fertilization.

The biodiversity of rangelands is naturally composed of different plant species, and the plant composition consists of Fabaceae, Poaceae, Asteraceae, Lamiaceae, and other families. Grasses, one of the main productive species of pastures, meet the carbohydrate needs of animals and are the most grazed species by cattle. Other families, such as Asteraceae, Lamiaceae, and Plantaginaceae, are also known to be grazed significantly by animals. Species belonging to Lamiaceae family can increase the aroma in the meat and milk of animals, such as fragrant thyme (*Thymus sp*.) and sage (*Salvia* sp.). Furthermore, another compound of interest is terpenes, a large group of unsaturated hydrocarbons divided into monoterpenes and sesquiterpenes. They originate from the secondary metabolism of plants, especially dicotyledons, such as Apiaceae, Lamiaceae, Asteraceae, and, to a lesser extent, Poaceae, and are characterized by an intense odor. Therefore, the terpene content in ruminant products is a function of the botanical composition of pastures (Fedele et al., 2004).

Among the plant families that form part of rangeland biodiversity, legumes (Fabaceae) are a source of protein and vitamins for animals. They are grazed mainly by sheep but are also essential protein sources for cattle. The genus *Trifolium* from the Fabaceae family is the most important in pastures, with 67 species in the European part of Thrace (Zohary and Heler, 1984). In addition, *Trifolium* species, such as *Trifolium repens, Trifolium arvense,* and *Trifolium* *pratense*, are used as an expectorant, analgesic, and antiseptic (Baytop,1984). Regarding their composition, *Trifolium repens* and *Trifolium pratense* are FA dominant (Body, 1974; Thomson and Knight, 1978), and *Trifolium nigrescens* is rich in carotene linoleic acid (Sabudak et al., 2009).

Regarding *Medicago* species, the total saturated fatty acid levels have been determined to be between 14.22 and 26.05%, with *Medicago sativa* having the lowest levels and *Medicago minima var. minima* the highest concentrations (Bakoğlu et al., 2010). On the other hand, Bagci et al. (2004) investigated the unsaturated fatty acid composition of *Medicago* species and reported high levels in other family members of Fabaceae. *Medicago sativa* had the highest level of unsaturated fatty acid (83.46 %), followed by *M. lupiluna* (78.55 %), *M. rigidula var. rigidula* (75.9 %), *M. rotata* var. *eliezeri* (75.01 %), and *M. minima var. minima* (70.71 %). *Vicia ervilia* and *Onobrychis fallax* (Fabaceae) have 80.43% and 79.58% unsaturated fatty acid concentrations in their seed oils (Bakoğlu et al., 2009, 2010).

Elgersma et al. (2013) obtained novel information on vitamins and FAs in various forage legumes and non-legume forb species compared to a grass-clover mixture and explored implications for animal-derived products. Lucerne and yellow sweet clover had the lowest α-tocopherol concentrations (21 to 23 mg kg^{-1} DM) and salad burnet and ribwort plantain the highest (77 to 85 mg kg^{-1} DM); β-carotene concentrations were lowest in lucerne, salad burnet, and yellow sweet clover (26 to 33 mg kg^{-1} DM) and highest in caraway, birdsfoot trefoil, and ribwort plantain (56 to 61 mg kg^{-1} DM). Total FA concentrations were lowest in lucerne, ribwort plantain, chicory, and yellow sweet clover (15.9 to 19.3 g kg^{-1} DM) and highest in caraway and birdsfoot trefoil (24.5 to 27.0 g kg^{-1} DM). Birdsfoot trefoil had the highest (53.6 g 100 g–1 FA), and caraway and lucerne had the lowest (33.7–35.7 g 100 g–1 FA) proportions of n-3 FA.

Collomb et al. (2002) found a positive correlation between PUFA concentrations and species belonging to Asterecae, Fabaceae, Apiaceae, and Rosaceae families. For example, to investigate the effect of grazing pastures with a different botanical composition on rumen and intramuscular FA metabolism, Lourenço et al. (2007) assigned 21 male lambs to three botanically different pastures: botanically diverse (BD) (consisting of 65% of various grass species), Leguminosa rich (L) (61% of Leguminosae), and intensive English ryegrass (IR) (69% Lolium perenne). They suggested that grazing different pastures induced changes in the rumen microbial population, which are most likely the reason for differences in biohydrogenation of PUFA. Furthermore, grazing a more diverse pasture might affect intramuscular FA metabolism, as suggested by PUFA desaturation and elongation indices. However, differences between treatments regarding absolute fat deposition might have provoked some confounding effects. Finally, higher PUFA proportions in the abomasum, subcutaneous, and intramuscular fat were observed in lambs grazing a leguminous-rich pasture.

Phenolic compounds are also specific to each plant species, and the phenolic profile of natural grasslands varies with botanical composition (Besle et al., 2010, Prache et al., 2020). Phenolic compounds are secondary metabolites found in plants that can transfer into milk or meat either directly unchanged or partially converted by rumen bacteria or host animal metabolism (Prache et al., 2020). Pasture grasses and legumes have a wide range of polyphenol compounds with potential antioxidant capacity. For example, chicory and perennial ryegrass have been found to contain higher phenolic acid concentrations, while plantain, brassica, and lucerne contain higher concentrations of flavonoids (Amrit et al., 2023). Besle et al. (2010) also showed that analyzing phenolic compounds in milk enables clear discrimination of diets based on hay, grass silage, maize silage, and grazed grass. However, phenolic compounds and the suitability of these compounds need to be investigated further (Prache et al., 2020).

Several other compounds also affect meat flavor, including terpenoids and carotenoids. Terpenoids, also known as terpenes, positively influence the flavor of milk and dairy products derived from native pastures with diverse species of grasses, forbs, and shrubs that produce many more terpenes than monocultures of grasses (Provenza, 2019). Terpenoids are transferred directly from pasture to animal tissue, and the presence of these compounds in animal tissues depends mainly on the botanical composition of the pasture (Martin et al., 2005). Different aromas in the meat or milk of pasture-grazed animals are sometimes not preferred by consumers. The pastoral aroma produced when animals graze on pasture can have a negative impact on consumer acceptance of sheep meat.

Several options are available to modify pastoral aroma in sheep meat, but the use of condensed tannin (CT) feeds has the greatest potential. (Schreurs et al., 2008)

In a study by Larick et al. (1987), they found that the concentration of neophytadiene in beef fat was four times higher in animals grazing tall fescue (*Festuca arundinaceae*) than in those grazing smooth bromegrass (*Bromus sp -Trifolium pratense*) or orchard grass (*Dactylis glomerata)* -red clover(*Trifolium pratense*) and that neophytadiene decreased when animals were fed corn for 56 days. Therefore, wheatgrass species in the pasture can cause significant differences in the meat fat of animals.

2.3.Compounds Affecting Color and Flavor

Carotenoids impart a yellow color and positively influence the flavor of milk and cheese (Provenza, 2019). Carotenoids, such as carotenes and xanthophylls, are pigments occurring in the vegetative parts of plants, leaves, seeds, fruits, and stems of pastures, fodders, and trees (Kearns et al., 2023). Carotenoid pigments such as Lutein and β-Carotene are present in high amounts in green feeds, while their content is reduced by 70-90% in concentrate feeds (Prache et al., 2005).

They are also involved in dairy products' nutritional and sensory characteristics and are potential biomarkers for traceability of cow feeding management (Nozi`ere et al., 2006). Carotenoids cannot be synthesized de novo by animals and are produced exclusively by higher plants; therefore, the carotenoid content of animal tissue and the resultant meat is directly influenced by their dietary carotenoid intake level (Calderon et al., 2007). In part, carotenoids are stored in the lipids of milk fat and adipose tissue, giving them a yellow color. Milk from grass-fed cows contains more protein and fat, resulting in dairy products of higher eating quality and notably different flavors often described as pastoral (Wedderburn et al., 2020). Pasture-based products also contain carotenoids, antioxidants that enhance the preservation of meat products, as well as precursors of vitamin A1 (retinol), which plays an important role in vision. Besides fats and vitamin A, condensed tannins, flavonoids derived from pasture-based plants can influence the functional properties of the meat product (Craigie and Loveday, 2020). Duckett et al. (2013) and Stanton et al. (2021)

have also reported that the external fat of pasture-derived beef is more yellow due to increased β-carotene in adipose tissue. While flavor acceptability varies depending on individual preference and cultural norms, trained sensory panelists reported that meat from pasture-finished cattle lacked beef flavor and presented greater off-flavors than beef from grain-finished cattle. Interestingly, unlike cattle, sheep and goats convert carotenoids into vitamin A; therefore, the fat of their dairy products and meat remains white (Avondo, 2013).

In studies where animals grazed BDP, the botanical composition of the pasture was not always clear, making it difficult to relate the nutritional composition of the meat to that of the field. Plant species, seasonality, and weather conditions significantly impact pasture's carotenoid content. More studies of animal grazing behavior are required to better understand the potential selective activity for specific plants in BDP, which could dramatically change the carotenoid content of ingested diets compared to the available diet (Kearns et al., 2023).

Carpino et al. (2004) found that products from grazing cows can be a good biomarker of pasture feeding as compared to those from cows housed indoors. In meat production, pasture grazing has greater difficulty in achieving consistency of quality due to the variation in diet and the time it takes animals to reach final weights. Additionally, older animals generally have higher levels of connective tissue in the muscles, which affects meat texture, and meat color tends to darken as animals age due to increased levels of myoglobin. In markets where animals are processed at a younger age, this phenomenon can easily be confused with dark cut, a quality defect caused by pre-slaughter stress. Given the requirements of specific demographics, such as active aging and sports persons, pasture-fed meat products from older animals provide desirable increases in their nutritional collagen and iron content.

Finally, appropriate pasture management can contribute to soil conservation by differentiating between ecological conditions on different soils, thereby creating a unique heritage of great value in terms of diverse pasture vegetation types, biodiversity, and the ability to sustain local production activities. Moreover, pasture biodiversity can be a key factor in the development of animal agriculture by imparting typical traits related to aromatic compounds and health-promoting properties, depending on the functional substances transferred from the plants ingested by grazing animals (Avondo et al., 2013).

3.CONCLUSION

The rapid increase in the world population increases the demand for animal products. Especially in countries with low economic levels, the capacity to provide people with animal products may be limited, and animal protein needs cannot be met. Thus, obtaining high yields at a low input cost in animal nutrition is vital to producing less expensive products. To this end, animal breeding, welfare, and nutrition are some factors to be considered in increasing animal productivity. In intensive agricultural systems in temperate or arid regions with low pasture productivity, cattle breeders may often not prefer pasture-based feeding systems for reasons relating to the effect thereof on animal products or animal health. However, there is a need for animal feeding systems that will provide quality, affordable, and productive products. The review of the scientific literature shows that the biodiversity of the pasture has important effects on the quality of meat and milk products of grazing animals. In pasture-based feeding, a more economical feed source, creating vegetation with high herbage quantity and feed quality can ensure that animal products are produced more efficiently and of higher quality. Each pasture has unique characteristics in terms of biodiversity and ecological factors, such as climate and soil characteristics. Therefore, livestock that graze pasture have the chance to feed on different plant species. Many features, such as livestock preferences, seasonal species structure of the field, and phenological status of the plants, create important differences in this way of feding. An animal product produced in one region often differs from those originating from other areas. When the quality of meat and dairy of animals grazing different areas of pasture with diverse species, these can be classified as specialty products. These products, like meat, milk, cheese, yogurt, and ice cream, obtained from extensive feeding systems will also have distinct tastes, smells, and colors, and many consumers will prefer and appreciate them due to their processing technology, taste, and aroma. Over time, this product receives a geographical indication according to the factors contributing to its differentiation, such as the relationship between animal products and pasture species diversity. Here, understanding the effect that the endemic plant species or the species that comprise the botanical composition have on pasture species diversity is essential.

Livestock producers can choose extensive, semi-intensive, or intensive feeding systems according to these preferences. Thus, the content of livestock products essential to human nutrition and health will be determined more clearly with these studies. Further research on these issues will provide resources for producers.

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CHAPTER V

CALCIUM AND POTASSIUM APPLICATIONS IN ADDITION TO STANDARD FERTILIZATION INCREASE YIELD IN CUCUMBER

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1.INTRODUCTION

Cucumber (*Cucumis sativus L*), one of the essential vegetable species grown in soilless agriculture, is a member of the Cucurbitaceae family. This family includes 90 genera and 750 species. The origin of cucumber plant is based in India or Burma, and it is a species with great diversity in terms of vegetative properties and fruit characteristics. The cucumber plant, first cultivated 3000 years ago, spread from India to China and then to the Ancient Greeks and Romans (Yılmaz, 2019). Cucumber is one of the oldest cultivated vegetable species and grown in almost all countries of most climatic zones (Tatlıoğlu, 1993).

According to FAO data, in 2021, 93,528,576 million tons of cucumbers were produced in 2,172,193 ha of land worldwide. In world cucumber production, the Asian continent ranks first (83.7 million tons), followed by Europe (6.1 million tons), America (2 million tons), Africa (1.5 million tons) and Oceania (60.7 thousand tons). While China ranked first in world cucumber production with 75.6 million tons, Turkey ranked second with 1.9 million tons and Russia ranked third with 483 thousand tons (FAOSTAT, 2023). Our country ranks second after cucumber tomatoes in the production of vegetables under cover (TÜİK, 2023).

Cucumber fruit contains a high percentage of water (96.73 g/100 g), while its energy content is quite low (12 Kcal/100 g). 100 g of cucumber fruit contains 136, 21, 14, and 12 mg of potassium, phosphorus, calcium and magnesium, respectively. Cucumber fruit helps to remove toxins from the body if consumed daily due to its high water content. It regulates blood pressure due to the fibers in its shells and the mineral substances it contains, so it also has a positive effect on blood circulation (USDA, 2023).

The elements necessary for the development of plants are; carbon (C), hydrogen (H), oxygen (O), phosphorus (P), potassium (K), nitrogen (N), sulfur (S), calcium (Ca), magnesium (Mg), iron (Fe), boron (B), manganese (Mn), copper (Cu), zinc (Zn), molybdenum (Mo) and chlorine (Cl). Of these, C, H and O are largely supplied by air (carbon dioxide and oxygen) and water (H). While these nutrients are supplied from the soil in soiled cultivation, a small amount is provided from the substrate in the culture or from the water in the hydroponic culture in soilless agriculture. Therefore, a large part of these mineral substances are given to the plant by fertilization. Of the nutrients N, P, K, S and Mg; It is called a macro element because it is more necessary for plants than other elements, and the other seven elements are called microelements because they are found at ppm level in plant tissues and plants need these nutrients less (Hochmuth, 2015).

Potassium (K), which is included in macronutrients, is an essential nutrient element that has a critical role in the physiological structure of all plants. Potassium is the activator of up to 60 enzymes necessary for the growth and metabolism of the plant. Potassium provides the opening and closing of the stomata by regulating the turgor of the guard cells in the stomata in the plant leaves and thus the exchange of gas and water vapor in the plant through the stomata and also regulates the water balance of the plant through the root osmotic gradient. The control of ATP formation in photosynthesis also increases the transport of mineral nutrients in the xylem, and organic compounds in the phloem, especially carbohydrates, take part in protein synthesis and reduce the sensitivity of plants to diseases and abiotic stresses. The presence of sufficient potassium in the plant increases the production and transport of carbohydrates, allowing the plant to withstand low temperatures, salinity, drought, and diseases. Therefore, the K necessary to raise the K level in the critical organs of the plant must be provided through fertilization. Severe K deficiency reduced starch accumulation in the leaves, reducing sugar transport within the plant. The cucumber plant is the only plant with a high potassium demand and needs more potassium than nitrogen. (Schwarz, 1995; Olfati, 2015)

Calcium, another essential nutrient among macronutrients, is necessary for calcium pectates in the structure of plant cell walls. In addition, calcium is used as a cofactor for some enzymatic reactions. It has been determined that calcium is necessary for special cell reactions induced by the calmodulin molecule in recent years (Hochmuth, 2015; Anonymous, 2018). Calcium plays a crucial role in increasing the strength of the cell wall by taking part in the structure and function of cell membranes. Calcium also reduces susceptibility to diseases. Calcium treatment on cucumber plants under saline conditions reduced the sensitivity of the plant to salt. In cucumber plants grown under conditions containing three different salt concentrations of 2, 4, 8 mS/cm, and 7.4 meq/L of calcium chloride, the dry weight of shoots and roots increased with the decrease in Na/Ca ratio under salt conditions of 4.0 mS/cm (Al-Harbi, 1995). Most calcium-related diseases occur due to improper growing conditions and calcium deficiency in the root zone in plants. Fast-growing plants during periods of hot winds carry more risk in this respect. Cultivation in constantly humid conditions such as greenhouses, flooding, soil salinity, high nitrogen or potassium, and root diseases also cause calcium deficiency. Calcium acts in the plant's transpiration pathway and is stored in older leaves mostly. Calcium deficiency is observed in younger leaves and growth points where transpiration is low. Because the newly developing leaves cannot fully expand, they are seen as scorched, twisted, and turned downwards. There is no deficiency in mature and older leaves. If the calcium deficiency is severe, the flowers fall off, and the growth points die. The fruits of calcium-deficient plants become smaller and tasteless and fail to show normal development at the tip of the flower (Schwarz, 1995; Resh, 2012).

In the study examining the signs of nutrient deficiency in cucumber fruits by reducing the amounts of N, P, K, Ca, and Mg one by one with a standard nutrient solution, it was found that the physiological deficiency symptoms of K and Ca in cucumbers appeared 2 and 3 days after the nutrient intake was reduced. While K deficiency in the plant first appeared as yellowing on the leaf margins and later necrosis, the symptoms of Ca deficiency were observed in the leaves close to the meristem, such as leaf shrinkage and tissue necrosis at the leaf margins. These deficiency symptoms appeared when K and Ca in the leaves were 9.5 and 1.5 g/kg, respectively. Therefore, it was determined that K deficiency symptoms appeared in the leaves in the middle part, and Ca deficiency appeared in young leaves in early fruiting plants (Carmona et al., 2015).

Soilless agriculture is the name given to the cultivation of plants in soil-free environments, and the reasons for the transition to soilless agriculture are the difficulty and cost of controlling soil-borne diseases and pests, soil salinity, and lack of water. In soilless cultivation, environments such as Rockwool, peat, perlite, vermiculite, tree bark, sand, and gravel are used individually or in mixtures (Olympios, 1993).

The rock wool technique, which gives better results than soiled agriculture, is one of the significant methods used for cucumber cultivation (Letard, 1982). The rock wool is obtained by compressing the fibers formed by blasting volcanic rocks in high-grade furnaces, and the air and water holding capacity is higher. Rockwool production blocks are produced as 13-liter plates 75 cm long, 30 cm wide, and 7.5 cm thick, covered with polyethylene film, and in the lower parts, there are holes to ensure drainage. Seedling production plates are produced as cubes of 10 cm rock wool and then placed on the production plates. Rock wool plates are placed in the greenhouse after the soil is covered with white plastic. 3-4 plants can be grown on one production plate (Burt, 2018).

In the literature search, it was determined that the most suitable form of soilless cultivation for cucumber plants was the rock wool technique, but it was seen that the number of studies on this subject was limited. In addition to the standard fertilization program in the rock wool technique, there is no work to increase the yield and quality by increasing different fertilizers. Studies on this subject have focused more on determining the effects of fertilizers on the prevention of diseases.

Therefore, in this study, the effects of increasing the amount of calcium and potassium in the standard nutrient solution in the fertilizer programs of cucumber plants grown with the rock wool technique in the greenhouse on yield and post-harvest fruit quality were investigated.

2.MATERIAL AND METHODS

In the study, seedlings of a hybrid cucumber variety of Silor type F1 were planted on rock wool boards with a row spacing of 90 cm and a row of 40 cm. Following planting, watering and fertilizing were carried out with pile drippers placed on each plant.

The fertilizer schedule applied to the plants is as follows: Control (Standard Fertilization Program (SFP)) 1: 1250 mg/L nitrogen (in 97% NO_3 form), 300 mg/L potassium, 160 mg/L Calcium, 60 mg/L Magnesium, 130 g/L Sulfur (SO_4), 120 g/L Phosphorus (H_2PO_4), 21 mg/L Silicon, 0.84 mg/L Iron, 0.55 mg/L Manganese, 0.33 mg/L Zinc, 0.27 mg/L Boron, 0.048 g/L Copper, 0.048 Molybdenum, pH 5.5-6, EC value 2.0-2.5 dS $m^{-1.}$

In the study, this SFP was added to 30, 60 and 90 mg/L Ca; 50, 100 and 200 mg/L K and 30, 60 and 90 mg/L Ca+50, 100 and 200 mg/L K have been added.

The fertilizers used in the study and the proportions of nutrients they contained: calcium nitrate (15.5% N and 26% CaO), potassium sulfate (50% K_2O), magnesium sulfate (16% MgO), mono potassium phosphate (52% P_2O_5 and 34% K_2O), ammonium nitrate (33% N), Fe-EDTA (6% Fe), borax (11.3% B), zinc sulfate (22.7% Zn), manganese sulfate (32.5% Mn), copper sulfate (25.4% Cu), ammonium molybdate (54.4% Mo) and nitric acid (H_3PO_4 and HNO_3) with phosphoric acid to regulate pH.

Fertilization was carried with an open system. The greenhouse soil was covered with black polyethylene before the Rockwool plates were placed. Irrigation was performedğ just enough for one plant, preventing excess water from leaking into the greenhouse soil. The experiment was set up according to the randomized block design.The plants were continuously monitored during their development, seat and leaf pruning was performed and they were grown as a single stem.

By monitoring the cucumber plants grown with the soilless agriculture technique in the greenhouse, the fruits that came at the time of harvest were harvested, packaged and stored at 7±1°C temperature and 90-95% relative humidity.

2.1.Measurements and Analyses

In the study, plant height (cm), stem diameter (mm), number of leaves per plant, chlorophyll SPAD amount, cumulative number of fruits per plant, the total number of fruits, fruit width (mm), fruit height (cm), plant/total yield (kg) were measured during cultivation. In addition, fruit color (L*, a*, b*), total soluble solids (TSS) content (%), and fruit firmness (N) were also measured and analyzed during storage after harvest.

The cultivation part of the study was established in three replicates according to a completely randomized block design, and eight plants were included in each replication. The post-harvest part of the research was carried out with a completely randomized design with three replications. The data obtained in the experiment were analyzed using the SPSS package program, and the difference between the applications was compared within the error limits of 5% using the Duncan multiple comparison test.

3.RESULTS AND DISCUSSION

3.1.Results Obtained During Plant Development

3.1.1.Plant Height (cm)

In the study, plant height measurements for four weeks starting from the week after planting seedlings are given in Fig. 1, and in the fourth week are in Fig. 2. When Fig 1 was examined, it was determined that plant heights increased due to the increase in weeks, but there was no statistical difference between the applications in this respect. On the other hand, it was found that plant heights ranging from 13-15 cm in the first week of the trial ranged from 51-52 cm in the fourth week.

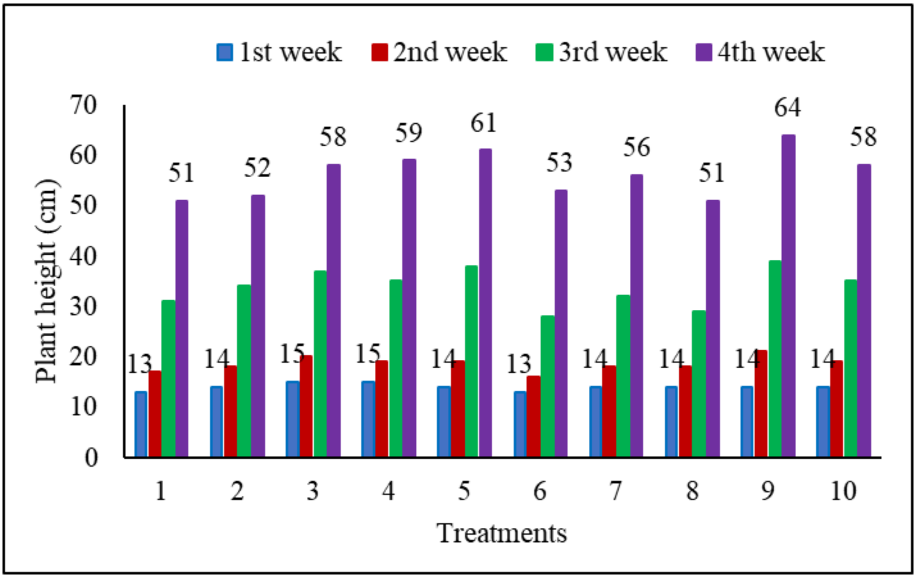

Figure 1: Height of plants in the first four weeks of development

However, according to the plant height measurements in the fourth week (Fig. 2), it was determined that the highest height was reached in group 9, this application was followed by number 5, and the plants with the lowest elongation were groups 1 and 8. The results of the statistical analysis showed that the difference between the application groups 9 and 5 and 1 and 8 was statistically significant (p≤0.05). The number 1 group is the control group, and only the standard fertilizer program (SFP) was applied here. For group 5, 50 mg/L potassium and Group 9, 60 mg/L calcium plus 100 mg/L potassium were treated in addition to SFP. Therefore, plant height results showed that supplementation to SFP with calcium and potassium in the greenhouse hydroponic system caused significant increases in plant height.

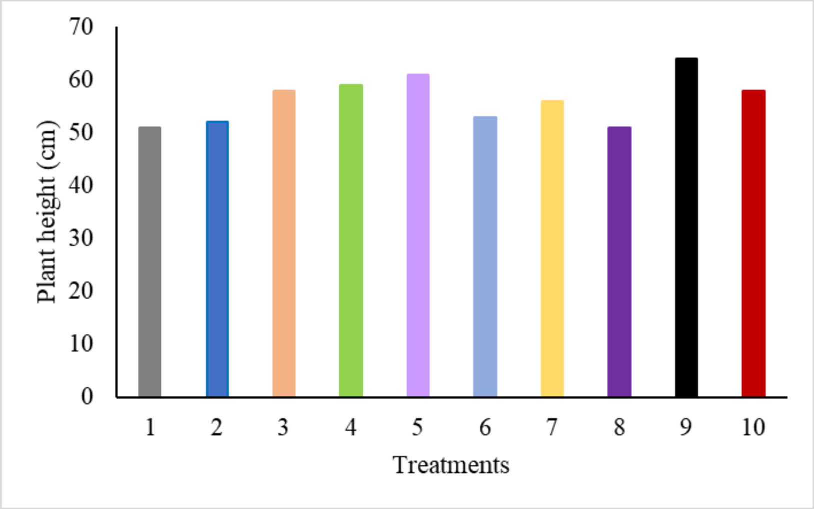

Figure 2. Plant height in the fourth week

3.1.2.Stem Diameter (mm)

The stem of the cucumber plants thickened according to the initial values in each application group during the four-week development period. Stem diameters ranging from 5.67-5.83 mm in the first week of the trial reached 6.81-7.46 in the fourth week of plant development (Fig. 3).

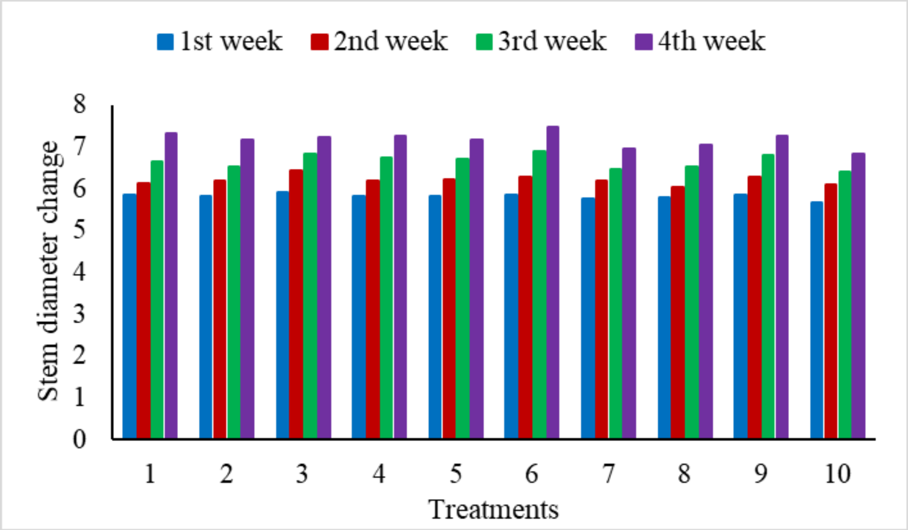

Figure 3. Changes in plant height during the four-week development period

However, among fertilizer applications, the highest increase in body diameter was achieved by application number 6, 100 mg/L of potassium in addition to SFP. However, although there was no significant difference between this application and other fertilizer applications and the control group in this respect, it was found that the difference between the administration of 30 mg/L calcium and 50 mg/L potassium (number 8) in addition to SFP, which led to the lowest increase in body diameter, was statistically significant (Fig. 4). It was also determined that the stem of the plants developed in parallel with the progression of the development period in each application group, and in this respect, there were no significant differences between the applications. Therefore, it can be said that fertilization applications did not show significant effects on body development.

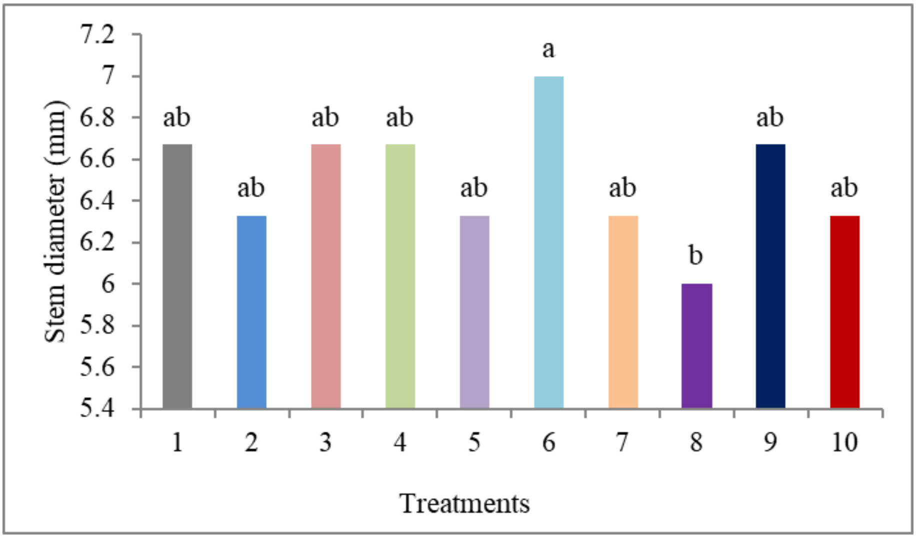

Figure 4. Average stem diameter values of cucumber plant

3.1.3.Number of Leaves per Plant

The number of leaves formed on the plant for four weeks following planting (Fig. 5) and the number of leaves at the end of the fourth week (Fig. 6) were determined in the study. In general, there have been increases in the number of leaves in parallel with the progress of plant development. In the first week of the trial, an average of six leaves were formed in the plants, although it varies according to the applications, while it was found to increase to 15-17 leaves in the fourth week. There were also significant differences between the applications in this respect whereas the number of leaves of the plants in the 5th application group reached 17.5 on average in the fourth week of the research, the number of leaves of the plants in the 6th group found to be 15.25, and in this respect, the difference between the two applications was statistically significant ($p \leq 0.05$). As in the plant height data, in terms of the number of leaves, the 5th application group, that is, 50 mg/L potassium application in addition to SFP, came to the forefront, but the difference between this group and other application groups other than the 6th group was not found to be statistically significant.

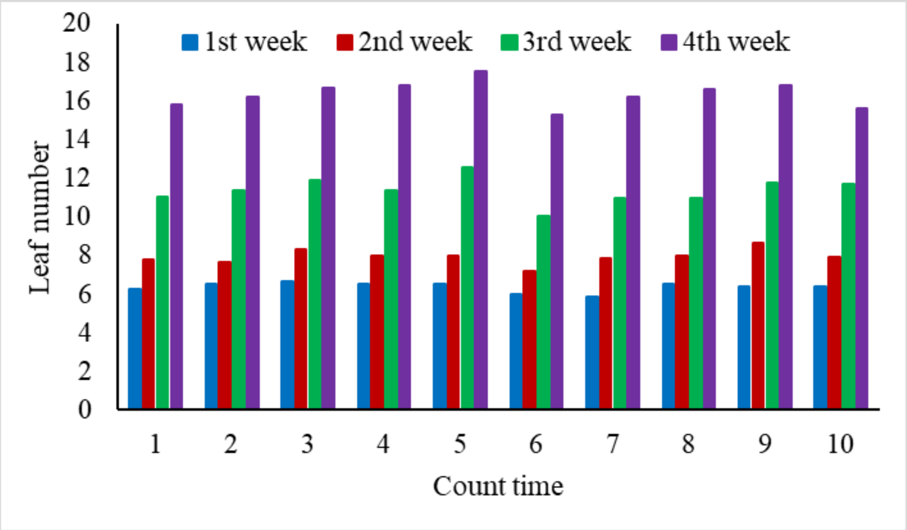

Figure 5. Number of leaf (pieces) in the first 4 weeks

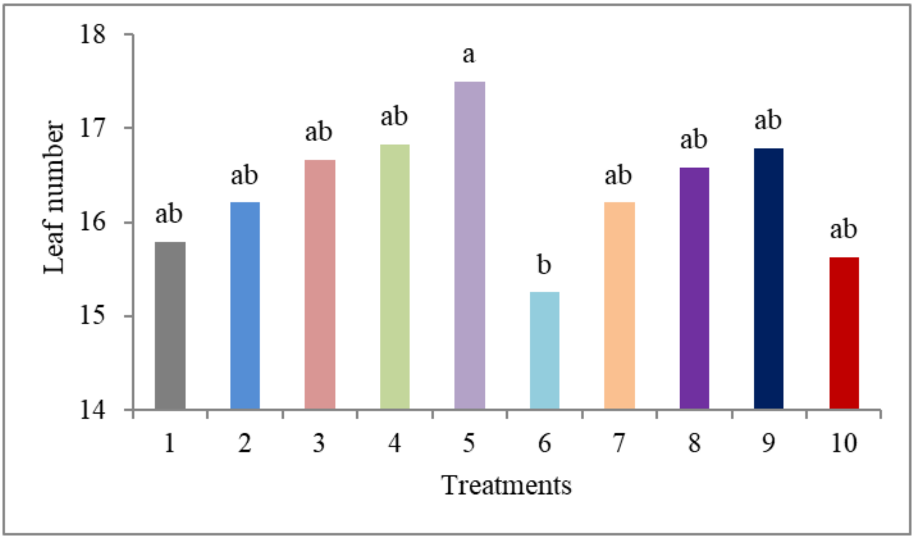

Figure 6. Number of leaf of cucumber plant in the fourth week

3.1.4.Chlorophyll SPAD Content

In the study, the chlorophyll SPAD amounts of the leaves were measured weekly for five weeks after the cucumber planting. The effect of fertilizer treatments on the chlorophyll SPAD of leaves was insignificant in the first week of the experiment, and the chlorophyll SPAD in this period ranged from 33.3 to 37.76 (Fig. 7). In the second week of the study, there was an increase in the amount of chlorophyll SPAD in the leaves, and the highest increase was found on leaves treated with the fertilizer numbered 43.13, followed by the applications numbered 6 (42.73) and 8 (41.83), and control group (Fig. 7). In this respect, the difference between fertilizer number 5 and control and fertilizer application number 4 was also found to be significant ($p \leq 0.05$).

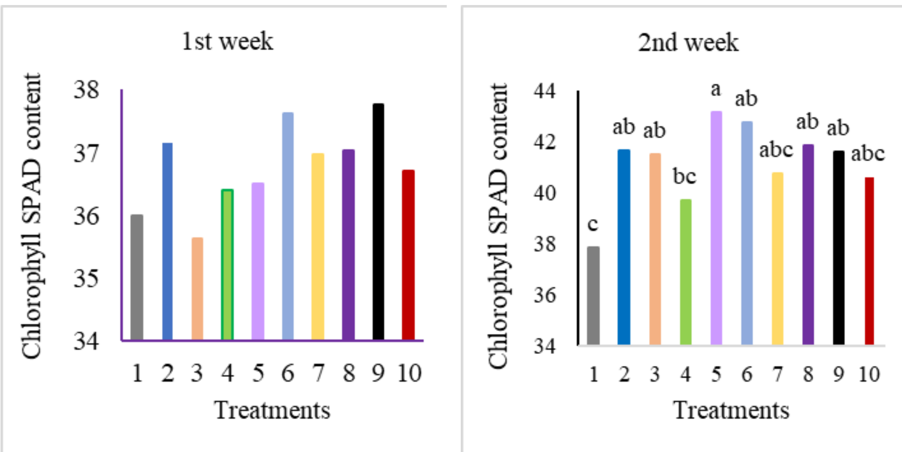

Figure 7: Chlorophyll SPAD values of cucumber leaves in the first and second week of the experiment

In the third week of the study, similar results were obtained as in the second week, and the chlorophyll SPAD amounts of the leaves in all application groups continued to increase (Fig.8). Likewise, the highest increase was achieved in application number 5 (51.4), followed by application number 8 (49.2). The highest increase occurred in the control (number 1) and group 4. In this respect, the difference between fertilizer applications 5 and 8 and 1 and 4 was statistically found to be statistically significant at the level of $p \leq 0.05$. Chlorophyll SPAD measurements showed that fertilizer applications 5 and 8 were more effective on the amount of chlorophyll than other applications. Therefore, it can be suggested that SFP+50 mg/L potassium or SFP+30 mg/L calcium and 100 mg/L potassium to increase the chlorophyll in the leaves.

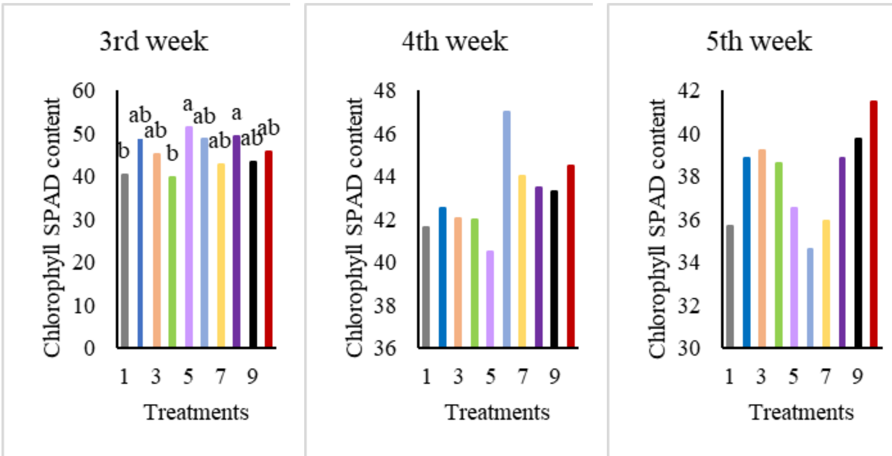

Figure 8. Chlorophyll SPAD values of cucumber leaves at the third, fourth and fifth week of the study.

Although there were no significant differences between fertilizer applications in terms of chlorophyll SPAD amount in the fourth and fifth weeks of the study, the SPAD content of the leaves in application group 6 in the fourth week and fertilizer application number 10 in the fifth week were higher than the other applications (Fig. 9 and Fig. 10).

The changes in the amount of chlorophyll SPAD in the leaves of the cucumber plants during five weeks, which were applied to different fertilizer programs in the study, are given in Fig. 9. Accordingly, the amount of chlorophyll SPAD in the leaves started to increase from the second week of plant development, the maximum chlorophyll increase occurred in application 5 (SGP + 50 mg/L, K) in the third week, 6 (SGP + 100 mg/L, K) in the fourth week, and 10 (SGP + 90 mg/L Ca+200 mg/L K)) in the fifth week. However, there was no statistically significant difference between the treatment groups in this respect. Tanaka and Tsuji (1980) showed that 50 and 100 mM calcium applications prevent chlorophyll accumulation by inhibiting the formation of δ-aminolevulinic acid in light and stimulating the decomposition of newly formed chlorophyll, but these effects were suppressed by potassium. In the current study, 50 mg/L potassium or 30 mg/L calcium and 100 mg/L potassium added to the standard fertilizer program led to an increase in the amount of chlorophyll SPAD. In particular, the chlorophyll content of leaves treated with SFP+potassium was higher than those with SFP+calcium+potassium. In this case, it was thought that the SPAD amount of the plant leaves treated with 30 mg/L calcium +50 mg/L potassium was lower than those applied only potassium may be due to the calcium.

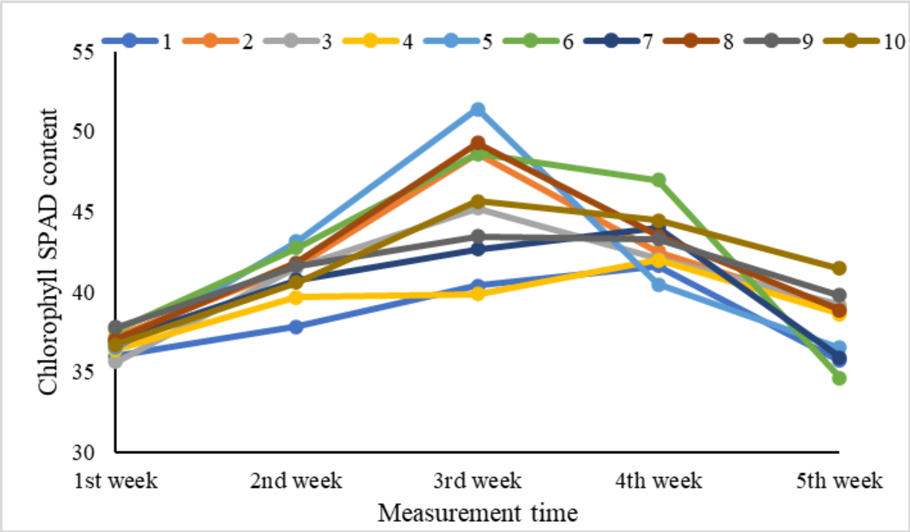

Figure 9: Change in chlorophyll SPAD in the leaves of cucumber plants treated with different fertilizers during a 5-week development period.

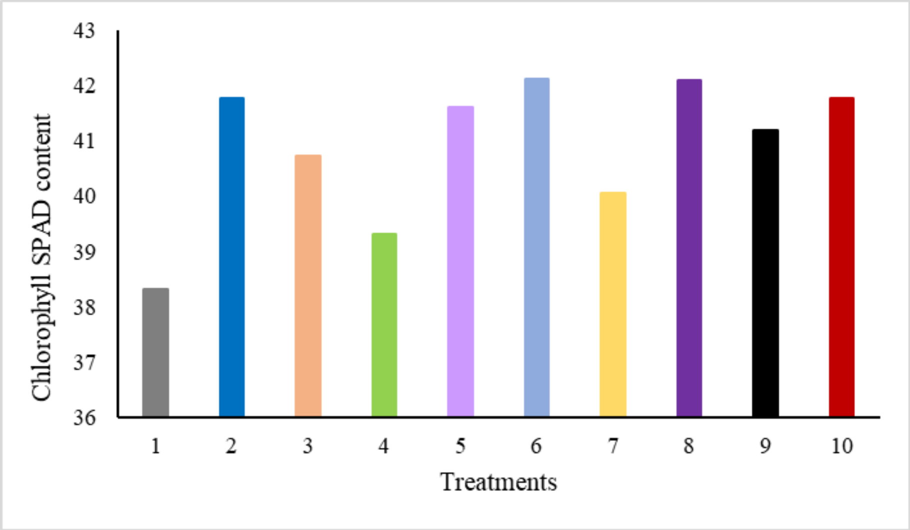

Figure 10. Average chlorophyll SPAD amounts in the leaves of cucumber plants with different fertilizer treatment

3.1.6. Cumulative Number of Fruits per Plant / Total Number of Fruits

The first fruit harvest in cucumber crops was carried out on June 15, 2021, 3 weeks (21 days) after planting the plants in the greenhouse. In the harvests from this period to the end of July, it is seen that the cumulative number of fruits increases in each application group in parallel with plant development (Fig. 11).

The total number of fruits was obtained by counting the fruits obtained from a total of 12 plants in each application. Accordingly, the application group with the most fruits was number 9 (92.3 pieces), followed by fertilization groups numbered 8 (80 pieces) and 7 (79.7 pieces), and the least fruit was obtained from group number 10. However, there was no statistically significant difference between fertilizer applications (Fig. 12).

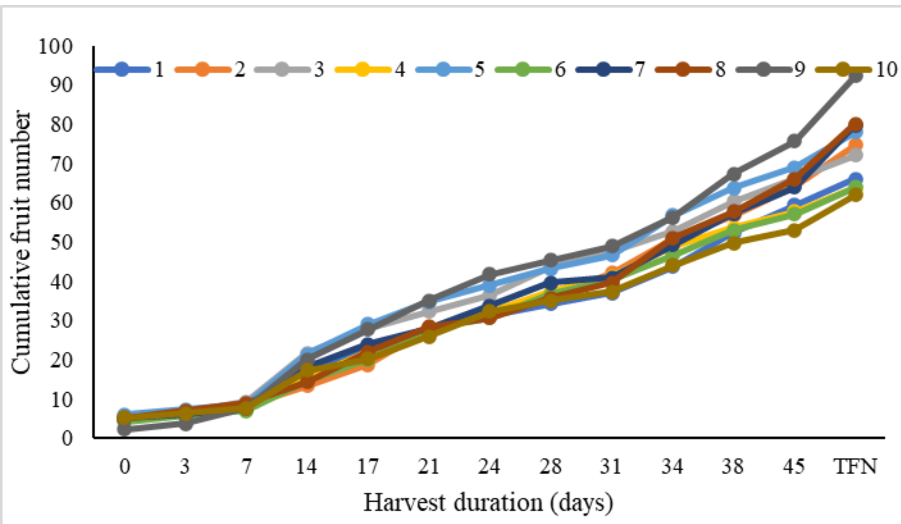

Figure 11. Cumulative number of fruits harvested per plant. TFN: Total fruit number. Day zero: 15 June 2021, 45th. Day: 30 July 2021.

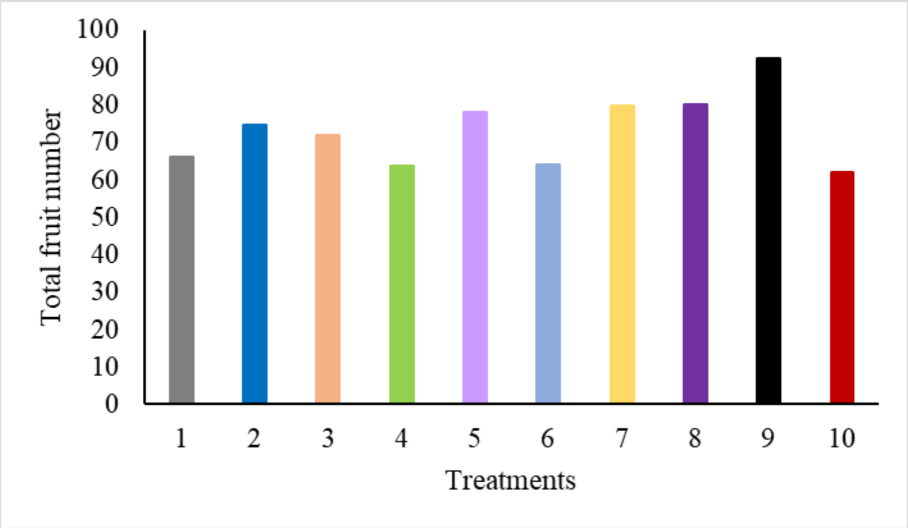

Figure 12. Total fruit number

3.1.7.Fruit Width and Length

The results of the width and length measurements of the fruits harvested with the first fruit harvest in the study are given in Fig. 13 and Fig. 14. Accordingly, the widest fruits were obtained from the fertilizer applications numbered 5, 3, 6, 7, and 9, respectively, and the narrowest fruits were in number 2, and the difference was found to be statistically significant in this respect. In terms of fruit length, it was determined that the number 5 treatment was more effective, and the average height of the fruits in this group was measured as 11.72 cm. According to fruit size, the difference between the application of fertilizer number 5, that is, 50 mg/L, potassium fertilizer applied in addition to the standard fertilizer, other fertilizer applications, and the control group was also statistically significant. In a study, as a result of fertilizer applications made by keeping the N concentrations constant and increasing the K concentration, the diameter of the cucumber fruits applied 1.0:2.0 N: K was higher than the other applications, while the best application in terms of fruit size was 1.0:1.4 N: K (Pedrosa et al., 2011). Although none of the fertilizer applications in the current study affect fruit width, SGP+50 mg/L K fertilization significantly increased fruit length, and the longest fruits were obtained from this fertilizer program. It was determined that other fertilizer applications had an insignificant effect on fruit length compared to the control. Also, the fruits of the plants that applied SGP+30 mg/L Ca were shorter than the others.

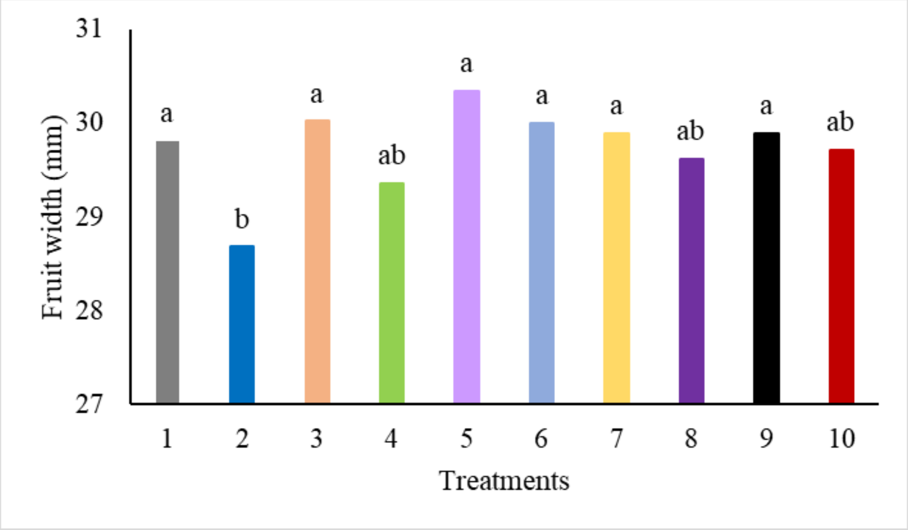

Figure 13. Average fruit width values

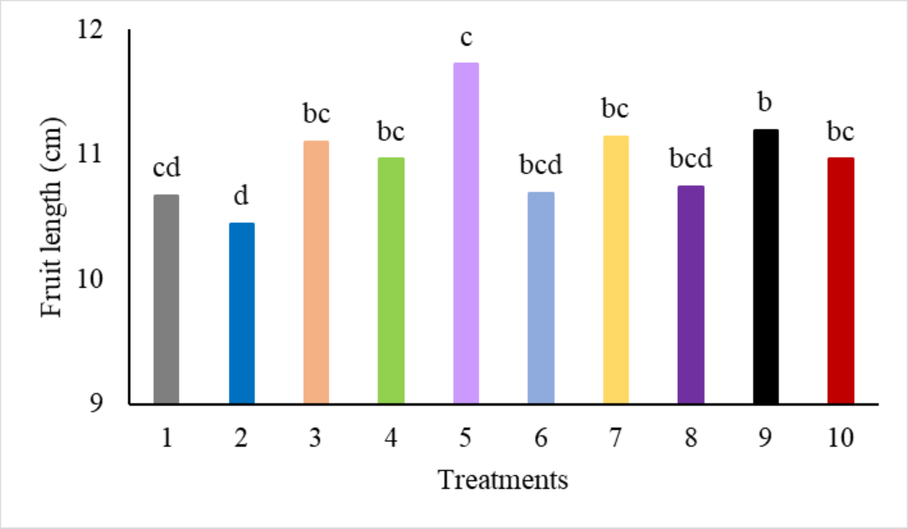

Figure 14. Average fruit length values

3.1.8.Cumulative Yield Per Plant / Total Yield

When the cumulative yield values per plant are examined, it is seen that the highest fruit cumulative yield is in fertilization application number 9 (6029 g), followed by applications numbered 5 and 2 (Fig. 15).

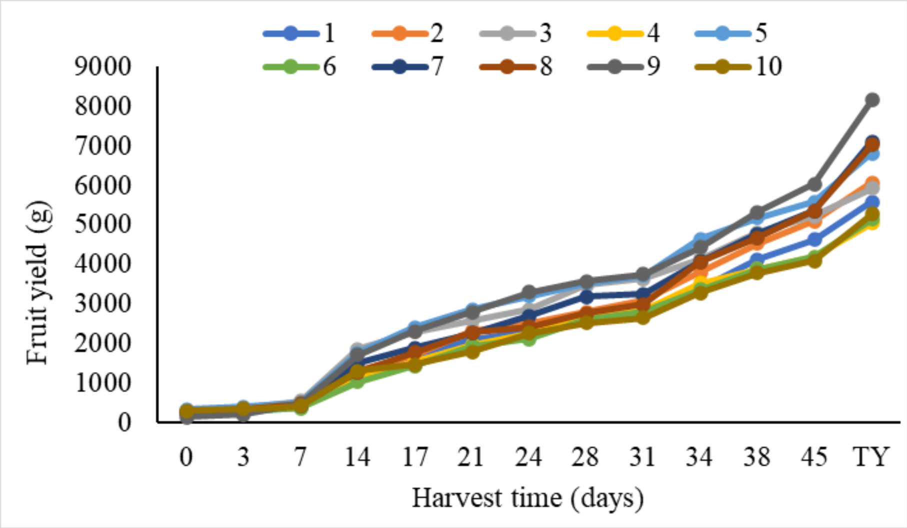

Figure 15. Cumulative yield change per plant over the harvest period, Day zero: 15 June 2021, 45th. Day: 30 July 2021, TY: Total yield.

According to the total fruit yield values obtained by weighing the weights of the fruits obtained from a total of 12 plants in each application group (Fig.16), the highest total yield was found in fertilizer application number 9 with 8157.79 g, followed by application group number 8 with 7106.30 g and application group number 7 with 7019.26 g. When these three application groups were examined, it was seen that 60 mg/L calcium + 100 mg / L potassium, 30 mg/L calcium + 50 mg / L potassium, and only 200 mg/L potassium fertilizer applications in addition to SFP increased both cumulative fruit yield per plant and total yield. It is stated that potassium is of vital importance for plant nutrition and that the addition of potassium in nutrient solutions in hydroponic systems positively affects processes such as growth, development, and protection of plants (Çalışkan and Çalışkan, 2017).

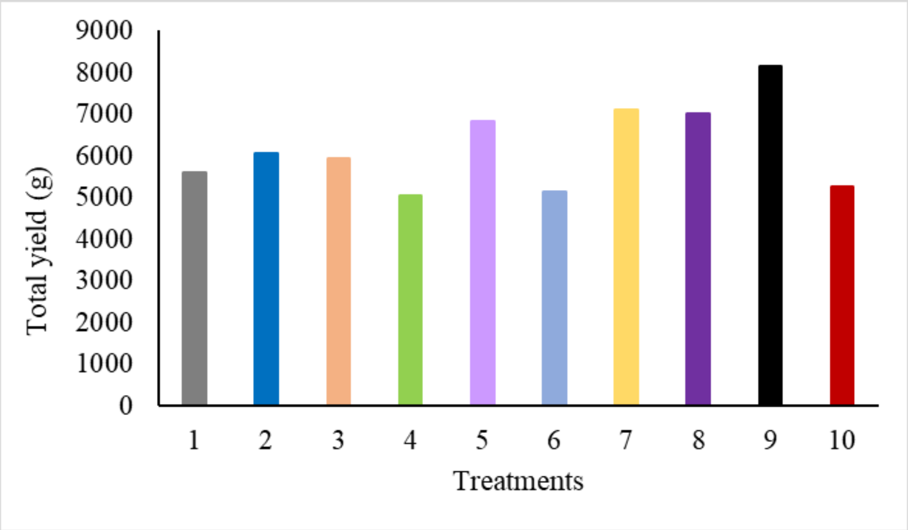

Figure 16. Total yield per plant (g) (the difference between applications is not significant)

3.2.Results Obtained During Storage

3.2.1.Fruit Color (*L**, *a** and *b**)

The color values of cucumber fruits stored for 7 and 14 days after harvest are given in Table 1. Accordingly, the *L** color value, which was 39.18 at the beginning of storage, is 7. 41.3 per day, 14. It increased to 47.75 per day. In this respect, the difference between the storage times was statistically significant at $p<0.05$. When treatments were examined the highest *L** value was measured in fertilizer application number 6, followed by fertilizer applications numbered 10 with 43.92 and fertilizer applications numbered 43.63 and 8. The difference between application number 6 and the control group was also statistically significant.

According to the *a** color data (Table 1), similar to *L** values, *a** values of -14.03 at the start of storage, 7. and 14. It increased daily (-15.66 and -18.36, respectively). The effect of fertilizer applications on *a** color value was similar to *L** color data, with the highest *a** color value obtained from fertilizer application number 6, followed by applications 8 and 10.

Table 1. Changes in storage fruit color of cucumber fruits with different fertilizer application before harvest

Parameter	Treatments	Storage duration (days)			Treatment Avg.
		0	*7*	*14*	
L*	1	38,96	41,77	45,27	***42,0 bc***
	2	41	38,38	49,35	***42,91 abc***
	3	38,03	40,27	46,88	***41,73 bc***
	4	40,31	38,21	47,78	***42,1 bc***
	5	37,68	39,44	44,82	***40,65 c***
	6	39,68	45,29	49,64	***44,87 a***
	7	39,2	42,42	48,87	***43.5 from***
	8	38,42	47,27	45,21	***43,63 from***
	9	38,86	38,02	49,5	***42,13 bc***
	10	39,66	41,94	50,15	***43,92 from***
Time Avg.		***39,18 c***	***41,3 b***	***47,75 a***	
a*	1	-14,26	-15,52	-18,05	***-15,95 abc***
	2	-15,27	-14,58	-18,22	***-16,02 abc***
	3	-13,94	-14,94	-17,6	***-15,29 c***
	4	-14,3	-14,17	-18,8	***-15,75 abc***
	5	-13,3	-15,26	-18,1	***-15,55 bc***
	6	-14,17	-17,65	-18,71	***-16,85 a***
	7	-14,07	-16,2	-18,47	***-16,25 abc***
	8	-13,55	-17,31	-18,5	***-16,45 from***
	9	-13,94	-14,64	-18,36	***-15,64 bc***
	10	-14,12	-16,36	-18,8	***-16,43 from***
Time Avg.		***-14,03 c***	***-15,66 b***	***-18,36 a***	
b*	1	20,64	24,81	37,6	***27,69 abc***
	2	22,62	22,04	41,52	***28,73 abc***
	3	18,73	23,18	38,82	***26,91 bc***
	4	20,98	20,93	40,7	***27,54 bc***
	5	18,39	23,43	36,79	***26,2 c***
	6	20,52	30,08	41,01	***30,54 a***
	7	20,41	26,27	40,59	***29,09 from***
	8	18,85	30,94	37,83	***29,21 from***
	9	19,93	22,51	41,15	***27,86 from***
	10	20,39	25,66	42,42	***29,49 from***
Time Avg.		***20,15 c***	***24,98 b***	***39,84 a***	

However, while the difference between application number 6 and application groups 3, 5, and 9 was statistically significant, it was determined that the difference between application number 6 and other applications was not significant ($p<0.05$). *b** color values measured in the experiment also showed a similar variation to the *a** color values.

According to the CIElab color coordinate system, although the *L** color value indicates the brightness of the fruit, the lightening of the fruit color, especially in dark fruits, can also be expressed with *L** color values. According to the color coordinate system, an increase in the values toward 100 on the *L** axis indicates that the product is bright, whereas approaching 0 (zero) indicates that it becomes dull. In the study, it seems that *L** color values of cucumber increase during storage (Table 1). Therefore, it can be said that the color of the fruit has been lightened during storage. When the effects of fertilizer applications on *L** color value are examined, it is seen that the highest *L** value is measured in fruits treated with SFP+100 mg/L K, and the lowest value is obtained from SFP+50 mg/L K. When the highest values were obtained from fertilizer application No. 6, this also indicates that color lightening has occurred. Therefore, the best treatment in this respect is group 5, which has the lowest *L** color value. The *L** color values of the fruits in this group were lower than the other applications, which showed that the fruit color was preserved as darker green than the fruits in other fertilizer applications. Similar results were obtained for the color values of a*, which is indicative of the green color of the fruits, and *b**, which is the indicator of the yellowness of the fruits, and it was concluded that the best application in terms of fruit color was SFP+50 mg/L of potassium.

3.2.2.Total Soluble Solids (TSS) Content

In the study, when the changes in the amount of TSS during the storage period of the cucumber fruits to which different fertilizer programs were applied before harvest were examined, it was found that the amount of TSS of the fruits increased during the storage period. So, the TSS content, which was 3.10 % at the beginning of storage, reached 3.55 at the end of the experiment (Table 2). It was determined that the amount of TSS of fruits fertilized with SFP+ 90 mg/L calcium was higher than in other applications but did not constitute a significant difference at the statistical level with applications other than fertilizer programs 3, 7, and 9.

Table 2. TSS (%) content of cucumber fruit treated with different fertilizers before harvest.

Treatments	*Storage duration (days)*			*Treatment avg.*
	0	*7*	*14*	
1	3,37	3,27	3,47	***3,37 from***
2	3,40	3,30	3,47	***3,39 from***
3	2,80	3,57	3,23	***3,20 b***
4	3,17	3,57	3,90	***3,54 a***
5	2,90	3,37	3,63	***3,30 from***
6	2,97	3,57	3,50	***3,34 from***
7	2,90	3,23	3,47	***3,20 b***
8	2,87	3,57	3,87	***3,43 from***
9	2,97	3,30	3,33	***3,20 b***
10	3,63	3,10	3,63	***3,46 from***
Time avg.	***3,10 c***	***3,38 b***	***3,55 a***	

In general, although different pre-harvest fertilizer program applications did not significantly change the amount of TSSof the fruits, it was determined that the application of 90 mg/L calcium in addition to SFG increased the amount of TSS compared to other applications. González et. al. (2020)**.** found that foliar calcium application increased the amount of TSS of cucumber fruits by 14.47%, 21.05 and 23.24% compared to silicon + calcium, silicon and control applications, respectively. Similar results were obtained in our study, and it was found that 90 mg/L calcium administration in addition to SFP caused an increase in potassium, potassium + calcium and the amount of TSS compared to other calcium doses compared to the control group. However, the increase rate in the study was not as high as that found by González et. al. (2020)**.** This is thought to be due to the direct foliar application of calcium. In the current study, calcium was applied to the plants from the root, so it could not be transported to the fruit sufficiently. Therefore, calcium fertilizer did not have a significant effect on the TSS content of fruit.

3.2.3.Fruit Firmness

In the study, the fruit firmness of the cucumbers to which different fertilizer programs were applied before harvest increased during the storage of the fruits (Table 3). Among the fertilizer treatments, the firmness values of the fruits to which calcium and potassium were applied together with SGP were higher than the others, and there was no significant difference between the fertilizer applications in terms of fruit firmness except for group 7. It was also determined that there was a significant difference between the control and the applications numbered 5, 8, 9, and 10 at $p<0.05$.

Table 3. Fruit firmness (N) during storage of cucumber fruits with different fertilizer application before harvest

Treatments	***Storage duration (days)***			***Treatments avg.***
	0	***7***	***14***	
1	18,60	22,34	23,42	***21,45 c***
2	20,74	23,08	22,83	***22,22 abc***
3	20,04	24,40	21,91	***22,11 abc***
4	19,34	23,05	24,22	***22,20 abc***
5	20,59	24,53	23,22	***22,78 from***
6	19,31	23,67	24,94	***22,64 abc***
7	19,62	22,90	23,61	***22,05 bc***
8	20,85	23,53	25,68	***23,36 a***
9	20,71	23,96	24,37	***23,01 from***
10	20,82	23,45	24,77	***23,01 from***
Time avg.	***20,06 b***	***23,49 a***	***23,90 a***	

In the current research, it was found that fertilizer applications increased the fruit firmness of cucumber fruits compared to control. In particular, SFP+calcium+potassium fertilizers and SFP+50 mg/L potassium have also been more effective in increasing fruit firmness. It has been noted that calcium plays a crucial role in maintaining fruit firmness and can delay aging by reducing ethylene production. It has also been stated that calcium treatments made in the pre-and post-harvest period can delay softening by delaying ethylene production by increasing the amount of calcium in the fruit (Bolat and Kara, 2017). It was found that the hardness of the fruit pulp was preserved in those who applied 2% calcium lactate from cucumber fruits to which calcium chloride, calcium propionate, and calcium lactate were treated after harvest (Yılmaz et al., 2021).It was determined that SFP+ potassium + calcium applications maintained the fruit firmness in the present study. Since calcium is a cell wall component, it is an essential element in maintaining the firmness of the fruit (Bakshi at al., 2005). In general, calcium applications delay the aging of the fruit by protecting the cellular organization of the fruit and regulating the enzyme activity, thus delaying the softening of the fruit (Mahajan and Dhatt, 2004). A 4% dose of potassium silicate on the leaves of Hisham F1 cucumber fruits increases the storage quality by preserving the fruit's firmness, color change, and TSS (Shehata, 2018). In our study, it was thought that potassium+calcium applications preserve fruit flesh firmness by delaying aging.

3.2.4.Calcium Content in Fruit

When the post-harvest calcium amounts of the fruits obtained from cucumber plants fertilized with calcium, potassium, calcium + potassium in addition to pre-harvest SFP were examined (Table 4), it was seen that the highest amount of calcium was the highest (63.67 mg/L) of the fruits in the fertilizer application number 6, followed by the applications numbered 10 (63.44) and 7 (63.22). The lowest amount of calcium was found in the fruits of fertilization applications numbered 3 and 8 with 49.78 and 49.22 mg/L, respectively, and the difference between these applications and applications numbered 6, 7 and 10 was found to be statistically significant.

Table 4. Calcium content (mg/L) during storage of cucumber fruits with different fertilizer application before harvest

Treatments	***Storage duration (days)***			***Treatment avg.***
	0	***7***	***14***	
1	59,67	30,33	69,33	***53,11 from***
2	64,33	32,33	68,67	***55,11 from***
3	48,00	33,67	67,67	***49,78 b***
4	40,33	36,00	88,00	***54,78 from***
5	49,33	23,67	71,00	***48,00 b***
6	96,33	20,67	74,00	***63,67 a***
7	64,33	30,67	94,67	***63,22 a***
8	52,67	35,67	59,33	***49,22 b***
9	57,00	33,00	68,33	***52,78 from***
10	67,00	46,00	77,33	***63,44 a***
Time avg.	***59,90 b***	***32,20 c***	***73,83 a***	

In our study, although the calcium, potassium, calcium+potassium fertilization applications performed at different doses in addition to SGP before harvest slightly increased the calcium amounts of the fruits, this increase did not constitute a statistical difference compared to the control group (standard fertilizer program), but on the contrary, the calcium amounts of the fruits who were administered 60 mg/L calcium in addition to SFP and 30 mg/L calcium and 50 mg/L potassium in addition to SFP fell below the control group. Bolat and Kara (2017) stated that calcium applications in the pre- and post-harvest period delay aging by increasing the amount of calcium in the fruit. Yılmaz et al. (2021) stated that as a result of the coating application created with different calcium sources and chitosan after harvest, the calcium amount of the fruits increased compared to the beginning on the 5th day of storage, especially in 2%, 4% and 6% doses of calcium propionate and 2% and 6% doses, but decreased again after this stage. In the study, it was found that fertilizer applications did not significantly increase the calcium amount of the fruits. It is thought that this situation is due to the fact that the plants cannot get enough of the fertilizer given due to the climatic conditions in the greenhouse during the fertilization period in the pre-harvest period.

4.CONCLUSION

This research was conducted to determine the effect of calcium and potassium fertilization in addition to the standard fertilizer program (SFP) on plant development parameters and quality characteristics of fruits in the post-harvest storage process in undercover soilless agricultural cucumber cultivation. The results obtained in the study are collectively given in Table 5. When Table 5 is examined, it is seen that the prominent applications in terms of the criteria measured during the cultivation period and storage period are SFP+50 mg/L potassium (number 5) and SFP+60 mg/L calcium + 100 mg/L potassium (number 9). For this reason, it was concluded that these applications, which have a significant effect on the seven parameters measured during plant development and after harvest, are applicable fertilizers for the soilless cultivation of cucumbers under greenhouses..

Table 5: Results obtained in the research

	Applications									
Analysis	1	2	3	4	5	6	7	8	9	10
Cultivation Period										
Plant Height										
Body Diameter										
Number of Leaves Per Plant										
Chlorophyll SPAD Amount										
Cumulative Number of Fruits per Plant										
Total Number of Fruits										
Fruit Width										
Fruit Size										
Cumulative yield per plant										
Total Yield										
Storage Process										
Fruit Color (L*, a*, b*)										
Amount of SOCM										
Fruit Pulp Hardness										
The Amount of Calcium in Fruit										

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CHAPTER VI

ABIOTIC AND BIOTIC STRESS FACTORS IN GRAINS

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1.INTRODUCTION

It is known that people in the world mix a large part of their daily calorie needs from cereals and products obtained from cereals. As a result of breeding studies carried out in order to meet the need in parallel with the increasing population, varieties and genotypes with high yield per unit area have been developed. However, despite all these studies, increasing global warming and the abiotic and biotic stress factors that arise due to this affect production negatively. The word stress, which is an inevitable part of life, is derived from the Latin verb "estrictia". Stress; It appears as a term that means disaster, pressure, trouble, trouble, grief, pressure, difficult, and causes undesirable changes in the external and physiological structure of the living thing (Cufta, 2016). If we consider stress as physical and biological stress; Physical stress is expressed as the change in the size of the object against the force applied to any object. Biological stress (Levitt, 1980) is expressed as the negative effects of plant development and growth due to changes in the habitat of plants due to environmental conditions. These stress factors include drought, salinity, high and low temperature, flood, radiation, heavy metals, oxidative stress, wind, nutrient deficiency, disease and pests. These stresses can negatively affect the growth and development or productivity of plants.

Factors that cause stress situations in cereals, which have an important place in plants, can be evaluated in two large groups. These are biotic stress factors (other living organisms, animals, insects, plants, fungi, bacteria, pathogens, etc.) and abiotic stress factors (physical and chemical factors such as temperature, solar radiation, drought, flood, salinity, etc.). Among these stress factors, the most common types of stress in plants are: heat stress (high temperatures cause physiological and metabolic damage), stress due to lack or excess of light (they need light and sun), stress produced by infections caused by pathogens, pests and viruses (The application of chemical treatments can also be stressful depending on the conditions in which they are applied), stress caused by a lack or excess of nutrients (excess such as nitrogen and phosphorus also have negative effects), salt stress (can be caused by excess salt in the soil or irrigation water) and water stress are the main causes of plant death.

In studies to be carried out for this purpose, the determination of protective measures by investigating stress physiology in grains will contribute to the preservation of yield and quality (Korkmaz and Durmaz, 2017). Abiotic stress factors such as drought, salinity, extreme temperatures, chemical toxicity and oxidative stress are serious adverse events that cause interruption of activities that threaten agricultural production and deterioration of the environment.

In similar studies, stress-induced yield reductions in many crop plants, especially cereals, were found to be more than 50% (Wang et al., 2004). Analyzing the situations that occur in the life cycle as well as how plants respond to non-living abiotic stress conditions will help in the development of new approaches (Wasternack, 2007).

In this study, determinations on how adverse conditions caused by abiotic stress conditions on grains affect yield and quality parameters are included.

2.ABIOTIC STRESS FACTORS

2.1.Water Stress

Water stress (Drought Stress) occurs when the water lost by transpiration in plants in a certain period of time exceeds the amount of water taken from the environment. Competition for water intake begins between plant tissues with reduced water content. In other words, the water balance between plant tissues is disturbed. In this case, the stress can be daily or long-term. Cell growth is negatively affected due to loss of turgor in the stress state, and cells remain small (Oliver et al., 2000). The decrease in cell growth also affects wall synthesis. While protein and chlorophyll are negatively affected, seeds seem to lose their germination ability. Photosynthesis and respiration slow down or stop (Yüksel and Aksoy, 2017). The regression in cell growth causes leaves to shrink and photosynthesis production to decrease. Lack of sufficient water negatively affects the material transport in the xylem and phloem, causing the fruits to remain small, while in cereals the seeds (grains) cannot be plump and the product quality decreases (Cabello et al., 2014).

Figure 1: Wheat under water stress (Todorova et al., 2021).

2.2.Temperature Stress

Heat stress is a stress factor that negatively affects the growth and development of plants. There is a suitable temperature range for the growth and development of plants. If the temperature is too cold for the plant, it can lead to cold stress, also called cooling stress. Extreme forms of cold stress can lead to frost stress. High temperature stress damages the physiological and biochemical functions of grains and causes a decrease in growth, product and quality. Each cereal species has an optimum temperature range in which it functions optimally, and outside this range, cellular metabolism and thus plant growth are adversely affected (Burke et al., 1990). This species-specific temperature range is defined as the “thermal kinetic window” (Burke et al., 1988). Temperatures above the optimum temperature range cause changes in many physiological functions including photosynthesis, membrane integrity and enzyme stability (Nguyen et al., 1992).

2.3.Oxidative Stress

Oxidative stress in plants is a condition that occurs as a result of the accumulation of reactive oxygen species (ROS) in cells (Schweitzer and Schmidt, 2003) ROS in plants can occur during photosynthesis or under environmental stress factors. When the antioxidant defense system is not sufficiently activated, ROS can damage cellular components and this is known as oxidative stress. Plants have an effective antioxidant defense system to protect themselves from the toxic effects of AOTs. Enzymatic and non-enzymatic components of this system prevent the formation of AOTs or detoxify AOTs after they are formed, thus protecting cellular structures from oxidative stress damage (Foyer and Noctor, 2005).

2.4.Salt Stress

Salt stress inhibits the growth and development of plants by causing osmotic and ion stress. With the increase in salt content, osmotic stress occurs first. This results in a reduction in the amount of usable water(Photo 2). This is called physiological drought. The decrease in the amount of usable water causes the cell expansion to decrease and the shoot growth to slow down (Glenn et al., 1997). Toxic effects such as inhibition of mitosis and inactivation of some enzymes are observed (Demir and KocaÇalışkan, 2002). In the ion stress phase that occurs after the osmotic stress, increasing Na and Cl ions in the environment, necessary nutrients such as K, Ca and NO3-2, and competition cause nutrient deficiency. In the environment where salt stress is experienced, the ions that cause the most toxicity in plants are sodium (Na) and chlorine (Cl) ions (Maas, 1986). Salt stress generally occurs in plants for two reasons. Firstly, the plant has difficulty in taking up water due to the increase in density as a result of the excess of dissolved salts in the root zone and it has toxic effects due to the increase in the amount of some ions. Secondly, excessive salt stress causes stunting and regression in root growth in plants. In addition to these effects, nutritional imbalance in plants, the effect of ions in the soil solution and combinations of all factors also cause adverse effects on plants (Ashraf, 1994; Marschner, 1986).

Figure 2: Wheat on salt stress (Oral, E., 2022).

2.5.Radiation Stress

Radiation stress in plants is one of the environmental factors that can occur at any stage of the plant's life, but can cause different reactions, in other words, it affects plants with different characteristics. Radiation stress can adversely affect the growth and development of plants. Radiation stress in plants can cause DNA damage in plant cells. This damage can adversely affect the growth and development of the plant. An increase in the activity of antioxidant enzymes can be observed in plants exposed to radiation stress. These enzymes can help protect the plant against radiation stress. Perception of Ultraviolet-B (UV-B) radiation, a component of sunlight, regulates photomorphogenesis, including hypocotyl elongation inhibition, cotyledon expansion, and flavonoid accumulation (Yadav et al., 2020). However, high intensity, continuous full wavelength UV-B damages plants and leads to abnormal plant growth and development, which is called UV-B stress. UV-B stress affects DNA synthesis and DNA replication by forming pyrimidine dimers, resulting in heritable variation (Britt, 1995). In addition to causing direct DNA damage, UV-B forms reactive oxygen species, resulting in oxidative stress and the oxidation of lipids and proteins. Too much UV-B causes cell death, resulting in wilting, yellowing, and abnormal growth. UV-B stress also impairs photosynthesis (Hideg et al., 2013). With longer exposure to UV-B irradiation, the maximum quantum yield of photosystem II (Fv/Fm) decreases continuously (Sztatelman et al., 2015).

2.6.Magnetic and Electrical Stress

Magnetic and electrical stresses are among the abiotic stress factors that plants are exposed to. While the magnetic field can positively affect the number of leaves, leaf area, petiole length, tillering and root length in plants, it can negatively affect the fresh and dry root weight. There is not much information about the effect of electrical stresses on plant growth (Gremiaux et. al., 2016; Vian et al., 2016). However, the effects of electromagnetic pollution on plant development and metabolism have attracted the attention of scientists in terms of both the fact that plants are the food source of humanity and their importance for the environment.

2.7.Stress due to nutrient deficiency

Stress caused by nutrient deficiency in plants can be summarized as nitrogen, phosphorus, potassium, calcium, magnesium, iron, zinc, copper and manganese deficiencies. These deficiencies can adversely affect the growth and development of plants. A lack of nutrients in plants can inhibit the growth and development of plants. Many problems can arise due to nutrient deficiency in plants. Nutrient deficiency symptoms in plants indicate which nutrient deficiency the plant is experiencing. For example, in a nitrogen deficiency, the leaves of plants turn yellow and turn pale. Root development slows down in plants with phosphorus deficiency and the maturation of the plant is delayed. In the absence of potassium, the leaves have a burnt appearance from the tips. In plants deficient in calcium, the leaf tips dry out and many flowers remain in baskets. In magnesium-deficient plants, leaves become thin and brittle; They lose their color at the ends and in the region between the veins, and take on a pale green color.Mineral nutrients absorbed in the inorganic form are indispensable for plant growth and development. The various processes underlying yield formation in crops such as biomass accumulation and its partitioning, are directly regulated by nutrient supply. Plants essentially require 17 elements for the production of optimum biomass and yield, while some additional elements are beneficial for their survival under stress and/or improvement in quality of economic produce. The relationship between nutrient supply and yield was well established by Mitscherlich (1947) and is known as the ‘Law of diminishing yield increment’. This law states that if the supply of a particular nutrient is increased, it will cause non-availability of other nutrients or the limitation of genetic potential of crops, resulting in no increase or even a decrease in yield. Furthermore, it is observed that when a particular nutrient is supplied in abundance, the decrease in yield could be due to physiological factors, toxicity or induced deficiency of other nutrients within the plant, or in the soil, and interactions with other elements.

For example, excess supply of nitrogen (N) to cereals causes lodging thereby reducing yield. Another example of induced toxicity is where excess nickel (Ni) supplementation displaces magnesium (Mg^{2+}) ions from Rubisco, resulting in a loss of enzyme activity (Wildner and Henkel, 1979; Van Assche and Clijsters, 1986). Likewise, higher tissue concentrations of zinc (Zn) reduce the uptake of phosphorus (P) and vice-versa (Mohammed et al. 2021). Nutrient availability in soil is primarily dependent on the pH of the soil solution, which is very often altered by the presence of excess amounts of some nutrients. For example, in acid soils with high aluminium (Al^{3+}) and iron (Fe^{3+}) content, the availability of inorganic P to plant roots is restricted. Therefore, to achieve optimal growth and potential yield of crops, not only nutrient deficiencies but also excesses or toxicity stresses need to be taken into consideration. The concentration of any particular nutrient in plant tissues beyond the critical threshold level, either in the deficit or the toxic zone, will result in decline in yield and quality(Pandey et al., 2021).

3.BIOTIC STRESS FACTORS

Biotic stress factors in plants; are stress factors caused by living organisms such as plant diseases, pests and weeds. These factors can adversely affect the growth and development of plants. plant diseases; It can be of many different types such as root rot, leaf spots, rust disease, powdery mildew disease, blight disease, brown rot disease. However, different mechanisms have been developed with research approaches to overcome biotic stresses. The biotic stresses in plants can be overcome by examining the genetic mechanism of the agents causing these stresses. Genetically modified plants have proven to make great efforts against biotic stresses in plants by developing resistant crop plants varieties (Gull et al., 2019).

4.RESULT AND RECOMMENDATION

There are many methods to protect cereals from biotic and abiotic stress factors. The morphological, anatomical and metabolic responses of plants to stress factors have led to the emergence of natural selection in the evolution process. Stress response mechanisms contribute to stress resistance or stress tolerance at different morphological, biochemical and molecular levels. Among the stress response mechanisms in cereals; activation of antioxidant enzymes, osmotic regulation, regulation of photosynthesis activity, regulation of hormones and change of gene expression. In this case, environmental stress factors have an important place among the main factors that provide the structural and functional shaping of plants. The concept of stress in plants is actually a term used in physics. However, it has also been defined in different ways in the biological sense. It is thought that effective strategies and mechanisms to cope with environmental stresses caused by biotic or abiotic factors will contribute by knowing these factors and understanding their mechanisms.

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CHAPTER VII

PHYSIOLOGICAL MECHANISMS OF FORAGE CROPS UNDER SALINITY STRESS

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INTRODUCTION

Stress is known as any biotic or abiotic factor that limits the photosynthesis mechanism in plants (Parihar, et al. 2015). Plants are subjected to several abiotic stress factors in nature, including salinity, drought, cold, flooding and heat stresses, causing yield losses in crops (Fahad, et al. 2015). Salinity stress is one of the most significant risks to agriculture worldwide (Demirkol 2020). It reduces the yield and quality through inhibiting physiological and molecular pathways in most crops (Hedayati-Firoozabadi, et al. 2020; Negrão, et al. 2017). It is characterized by an excessive concentration of soluble salts in the root zone, including chloride, sulfate, and carbonate ions of sodium, calcium, magnesium, and potassium, causing a block in plants to extract water and nutrients from the soil (Bhattarai, et al. 2020). It has been shown that soil salinity is a natural process; however, human agricultural practices (especially irrigation) have accelerated its occurrence and impact, causing problems to sustainable agriculture and land use (Parihar, et al. 2015). In recent times, there has been a notable increase in the severity and frequency of reported instances of salinity stress (Shamloo-Dashtpagerdi, et al. 2022). Therefore it is critical to reveal the physiological status of the plants against salinity stress for designing ways to improve their stress resistance.

Forage crops are essential components of livestock production systems (Chaudhry 2008; Tan and Yolcu 2021). In addition, they play key roles in conserving soil and biodiversity, and mitigating environmental issues such as erosion and water pollution (Keeney and Sanderson 2006), sugggesting that forage crops that are grown in high rates in developed countries, are important components of sustainable agriculture (Deveci, et al. 2016). However, one of the most significant disadvantages of forage crops is their susceptibility to abiotic stressors such as salinity and drought (Demirkol 2021; Demirkol 2021; Demirkol 2023). Therefore, identifying the biological process of salinity stress in is critical for forage crops breeding. This review summarizes the literature highlighting the physiological salinity stress mechanisms of forage crops.

Salinity stress signaling in plants typically entail a series of fundamental steps, as described by Hussain et al. in 2021, and are showed in Figure 1 with the following basic three steps: 1) Sensor perception of signals, (2) signal transduction, (3) stress response (Hussain et al., 2021) (Figure 1). The first step includes the recognition of salinity stress signal via receptors. The final step includes the expression of functional genes associated with critical functions shown in Figure 1 (Hussain, et al. 2021).

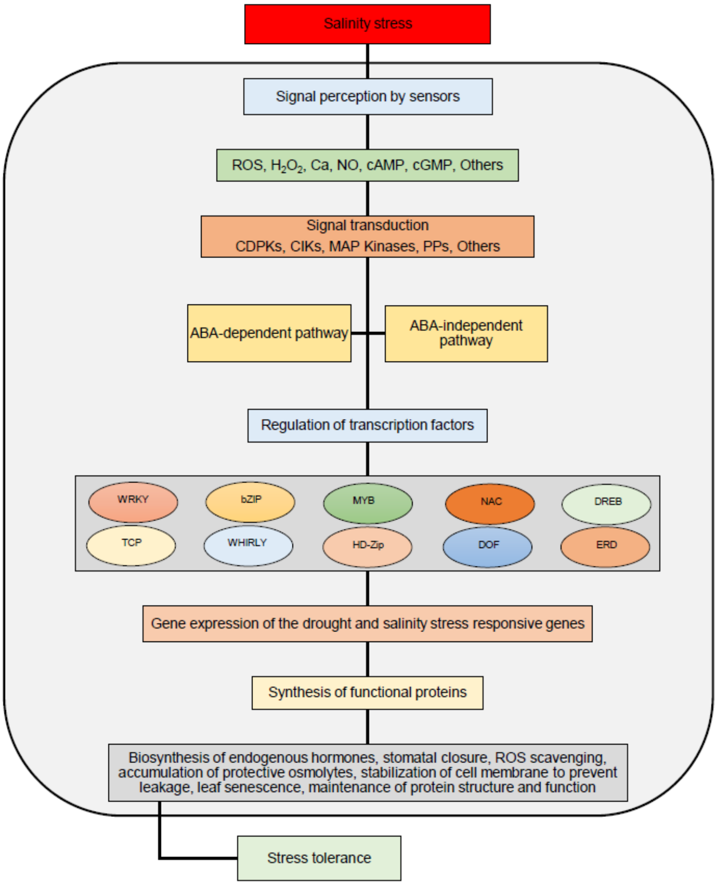

Figure 1. The salinity stress mechanism in plants (modified from Hussain, et al. (2021)).

Salinity stress effects on morphology, growth, forage yield, and forage quality

Salinity stress inhibits plant growth by affecting with photosynthesis (Cornacchione and Suarez 2017). This influence may reveal in two stages: osmotic stress and ionic stress (Bhattarai, et al. 2020) (Figure 2). The initial phase is characterized by the osmotic impact arising from elevated salt concentrations within the root zones, while the subsequent phase is marked by the toxic effect resulting from the accumulation of high salt levels within the leaf tissues (Munns 2005).

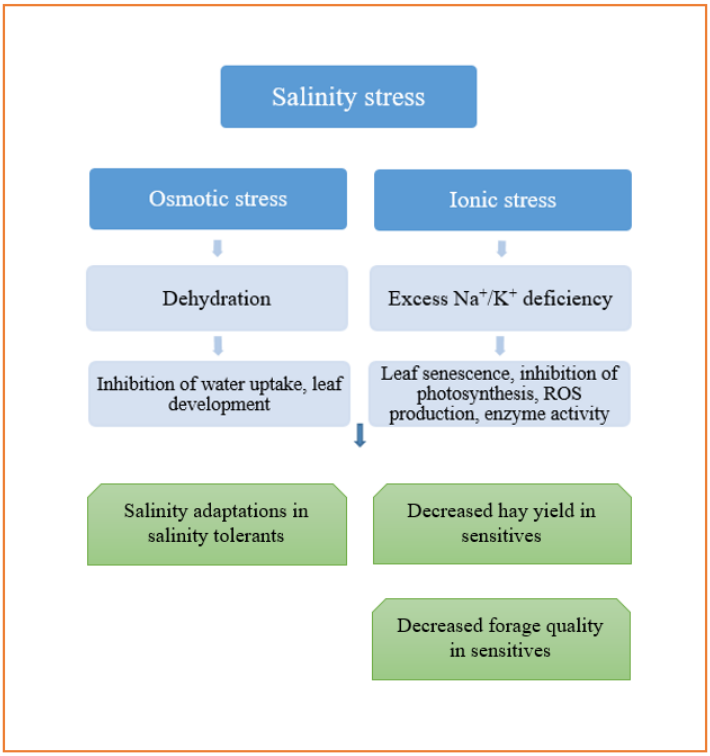

Figure 2. Salinity stress mechanism in plants

Under salinity stress, sensitive forage crop populations had lower forage yield (hay yield) and quality (crude protein, ADF, NDF rates) than under normal conditions (Hedayati-Firoozabadi, et al. 2020; Jiang, et al. 2022; Tokas, et al. 2021) (Figure 2). Salinity stress causes germination problems The studies showed that the maintenance of a regular photosynthetic rate, increased free proline content, increased antioxidative enzymes (such as SOD, POX, GR, CAT) maintained lipid peroxidation and ionic ratio, maintained H_2O_2 are important traits for salinity-tolerant forage crop populations (Ahmad, et al. 2012; Demirkol 2020; Demirkol 2023; Rasool, et al. 2013). Also, the researchers have reported that salinity was shown to be more damaging to forage crops shoot growth than to root growth (Bhattarai, et al. 2020; Demirkol 2023). Despite common reductions in growth rate and shoot mass, forage crop populations including red clover and alfalfa under salt stress exhibited significant genetic variety, indicating large genetic variation for continued selection for greater salt resistance (Asci 2011; Bhattarai, et al. 2020; Farissi, et al. 2011).

The effect of salinity on the quality of forage crops varies depending on the species. While Festuca arundinacea plants had higher ADF and NDF rates under salinity conditions, in another study Festuca arundinacea plants showed decreased ADF and NDF rates and increased crude protein content under salinity conditions (Asci and Acar 2018). While salinity stress decreased the ratio of ADF and NDF in bitter vetch, there was increases and decreases in the crude protein ratio depending on the salt dose (Uzun, et al. 2013).

Salinity stress causes changes in mineral (such as Na, N, P, Ca, Cl, K, Mg) and some secondary matter contents of forage crops (Asci and Acar 2018; Elfeel and Bakhashwain 2012; Uzun, et al. 2013).

Salinity causes senescence in leaves of forage plants, which is one of the quality-reducing impacts of salinity stress. Plants accumulate salt, particularly in the lower leaves, to protect themselves from the harmful impacts of excessive salt intake. As a result, the leaves on which the salt accumulates turn yellow and fall off after a while (Asci and Acar 2018).

Recent studies have been indicated that some of the exogenous treatments increase the salinity tolerance of forage crops (Table 1). Exogenous treatments have a key role in enhancing salinity stress tolerance in forage crops. They are critical for reducing the harmful impacts of salinity stress on productivity (Demirkol, 2021).

Salinity stress effects of molecular mechanism in forage crops

Recent studies showed that tolerant forage plants reveal up-regulated regulation of gene expression of important stress-responsive genes such as; DREB, WRKWY, bZIP, RD, ERD familiy member genes than susceptible plants (Demirkol 2021; Demirkol 2023; Erpen, et al. 2018; Shao, et al. 2014; Wang, et al. 2018; Zhang, et al. 2020; Zhao, et al. 2018). These family member genes are generally associated with ABA machanism that regulate salinity stress tolerance in forage crops (Dong, et al. 2020; Mahdavian, et al. 2021; Ollas, et al. 2013; Shao, et al. 2014; Zhao, et al. 2018), suggesting that these genes have been accepted to associated in salinity resistance via activating ABA mechanisms.

These genes and phytohormones (ABA, SA, JA, GA, IAA, CK, ETHY) are strongly linked, as phytohormones activate many of these genes that are required for the action of plant hormones and other plant genes (Demirkol 2021; Demirkol 2023; Kareem, et al. 2019; Ollas, et al. 2013; Rajasheker, et al. 2019; Zhang, et al. 2021; Zhang, et al. 2020).

Table 1. Recent studies on exogenous treatments that enhanced salinity stress tolerance in forage crops

Treatment	Species	References
PopW	*Trifolium pratense*	Demirkol, 2023
Selenium	*Glycine max*	Wang et al., 2023
Proline	*Medicago sativa*	Guo et al., 2022
Silicon	*Medicago sativa*	Meng et al., 2020
Ethylene	*Medicago sativa*	Wang et al., 2020
Jasmonic- and humic acid	*Sorghum bicolor*	Ali et al., 2020
Potassium	*Glycine max*	Taha et al., 2020
Melatonin	*Medicago sativa*	Cen et al., 2020
Salicylic acid	*Lolium perenne*	Dong et al., 2015

CONCLUSION

Today, salinity stress has become one of the most threating factor to agricultural productivity. The studies showed that salinity-tolerant forage crops had several mechanism (increased antioxidative enzymes and endogenous hormones, up-regulated stress-responsive genes of developing tolerance against salinity by regulating physiological mechanism, suggesting that these traits were found to have critical roles in enhancing salinity stress tolerance of forage crops. Therefore, it is critical to have forage genotypes with these mechanism for developing plants having the potential to tolerate salinity.

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CHAPTER VIII

REDUCING CATTLE METHANE EMISSIONS BY FEED ADDITIVES: AN OVERVIEW

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1.INTRODUCTION

A significant portion of anthropogenic methane is produced as a result of agricultural practices, and enteric fermentation by ruminants is thought to be the single greatest global source of anthropogenic methane emissions. Cattle can consume a variety of forage plants and grains, but this has an impact on the environment. Ruminant methane production is significantly influenced by dietary composition, hence changing diet is a promising way to reduce methane emissions. Adding feed supplements to livestock diets in general is a common global nutritional management approach. As a result, feed additives designed particularly to lower enteric methane emissions are expected to be able to quickly penetrate the market due to the existing commercial feed additive marketing and distribution methods.

Methane emissions and energy savings are significantly influenced by rumen microbial fermentation, which may have a direct impact on animal productivity. Feed efficiency may suffer significantly as a result of methanogenesis. As a result, reducing methane emissions in the production of ruminant cattle is a major goal, and numerous techniques have been proposed, including various dietary formulations, chemical and biological feed additives, chemogenomics, and antimethane vaccinations (Tong et al., 2020). Ruminal methane (CH_4) emissions from ruminants cause animal energy losses and poor production efficiency in addition to environmental pollution and a worsening of the greenhouse impact. According to studies, feed additives such plant extracts, probiotics, prebiotics, and nitrogen-containing substances greatly lower ruminant methane (Sun et al., 2021). Methanogens, a subgroup of the *Archaea*, which produce methane as a byproduct of the metabolism of hydrogen, carbon dioxide, or formate released during bacterial breakdown of the feed, are responsible for producing methane in the rumen. The removal of hydrogen from the rumen during methanogenesis facilitates the optimum performance of the bacteria involved in the fermentation as it supports the complete oxidation of substrates which would not be possible if the hydrogen was not removed. Additionally, some methanogens might produce methane using methanol and methylamines (Eger et al., 2018).

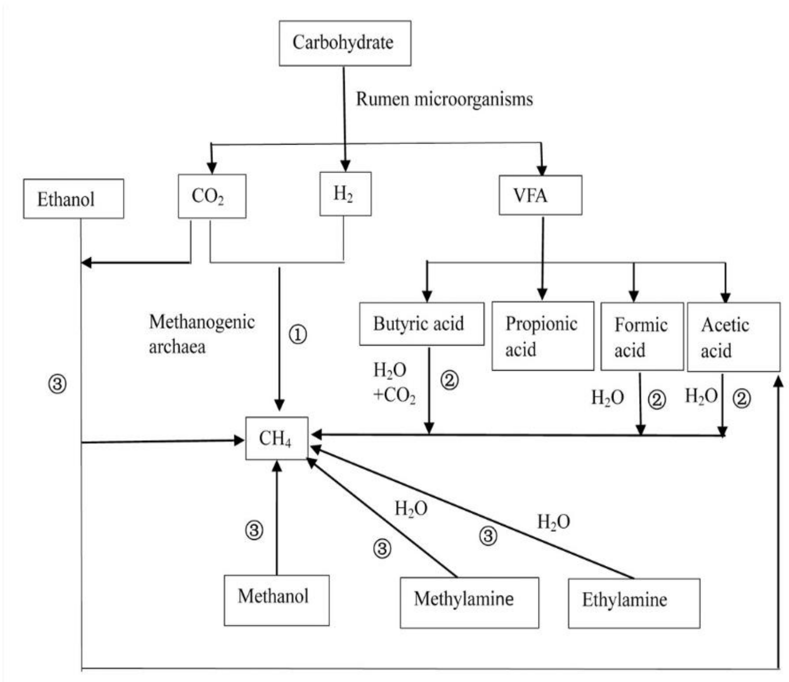

Figure 1. Production of methane is shown schematically. Ruminal methane is produced via three fundamental pathways: (1) the CO_2-H_2 reduction pathway, (2) the synthesis pathway using short-chain fatty acids as substrates, such as formic acid, acetic acid, and butyric acid, and (3) the synthesis pathway using methyl compounds, such as methanol and ethanol. Route (1) is thought to be the main method of producing methane among these (Sun et al., 2021).

2.MAIN TYPES OF ADDITIVES AND RELATED PATENTS IN RUMINANTS FOR REDUCING METHANE EMISSIONS

Globally, there has been a noticeable increase in patent activity, and although each country's plans vary, all are addressing the need to switch to a new method of balancing the livestock business with GHG reduction measures. This evaluation revealed a patenting activity that was significantly increased by the shared political structure in the European region, which is regarded as a benchmark for the feed sector. From a technological standpoint, the market for plant-based additives is experiencing the fastest development. R&D activities in this area are likely driven by the rising focus on environmental issues and the need to transform a whole production system that is all too frequently condemned for climate change, providing a base for the industry's sustainable future. When patents are evaluated it can be seen that different types of additives are subject of research and patening activities in this sector. These are: Probiotics (36 patents); Cashew nut shell liquid (31 patents); Flavanone glycoside (24 patents); Nitrate and sulfate (23 patents); Protein extract (20 patents); Enzymes (19 patents); Red marine macroalgae (18 patents); Encapsulated nitrates and sulfates (16 patents); Oligosaccharides and medium-chain fatty acids (16 patents); Lauric acid and 3-nitrooxypropanol (15 patents); Nitrooxy organic molecules (15 patents); Para nitro amino derivates (12 patents); Nitrooxy alkanoic acids (11 patents); 3-nitrooxypropanol (9 patents); Diallyl disulfide, nitrate and eucalyptus oil (9 patents); Dihydroxyquinoline compounds (9 patents); Cysteine and its salts (8 patents); Polycyclic quinone and ionophore composition (8 patents); Eugenol; cinnamaldehyde; extract of a plant belonging to the alliaceous family (7 patents); Nitroaniline derivative or a salt (7 patents); Lignin (6 patents) and Prebiotics (6 patents) (Caprarulo et al., 2022).

3.NITROGENOUS COMPOUNDS METHANE PRODUCTION

Nitrate has been investigated as an electron acceptor for use as dietary feed addition for ruminants to reduce CH_4 emission. Due to a larger Gibbs energy change than the CO_2 to CH_4 pathway, nitrate is reduced to nitrite and then further reduced to ammonia, which is highly competitive with methanogens for hydrogen utilisation in the rumen (Olijhoek et al., 2016). By suppressing the hydrogen consumption mechanism, Alvarez-Hess et al. (2019) administered nitrate at a rate of 20 mg/g dry matter to achieve a maximum 21% methane suppression quantity. By preventing the growth of methanogens and lowering their activity and abundance, Wu et al. (2019) added nitrate with an addition amount of 5 mmol/L and achieved a maximum methane suppression amount of 33%. By enhancing methane oxidation by stimulating the NC10 population in ruminal culture, Liu et al. (2017) added nitrate with an addition amount of 5 mM and obtained a maximum methane suppression amount of 43%. By eliminating methane reducing bacteria, Granja-Salcedo et al. (2019) administered encapsulated nitrate with an addition amount of 70 g/100 kg of body weight and obtained 18.5% CH_4/kg of forage dry matter consumption.

By including 2.5% more encapsulated nitrate into the microbial biomass, Capelari et al. (2018) were able to enhance the efficiency of microbial protein synthesis and achieve a maximum methane suppression quantity of 9.37 mM/d. Alemu et al. (2019) obtained 2.8 g/kg dry matter intake by adding 2.5% more encapsulated nitrate. Zhang et al. (2019) reached the greatest methane suppression amount of 10% through the indirect consumption of hydrogen by adding a mixture of urea (34 g/kg straw on a dry matter basis) and nitrate (4.7 g/kg of rice straw on a dry matter basis). Alvarez-Hess et al. (2019) inhibited the activity of methyl-Coenzyme M by adding NOP at a rate of 0.08 mg/g dry matter and achieved a maximum methane suppression level of 44%.

Martinez-Fernandez et al. (2018) increased NOP consumption by 2.5 g/day per animal and obtained a dry matter intake of 38%. In order to achieve a maximum methane suppression amount of 26% per day, Melgar et al. (2020) introduced NOP at a rate of 60 mg/kg of feed dry matter. Van Wesemael et al. (2019) added NOP with an addition amount of 1.6 g and obtained a maximum methane suppression amount of 28% (roughage), 23% (concentration pellet).

Jayanegara et al. (2018) carried out a meta-analysis on the impact of 3-nitrooxypropanol (3-NOP) on intestinal methane (CH_4) emissions from ruminants, which included 12 in vivo investigations from 10 papers. Ruminant species included were dairy cows, beef cattle, and sheep. According to the results, adding more 3-NOP to ruminants' diets reduced their enteric CH_4 emissions per unit of body weight, DMI, milk production, CH_4 digested organic matter, and gross energy intake. As the level of 3-NOP addition increased, more H_2 was produced. The addition of 3-NOP reduced the concentration of all VFAs and changed the proportions of C_2 and C_3 in opposite directions. The addition of 3-NOP reduced the population of archaea but had no effect on the populations of overall bacteria and protozoa. The chemical barely affected how easily nutrients could be absorbed. The addition of 3-NOP to the diets had only a little impact on the production performance of dairy cows and beef cattle, and it had no adverse effects on the DMI of ruminants. It is concluded that 3-NOP is an effective feed additive to mitigate enteric CH_4 emissions without compromising productive performance of ruminants.

4.PLANT EXTRACTS AND METHANE PRODUCTION

Although it has been demonstrated that altering the rumen microbiome through dietary interventions, such as modifying diet composition or adding natural or synthetic feed additives, can reduce methane production and increase productivity, this strategy has not yet been widely adopted in the agricultural sector due to a number of factors, including microbial adaptation, practicability, residues, costs, or adverse effects on feed intake. Natural product-based dietary interventions have garnered interest for a while as potential agents in the reduction of methane production and have been shown to be appealing substitutes for synthetic chemicals in animal health (Eger et al., 2018). Natural substances derived from plants, such as essential oils, saponins, tannins, and other polyphenols, are promising anti-methanogenic chemicals (Ma et al., 2020).

Research studies conducted on different natural components on different ruminants under diversified rations conditions are: Olive leaf extract (Shakeri et al., 2017), Pomegranate peel extract (Hundal et al., 2019), Garlic (Allium sativum) extract (Eger et al., 2018), Mulberry leaf flavonoids (Ma et al., 2017), Chicory (*Cichorium intybus*) (Niderkorn et al., 2019), Eucalyptus leaf extract (Boussaada et al., 2018), Bamboo Leaf (Jafari et al., 2020), Grape pomace powder (Foiklang et al., 2016), Acacia leaf (Montoya-Flores et al., 2020), Rhubarb (*Rheum* spp.) (Arokiyaraj et al., 2019), Propolis extract (Santos et al., 2016), Marine red algae *Asparagopsis armata* (Roque et al., 2019), *Corymbia citriodora* tree leaf extract (Hassan et al., 2020), Aloe vera, *Azadirachta indica* tree, *Moringa oleifera* tree, *Jatropha curcas* tree, *Tithonia diversifolia* (Mexican sunflower), Carica papaya tree (Akanmu et al., 2020), Desert teak tree extract (Hundal et al., 2019), *Rhus succedanea* tree extract Kim et al., (2018), *Areca catechu* tree extract, *Acacia nilotica* tree extract (Wadhwa et al., 2020), plant extract resveratrol (Ma et al., 2020), plant extracts (caffeic acid and p-coumaric acid) (Berchez et al., 2019), Licorice extract (Ramos-Morales et al., 2018), Ginkgo extract (Oh et al., 2017), Honeysuckle extract (Yejun et al., 2019), Papaya leaf extract (Jafari et al., 2018), Patchouli, Atractylodes (Wang et al., 2019), Myrobalan (Anantasook et al., 2016), Sanguisorba (Cieslak et al., 2016), *Centella asiatica* powder, Mangosteen peel power (Norrapoke et al., 2014), Rambutan peel (Gunun et al., 2018), Black wattle bark extract (Denninger et al., 2020), Pitaya peel powder (Matra et al., 2019), Chinese chestnut (Witzig et al., 2018), Quebracho tannin (Norris et al., 2020), Red bean grass and Hazelnut peel extract (Niderkorn et al., 2020), Grape seed extract (Zhang et al., 2020), Mangosteen Peel (Paengkoum et al., 2015), Lavender essential oil and lavender meal (Coşkuntuna et al., 2023).

5.PROBIOTICS AND METHANE PRODUCTION

Conventional antibiotics have had a positive impact on the use of feed, but the European Union has prohibited their further use due to public concern. Worldwide researchers have developed a keen interest in the search for favourable natural alternatives to reduce GHG emissions for a more sustainable society. For measuring the emission of biogases, researchers focused on the safer use of various natural feed additives (Pedraza-Hernández et al., 2019). Probiotics are living microorganisms added to meals that affect rumen fermentation and enhance health by modifying gut flora. Yeast, *Saccharomyces cerevisiae*, *Lactobacillus sporogenes*, and a few other probiotics are the most commonly utilised. The principle is not yet clear, however, it is assumed that yeast cultures reduce methane production in more manners. Probiotics increase butyrate or propionate production (Broucek, 2018).

One of the best mitigation methods to lower CH_4 emission intensity is to improve pasture quality and digestibility. Additionally, there is a negative correlation between CH_4 generation and rumen propionic acid levels. By altering the lactic acid and water-soluble carbohydrate (WSC) content during ensiling, the LAB inoculums can change the propionic acid synthesis of silage in the rumen, which may indirectly lower methane production (Navarro-Villa et al., 2011). Therefore, LAB inoculums would increase the amount of forage nutrients retained during ensiling and, more significantly, would lower methane emission and increase the efficiency of the silage's energy metabolism during rumen fermentation. Long-established feed additives like lactic acid bacteria not only lower CH_4 emissions per unit volatile fatty acid (VFA) output but also enhance silage's fermentation quality and fibre digestibility (Gang et al., 2020). According to Deng et al. (2018), *Bacillus licheniformis* boosts feed energy and protein utilisation while decreasing CH_4 generation. More study will need to be done in the future on the impact of lactic acid bacteria on rumen microbes and hydrogen competition in order to clarify the mechanism of limiting CH_4 formation as the inhibitory mechanism of lactic acid bacteria on CH_4 is still unknown (Sun et al., 2021).

6.PREBIOTICS AND METHANE PRODUCTION

Prebiotics are chemicals that the host cannot readily digest or absorb. They favourably influence ruminal fermentation by selectively promoting the growth and activity of one or more ruminal bacteria. Ruminant ruminal CH_4 generation is reduced by prebiotics. Prebiotics primarily lower rumen CH_4 synthesis by changing the composition of the bacterial community, affecting the permeability of methanogenic archaea's cell walls, and encouraging other bacteria to compete with methanogens for H_2. In recent years, it has been demonstrated that chitosan, a novel feed addition, plays a specific role in ruminant methane emissions reduction. It is not yet known how varying molecular weights of chitosan affect rumen fermentation, methane generation, and bacterial community structure. According to Tong et al. (2020), the prebiotic chitosan can modify the composition of microbial populations, such as by replacing out fibrinolytic enzyme-producing microbes (*Firmicutes* and *Fibrobacteres*) with amylolytic enzyme-producing microbes (*Bacteroides* and *Proteus*), thereby lowering CH_4 production.

7.EXOGENOUS ENZYMES AND METHANE PRODUCTION

Enzymes having fibrolytic or proteolytic activities are another supplement utilised in the diet of ruminants. These enzymes can increase the digestibility of plant cell walls, improving production efficiency. For instance, adding cellulase resulted in a linear, quadratic reduction in the amount of CH_4 produced per unit of DM that was degraded (Tang et al., 2013), or adding xylanase (enzymes that break down hemicellulose by converting the linear polysaccharide xylan into xylose) increased the amount of CH_4 in rice straw and grass substrates (He et al., 2015). On the other hand, a mixture of beta-gluconase (an enzyme that uses hydrolysis to break down large polysaccharides), xylanase, and cellulase (enzymes that break down cellulose and related polysaccharides). In cereal endosperm cell walls, 1, 3, and 1, 4 glycosidic linkages are hydrolyzed by beta-glucanase, although this process has no effect on CH_4 generation (Mohamed et al., 2017). The effects of enzymes on CH_4 generation in ruminants have been investigated in a few in vivo investigations. Supplementing the diets of beef cattle with proteolytic enzymes (enzymes that break down proteins) did not have a significant impact on the amount of CH_4 produced, the CH_4/DMI ratio, the percentage of CH_4 energy consumed, or the pattern of ruminal fermentation. In contrast to the control group, the dry matter's digestibility was improved by 8%. Further research on dairy cattle revealed that CH_4 production and CH_4/DMI increased linearly with increasing fibrolytic enzyme dosages (0, 0.5, 1 mL of enzyme/kg of TMR, total mixed ration,% DM), with no effects on methanogens, protozoa and bacteria communities, or acetate, propionate, and butyrate concentrations (Chung et al., 2012). Although the breakdown of fibres and the acetate/propionate ratio can both be improved by enzymes, more research is necessary in this area because the observed responses may vary depending on the kind of enzyme activity, dosage, feed composition, and substrate type (Palangi and Lackner, 2022).

8.NANOPARTICLES AND METHANE PRODUCTION

These substances have been found to improve feeds' bioavailability. The primary characteristic of interaction with biological systems is the capacity of nanoparticles to pass through cell membranes. In this manner, biological facilitation of immune system interaction, uptake, absorption, distribution, and metabolism. Carbon nanoparticles have been shown by Fujinawa et al., (2019) to particularly inhibit methanogens in an anaerobic environment. Granular activated carbon has an inhibitory action against CH_4 in anaerobic circumstances, according to Jiang et al. (2021). According to Wang et al. (2019), the addition of magnesium oxide decreased the amount of in vitro gas generation and the percentage of acetate while increasing the percentage of propionate. Magnesium oxide increases organic matter degradability by reducing methane output, as shown by Kazemi and Vatandoost (2019).

9.CONCLUSIONS

According to the findings of the research that have been published in the last ten years, nitrogenous chemicals, probiotics, prebiotics, and plant extracts can all help to lower ruminal CH_4 emissions. The three basic methods for lowering CH_4 production are as follows: Methanogen activity can be inhibited by (1) fewer rumen protozoa, (2) more propionic acid synthesis to compete with methanogens for hydrogen, and (3) blocking the activity of enzymes involved in methanogen activity. The majority of plant extracts' mechanisms of action, however, are still unknown, and practically all investigations are based on in vitro fermentation testing. Additionally, the majority of plant extracts are abundant in resources and have no negative impacts on animals.

Studies on extracts of wild species (not under threat) of gene origin Türkiye may be interesting research subjects especially in coordination with experienced labs on that subject.

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CHAPTER IX

THE ROLE OF DIGITAL AGRICULTURE APPLICATIONS IN MITIGATING GLOBAL PROBLEMS AS A NEW PERSPECTIVE

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1.INTRODUCTION

Obtaining healthy, high quality and productive products in the agricultural industry is important not only the prevention of plant losses for the but also for production and economy.While the problems experienced on a global scale can be solved by remote control with current technological solutions in areas such as agricultural production, the inadequate and time-consuming of current agricultural technology systems in solving today's problems and problems paved the way for the development and promotion of digital agriculture applications. For such reasons, there is a need for up-to-date, economical, fast and time-saving technologies with an innovative perspective in ensuring food safety and security as well as agricultural activities. In this context, the use of digital applications that provide remarkable results in agriculture and food systems has emerged as a current technological development that plays a very important role in many other fields, too. Especially, the use of digital agricultural applications in reducing the problems experienced within the scope of concerns about food is universally an important technological development. In addition to overcoming many effects caused by climate change, the usage areas of digital agriculture applications are increasing day by day in order to protect food safety and security, and the environment. Shortly, digital agriculture applications provide great advantages in today's world where the effects of global climate factors are experienced. This book chapter contains information about the current developments in digital agriculture applications, which also have great potential in maintaining the sustainability of the agriculture and food industries as well as the environment. It is thought that thanks to this fast, sensitive and innovative technology, reducing the greenhouse gas effect and environmental problems (precipitation, temperature, pollution, etc.,) will enable much more efficient and quality products to be obtained, and indirectly to the development of agriculture and its economic development.

1.1.Agriculture and Food Industries

Agriculture, which is accepted to be the beginning of human beings' ability to obtain food from plant products, is the focus of many fields (Mahapatra et al., 2022). The location and geographical characteristics of Turkey, which is especially considered to be the origin region of many agricultural products in this industry, creates a very competitive and strategic environment. However, the role of agricultural products in adequate and balanced nutrition is directly related to their yield and content. For this purpose, increasing the yield of agricultural products or obtaining agricultural products with certain characteristics in order to provide high production capacity are accepted as the common denominator of scientists for quality and healthy production. In addition, increasing agricultural production, regardless of yield and quality, also depends on the abundance of arable agricultural land, its availability within the framework of sustainability, soil quality and characteristics, and plant biodiversity depending on the location of the agricultural area. As a common denominator with food, it is associated with the usability of techniques on food production, processing and preservation.

The fact that the global problems experienced with the unstoppable increase in the world population affect the food industry as well as the fields related to agriculture accelerates investments in technological innovations and even makes them indispensable. However, plant diseases, which cause significant input losses in terms of agriculture, cause difficulties in obtaining raw materials for food and create undeniable effects (Johnson et al., 2018). In fact, the global economic dimension of these universal problems reveals the enormous damage that has occurred. Moreover, for Turkey, which has a very important biological diversity in terms of agriculture, fungal diseases that threaten wild plant genotypes also affect the decrease in biological diversity (Gümüş et al., 2023). In this context, reducing the impact of diseases on agriculture, food and even the environment is of great importance universally, including in Turkey. In addition to science, the use of biological and technological-based innovative developments to solve problems and problems is one of the first options used in recent years. Especially in disease detection and diagnosis, the development of alternatives compared to existing techniques and technologies has tremendous results that are essential for technological advances (Demirel et al., 2024).

1.2.Some Challenges and Effects

Climate, which has different meanings for every field of science, is at the top of the world's most serious and important global problems. It is a fact that should not be forgotten that the changes in the climate parameters greatly affect the present and the future. Addictionally, it is also important in determining the yield, quality and production of agricultural products, as well as growing conditions (soil, water, humidity, temperature, light, etc.,) (Attri et al., 2023). Many similar global challenges and problems such as the global epidemic and climate change directly affect the agriculture industry, and indirectly the economy in addition to the food industry. Agriculture, including national or international events and conflicts, is deeply injured by all kinds of human activities and also by all kinds of natural events. The role of fungal diseases is undeniable, especially in products where water and temperature are highly effective, but also in yield and quality (Dreccer et al., 2018; Kocalar et al., 2020; Altınok et al., 2023).

As an effect of the changing climate, increases or decreases in the amount of water vapor cause differences in precipitation regimes and great effects on the yield and quality of agricultural inputs (Kukal et al., 2023). The management of agricultural areas that receive little or no precipitation and are exposed to excessive precipitation is a critical determinant of planted agricultural products. Excessive population growth, human activities, environmental challenges and problems are some of the factors that constantly bring food security to mind. Especially the problems experienced in today's biological diversity and unconscious activities are some of the prominent effects in the deterioration of agriculture (Önder et al., 2011; Gümüş et al., 2023). Digital agriculture is also used to increase production for arid or waterless agricultural arable lands, which are shown as the potential effect of all these, and to prevent food security from being adversely affected (McLennon et al., 2021; Estébanez-Camarena et al., 2023; Finger, 2023).

The increase in global greenhouse gas emissions, which is another important factor that poses a problem in agriculture, is shown as the main and important responsible for global warming (Chataut et al., 2023). Fossil fuel uses, deforestation, improper industrialization, excessive use of chemicals, etc. many other applications negatively affect life by promoting the formation of greenhouse gases. Similar to the food industry, global warming is the source of environmental problems (precipitation irregularity, chemical accumulation, pollution, acid rain, etc.,), which causes people to worry and indirectly affect their health (Mahato, 2014). On the other hand, disagreements between farmers and agricultural landowners, who are responsible for the management of agricultural activity areas, and the fact that farmers or owners do not follow innovations and produce using existing production techniques are other limiting factors that hinder digitalization. This important problem associated with digital agriculture causes disruptions in the flow of information by slowing down the already limited developments (Kayad et al., 2020).

1.3.Sustainability of Food Safety and Security

Sustainability has a great share in the healthy functioning of the food industry, as in all areas, and in minimizing all the effects experienced. Just like agriculture, working within the framework of sustainability in meeting food supply and demand and obtaining healthy food is important for economic development and environmental protection. Moreover, food which is the basis of nutrition, and agriculture, which is the basis of food, are some of the most important industrial areas. The demand for plant-based foods under the functional food, which is currently being consumed, is increasing day by day (Schmidt et al., 2023). On the other hand, the food industry is also affected by the chalenges and problems experienced in agriculture, and it reveals the importance of conducting comprehensive and multidisciplinary research. In today's world, alternative technological applications are developed and used against the negativities caused by plant diseases, especially to overcome the limitations. Shortly, the availability of agricultural lands, the existence of fertile-healthy soil and plant biodiversity are shown as important criteria for food production in terms of sustainable agriculture rules.

In addition to product-related improvements in ensuring food safety and security, the development of the environment and agriculture determines the main line of obtaining an economic and sustainable life (Demirel et al., 2022).

The use of chemicals is one of the most common uses in order to ensure agricultural improvement and increase product quality and yield. Intensive use of chemical management techniques harms the environment and plants, and even poses risks by entering the human food chain (Rani et al., 2020). The fact that the remediation techniques used to clean the environment from pollutants also provide permanent pollution or fail to perform full and effective cleaning accelerates the transition to bioremediation techniques, allowing biological-based innovative cleaning systems to be made without harming the environment (Güneş et al., 2022). Switching to biological management techniques in order to eliminate these effects offers an innovative perspective that is more eco-friendly, efficient, high quality, and most importantly, non-toxic. Accordingly, innovative techniques and technologies play an important role in drastically reducing pollution growth, as well as fostering different perspectives and the development of chemical-free agricultural systems. Thus, by creating a more sustainable and environmentally friendly agricultural industry, concerns about the protection of food and its safety and security are reduced.

The multidisciplinary use of digitalization technologies, biological-based technologies and techniques, which are associated with innovation on agriculture, provide significant progress in current developments. However, increases in environmental pollution and population prevent adequate food intake and cause problems in balanced food distribution. There is an increasing demand for the development of user- and eco-friendly techniques and technologies with innovative features in order to eliminate the negativities experienced and the nutritional deficiencies. These technologies, which also have been developed to be used as unmanned, especially as a result of the global adversities, are frequently preferred because they are fast, accurate and environmentally friendly in addition to being cost-free for many years of use.

Identifying the underlying challenges and problems of existing techniques and technologies is one of the main points to focus on in providing current innovative developments. Thus, by providing a holistic perspective, it is potantially possible to develop promising, alternative, valuable and sustainable techniques and technologies for food as in the agricultural industry. In addition, the sustainability of agriculture and food, while providing improvements in obtaining quality and efficient products in agriculture, also leads to an important breakthrough in terms of safety and security in the food industries. There are some techniques and technologies that will be realized, realized or still in their infancy, in order to ensure that there are deficiencies and up-to-date information on this subject within the information in the literature. Focusing on the use of these techniques and technologies in the food industries from a multidisciplinary perspective allows the affiliation of their use for agricultural purposes. Promising digital farming technologies have potential advantages as well as challenges and problems. In addition to the use of digitalization in many areas, it is seen as a turning point approach that this article, which is discussed with the aim of contributing to those working in this field and to the agriculture and food industries, is preferred in agricultural technologies. Here, an approach that includes the sustainability of the surrounding of the agriculture-food-environment triangle by digital agriculture technologies is adopted. Moreover, attention is also drawn to the use of innovative techniques and technologies such as chip technologies, new generation biosensors, remote sensing systems, etc., which will have many benefits in addition to obtaining healthy growing, quality and efficiency agricultural products in agri-food integration.

2. DIGITAL TRANSITION AND USAGE IN AGRICULTURE

Digitalization, one of the technological developments in agricultural industrialization, is a contemporary agricultural empirical field in which applications called digital agriculture are used to solve the challenges and problems experienced since the beginning of agriculture (La Rocca, 2023). In short, digital agriculture is also defined as the use of digital techniques and technologies in all processes, supported by digital technological developments and resources, and in increasing agricultural product potentials for the purpose of improvement and development in agriculture. It is a summary of the final outputs of digital agricultural practices firstly bringing agricultural improvements and then achieving economic development and multidisciplinary uses (Moysiadis et al., 2021).

The digitalization of automation management, with the aim of providing remote control of the agricultural industry, accelerates the age of smart technology. The development of online-based software and their integration into agricultural applications have led to developments in the field of food as well as the agricultural industry and facilitated the transition to the era of sustainability. Especially with the global COVID-19 epidemic, in which Turkey is also involved, the use of developing technology in agriculture and food industries and the development of technological infrastructures in unmanned mechanization and remote command systems have revealed the necessity of developing (Ceylan and Özkan, 2020; Sridhar et al., 2023). In addition to the positive effects of agricultural improvement on food, the advantages of digitalization contribute to the economic evaluation and sustainability of the agriculture and food industries (Balasundram et al., 2023).

This innovative technological move, which provides precise, accurate, fast and cost-free time saving, prepares the basis for the shift of agricultural systems in this direction and the development of unmanned automation. Digital agriculture technologies, which are used in the management of products whose importance for agriculture cannot be denied, have many advantages such as increasing product yield and quality, as well as obtaining disease-free products, correct use of water resources, monitoring of climatic data, improvement and control of soil conditions, etc. In this context, applications form a warning network depending on the programming process after data is obtained from various online-based sources (satellite imaging, sensors and mobile sensing systems, etc.,) and processed (Basso and Antle, 2020). The positive and negative effects of change and transformation on many areas with global events have made it usual to affect agriculture and food, and to redefine smart agriculture applications surrounded by sustainability with digital technologies. Accordingly, the fact that digital-based tools, which can also be used unmanned, prevent loss of time for people and provide added value to countries in economic inputs are among the first reasons why they are primarily preferred (Sparrow and Howard, 2021).

Digitalization not only provides a technological development, but also enables the fusion of many fields, especially agriculture, and the use of information much more effectively by making use of technology (Cambra Baseca et al., 2019). In this sense, the transition to sustainable agricultural technologies is facilitated by making digital transformations in agriculture. In short, digital agricultural technologies accelerate to technological progress in the agriculture-food-environment, and to management in terms of economy-sustainability-protection by enabling the acquisition of information as soon as possible. Accordingly, while the benefits of digital agriculture technologies on food and agriculture and their use in solving problems constitute the main subject of this chapter, transformation technologies and their limitations also shape the sub-titles of the chapter.

Digital technologies in agriculture provide great returns in terms of reducing concerns over food and better management of agricultural resources, better economic added value and better eco-friendly applications (Thompson et al., 2019). Digital agriculture technologies, which is one of the sustainable agricultural systems technologies in which farmers are also involved, are among the indispensable and constantly developed agricultural applications of the future with the support of artificial intelligence in the sub-base of decision-making and implementation. Thus, agricultural problems and difficulties can be solved in a short time with digital solutions (robotics, artificial intelligence, sensors, 3D printers, drones, chips, extended and virtual reality, etc.,), and any bottleneck in the food field can be overcome to some extent. Learning modern and sustainable agricultural applications and transferring them to new generation farmers, and then bringing future generations to a position where they can improve themselves, is defined as an example of transferring the principles determined in a completely sustainable framework into practice. In particular, benefiting from digital agriculture applications creates great potentials in terms of increasing sustainable resources, enriching agricultural areas, increases in food inputs, environmental improvements and improvements in economic development within the scope of conservation and sustainability of natural resources (Cambra Baseca et al., 2019). That societies have made such progress in agriculture allows them to be surrounded by sustainability rules as the information and digital age, in a manner befitting the 21st century, and to solve challenges and problems based on data.

Digital agriculture practices, which also prove their effectiveness in the face of changes in climatic parameters that force us in every field, contain different technological infrastructures that will reduce the compelling effects in the face of global climate crises. Thus, reducing the problems experienced in obtaining agricultural products and increasing herbal resources is one of the foremost goals of this age. In addition to the epidemic such as COVID-19 experienced in the past years, the protection of the yield and quality of agricultural products against natural events such as earthquakes, floods and heat waves this year is one of the areas where necessary and measures should be taken in order to avoid food crises. When the information in the literature is examined, it is clearly seen that agricultural digital technologies are used to minimize the effects of global problems (Smith et al., 2020; Pabitha et al., 2023). Moreover, it is seen that digital agriculture applications (sensor, chip, satellite data processing and imaging, etc.,) contribute to the multidisciplinary work of the food industry with sustainable agricultural activities, as well as reducing environmental pollution, increasing the potential of arable land and ensuring equal and adequate food intake (Ma et al. al., 2022; Wijerathna-Yapa and Pathirana, 2022).

2.1. Remote Sensing Technology

The use of management systems used in traditional agriculture in innovative agricultural practices is the first thing that comes to mind among the many problems that limit today's agricultural activities. Instead, it is remote sensing technologies that make it possible to use site-specific management systems and are one of the first technological and digital developments on the basis of obtaining products with the desired features by ensuring precise production (Du et al., 2023). In other words, this enormous technology, which is also defined as remote sensing, is a science that provides information from the data obtained by aircraft and satellites, without any physical contact, only through earth image and geographical features such as physical maps. In this respect, benefiting from this information in agricultural activities is very important for the digitalization of agriculture as well as for the producers and us. Thus, in addition to the ever-increasing consumption and adequate and balanced nutrition of the population, the use of technological developments in the field of remote sensing in healthy food consumption is also associated with many areas in the age of sustainability (Beckmans et al., 2022).

In order to benefit from this technological application, especially in the fields of agriculture and food, it must first be used in the monitoring of agricultural activities. As with all remote sensing data systems/technologies, agricultural data has all the characteristics of big data and lays the groundwork for the creation of big data. Success in agricultural production is associated with the successful collection, processing, storage, analysis and visualization of big data in agricultural mapping (Verschae, 2023). It should not be ignored that the types of geographical data to be obtained will also enable the continuity and development of agricultural remote sensing technologies based on geographical information and GPS data (Huang et al., 2018).

Today, this technological development is used in many areas and positive/negative results are obtained. Similar to the examination of natural resources in natural disasters and epidemics, obtaining data from agricultural remote sensing in agriculture and using it in various sensors after processing enables the collection of new data at certain time intervals and scales. The use of different disciplines for the processing of new data ensures the establishment of an effective and sustainable working network (Huang et al., 2018). There is no doubt that the multidisciplinary use of science with knowledge and techniques in different fields, especially electronic technology, will have effects on agricultural fields such as precision agriculture, smart agriculture, etc., thanks to current and future developments in remote sensing and big data support (Wolfert et al. 2017).

2.1.1. Disease Monitoring and Detection of Pathogens

The rapid detection of pathogens infecting plants is very important for reducing yield and quality problems within the scope of plant diseases, increasing plant-based nutrient production in addition to economic return and providing environmental improvements (Demirel et al., 2024). In particular, it has a great effects on the management of diseases caused by pathogens that can infect many hosts and the protection of biodiversity. However, the ability of chemical-containing materials used in the improvement of herbal products to enter the food chain and threaten human health causes consumers to worry about food safety and security (Liliane and Charles, 2020). For this reasons, benefit digital agricultural technologies helps to have features such as speed, low cost, accuracy, and to stay safe by keeping up-to-date.

2.1.2. Control of Product Physiological Conditions

After the detection, diagnosis and identification of plant diseases, determining the physiological conditions and characteristics of plants for agricultural production and food preservation will support the understanding of the habitats, demands and problems of plants. Accordingly, it will be ensured that obligations such as harvesting mature plants or fruits, or waiting for harvest do not affect yield and quality. It is very necessary and important in order to protect, ensure and even improve the sustainability of agricultural products and to observe increases in yield and quality. In ensuring the adaptation of plants to their environment just like us, determination of plant environmental conditions (aspect, humidity, pressure, water, etc.,) and monitoring of changes are carried out within the scope of xylem studies, which control their effects on plant growth and development (Ece et al., 2023). It is no doubt that the observations and researches of the effects of global warming will be an important source of information for future generations in finding solutions to the problems experienced in the global sense.

2.1.3. Management of Agricultural Products

Agriculture, which is important in terms of plant nutrition and as a source of economic added value in terms of production, is a valuable industry for countries as well as for the whole world (Par, 2023; Suryawanshi and Patil, 2023). The management of this industry, which is highly affected by today's challenges and problems and indirectly causes problems in food supply, ensures that future generations reach sustainable systems and there are no problems in meeting food demand. The management and protection of the resources of this system, where appropriate management techniques are used, is another important factor. It should be known that the decrease and even extinction of plant genetic resources caused by fungal diseases has great importance for the ancestral species as well as the cultivated species, and it has great effects on food as well as agricultural effects (Kahraman, 2023). Accordingly, in minimizing the challenges and problems to be encountered in the protection and management of the environment, it is necessary to work multidisciplinary in the light of technological developments within the rules determined within the framework of sustainability and to use innovative applications by ensuring their harmony with different fields (Abbate et al., 2023). In this context, the use of agricultural application areas such as smart, digital, technological, sustainable and sensitive, etc., for agricultural improvement is considered necessary to ensure the adaptation of agricultural products to growing conditions and to increase agricultural production (Nolte et al., 2023). It is reported that the management of agricultural products also plays a significant role in reducing greenhouse gas emissions (Shen et al., 2018). Co-planting of legumes and grains and rotational cultivation are some of the agricultural systems that are frequently used to reduce greenhouse gasses. It should be noted that the integrated use of these systems with digitalization will greatly reduce emissions, which will support productivity and quality increases (Qian et al., 2023).

2.1.4. Management of Water, Nutrient and Soil

A combination of technologies known as "smart agriculture" combines sensors, information systems, improved equipment, and knowledgeable management to maximize productivity while considering uncertainties in environmentally friendly agricultural systems (Gebbers and Adamchuk, 2010). Remote sensing tools that track crop growth and soil health are crucial among these technologies (Wang et al., 2023). They collect and analyze essential information for management and decision-making, particularly where crop growth conditions vary widely over time and geography. Various soil parameters such as water, nutrients, soil, nutrients, moisture, temperature, and pH are among the soil properties that are important for crop growth (Yin et al., 2021).

For a comprehensive understanding of soil information, soil properties are usually examined by soil sampling and testing directly or by laboratory analysis elsewhere (Yin et al., 2021). Visual observation of plant growth conditions and laboratory examination of plant tissues are used to assess seasonal variables such as biotic and abiotic stress factors, nutrient deficiency, weeds, and insects. The irregular and inadequate sampling/measurement rates of these traditional techniques may be insufficient to detect geographical and temporal resolution. The development of intelligent farming systems has been made possible by remote and on-site monitoring of soil nutrient content, salt, moisture, and pH readings.

The fact that climatic change has increased the interest in water and its resources in today's agricultural activities, and also within the scope of international negotiations, reveals water hunger and deficit. The fact that correct and appropriate irrigation is a defense against drought also shows us the importance of focusing on this issue. Moreover, increases in water demands, such as food demand, are very important both in terms of nutrition and for the continuity of agricultural activities. Water management is necessary for future and sustainability in order to prevent water scarcity and not to deplete water resources. In short, the use of innovative techniques and technologies should be encouraged to conserve water and improve water management (Vandôme et al., 2023).

On the other hand, when assessing soil health, soil moisture, sometimes called soil water, must be taken into account, which is very important for plant growth. Soil moisture sensors are also used to determine the amount of water in the soil. Farmers use such remote sensors to determine the timing and frequency of irrigation to ensure optimum plant growth (Robinson et al., 2008). Current moist soil sensors measure alterations to soil parameters associated with water material, including the dielectric permittivity, osmotic potential, and volume of soil (Su et al., 2014). Four types of soil moisture sensors can be grouped: capacitive-based, electromagnetic induction-based, ultrasonic-based, and visual sensors to measure water in the soil (Sánchez et al., 2004; Sulaiman et al., 2009). The preferred soil moisture-detecting technology is a capacitive-based sensor that monitors inductance without contact metals (Robinson et al., 2012).

Soil structure and microbiological processes are significantly affected at soil temperatures between 10 and 50 °C. This causes germination, flowering, and many other plant growth processes to be adversely affected by soil temperature (Brusseau et al., 2019). A soil temperature sensor consists of temperature probes that convert temperature variations into electrical signals and bias and readout circuits that convert these signals into digital information (Dane et al., 2002).

A measure of the soil's acidity, basicity, or alkalinity called soil pH takes into account the combined impacts of soil-forming elements such parent material, organisms, and temperature. The pH value of the soil can offer helpful data for managing the soil's health in a range that's appropriate for particular crops on the farm, which is essential for intelligent and precise agriculture. The following sensing devices are used to determine soil pH: techniques using sound, electrochemistry, and optics. Colorimetric and optoelectronic indicators, including dyes and pH test segments, depend on the color changes of certain natural pigments that are pH sensitive, hence the acid-color plots required to determine the pH level (Khan et al., 2017; Taylor et al., 2019).

N, P, and K are the three most crucial nutrients for crop growth in the organic soil matter (Sharma et al., 2017). Additionally, the management and efficiency of fertilizer and nutrient use during agricultural activities is a critical step of great importance (Ennaji, 2023). Moreover, the development of precision agriculture and environmental sustainability depends on the efficient and accurate detection of nutrient molecules in the soil so that plants can adapt to nutrient deficiencies (Zhu et al., 2019; Chivenge et al., 2022). NIR spectrophotometry has reportedly been used to calculate soil nitrogen levels (Kuang and Mouazen, 2013). A phosphorus (P) sensing system may utilize UV, apparent, or NIR to produce a noncontact, affordable, efficient, less strenuous assessment of phosphorus concentration in soil (Maleki et al., 2006).

Plant pests and diseases have the potential to significantly reduce the nutritional value and output of crops (Cardim et al., 2020). Several promising techniques, such as optical sensors, audio sensors, conductivity sensors, and nanotechnology biosensors, have been put forth to find soil insects (Martin et al., 2013). Insects can be observed non-destructively, remotely and automatically using acoustic sensors. Numerous variables such as sensor category, spectrum diversity, surface structure, length of the assessment, and the size and habits of the insects can affect how well the sensors work. A flexible and adaptable solution for a cost-effective soil pest management technique is air sensor technology. High-quality images, image processing techniques, and the required spatial resolution are essential for such detection (Yin et al., 2021).

Soil degradation or contamination is caused by pollution from a variety of unwanted heavy metal accumulations, industrial wastes, herbicides, pesticides, and hydrocarbons that enter the soil inappropriately (Grumezescu, 2017; Alengebawy et al., 2021). It is possible to analyze phosphorus-containing amino acid-type herbicides, such as glyphosate and glufosinate, in soil using pulse anodic state strip voltammetry (Prasad et al., 2014). In comparison to electrochemical techniques, biological sensors or immunity sensors are more frequently used in herbicide detection (Tang et al., 2008). Bioavailability sensors fall into one of three categories: electrolytic microbiological biosensors, conductometric sensors, or optical microbial biosensors, depending on the sensing methods or transducer components (Wang et al., 2013).

2.2. Early Warning and Forecasting Technologies

Climate change has led to extreme weather conditions in recent years, making insects and disease more resistant to environmental fluctuations. In today's world, farmers can continuously check the environmental information of each region by placing various sensors in remote fields. Given the early warnings controlled and generated by a forecast system, farmers can plan control actions even at the preparation stage (Bradhurst et al., 2021; Ibrahim et al., 2022). Successful disease and pest prediction systems are associated with the effective evaluation of data from environmental, physiological and diseased/pest products (Aharoni et al., 2021).

Early warning is the evaluation of how a functional system will develop in the future over time, allowing the creation of strategies and measures before a threat or problem is detected (Hu et al., 2021). Conditions, demographics and economic conditions of agricultural land are factors that can provide early warning about the security of agricultural supply (da Cunha Dias et al., 2021). Combining advances in agricultural technology development with the use of smart methods in agricultural decision making will greatly assist researchers and farmers in creating and implementing decision-making systems for conditions and early warning programs for disease/pest attacks (Saleem et al., 2023). Focusing on the lack of reliable early detection and monitoring tools for the most important crop-related diseases and pests, it should be emphasized that emphasis should be placed on the development of image recognition algorithms, robotic counting technology and techniques and technologies that will facilitate the identification of adaptive diseases and pests.

2.3. Cyber Agriculture Technologies

Cyber agriculture technologies, which have basic features such as detection, modeling and activation, are among the advanced agricultural systems with unmanned uses. Just like today's agricultural techniques and technologies, the affordable cost of this technology, shed light on science in today's digital age, has minimal security problems and provides unique designs specific to individual areas, making it easier for it to become widespread in wide areas of agricultural activity and to spread its use to various areas. Integration with smart agricultural technologies provides advantages to agricultural industries and other related areas for efficiency, productivity and sustainability. Those working in the research and development part of this agricultural system argue that the technology should always be kept up to date by integrating it with other innovative techniques and applications, and thus, the efficiency of processing the information received and reusing it in the decision-making phase will increase the effectiveness. Moreover, always available information brings with it extra features such as flexibility and optional editability (Sarkar et al., 2023).

3. PROS AND CONS OF DIGITIZATION

The adoption of new technologies by areas affecting sectors of the economy, such as industry, constitutes a component of industrial revolutions (Rymarczyk, 2020). With the use of digital technologies like artificial intelligence, informatics, the internet, autonomous robotics, computer vision, cyber security, and software integration, Industry 4.0 creates new structural and organizational aspects (Kumar et al., 2022). It is seen as a result of technological developments that digital technologies used in the management of many difficulties experienced by the agriculture, food and environmental industries not only offer solutions, but also create chalenges and problems. The importance of digital technologies applied in the processing, management and protection of agricultural areas is great. Incorrect applications lead to incorrect results and limited infrastructure and data deficiencies make integrated use of applications difficult (Kayad et al., 2020). On the other hand, the fact that countries do not have enough development in terms of digital infrastructure or lack of access is one of the most important and major limitations of this age (Huang, 2023). In this context, including limited access to information causes challenges to turn into unavoidable problems. On top of that, the huge cost of using digital agricultural applications in small areas and the inability of the areas to be used in terms of sustainability are also factors in the solution of the problems (Gabriel and Gandorfer, 2023). Moreover, providing unsuitable infrastructure and working with limited data makes it difficult to make effective use of agricultural activity areas.

The challenges and problems in food access are associated with the agricultural activity areas that are at the base of their commitment to food safety and security. The fact that the increase in unbalanced and unhealthy consumption with each passing day brings many problems, especially health (obesity, cardiovascular, etc.,) is the primary factor for individuals to experience anxiety and anxiety (Cole et al., 2018). In addition, the management of technological initiatives in an impersonal manner (data privacy, security vulnerabilities, etc.,) is another important factor that prevents individuals from worrying and transitioning to digitalization. Accordingly, it is of great importance to work in an integrated manner with existing systems in the transition to digital agricultural practices and to switch to appropriate technological initiatives after improving the technical infrastructures in the implementation of digital management technologies (Soma and Nuckchady, 2021). It is necessary to address the limitations of digital technologies along with their current potential, to determine the advantages and disadvantages in the area where they will be used, and to search for appropriate solutions. Significant limitations arise especially in underdeveloped countries or their small-scale use (Xie et al., 2021; Gabriel and Gandorfer, 2023). The similarity of problems and problems in both shows that these technologies should be chosen in accordance with their use. It should also be known that this technological development, which has been reported to have many positive effects in terms of agriculture, has the potential to increase greenhouse gas emissions instead of reducing it, or that it is defined as a cost-free development as a result of its application to large-scale areas. Such information deficiencies or inaccuracies arise from not working too much on this subject or from applications that are not selected as suitable and effective for use (Du et al., 2023).

In other words, there is no doubt that this unique technological revolution, which makes it possible to reduce greenhouse gases, will also create environmental effects during the disposal of electronic waste (Motalo et al., 2023). However, it is seen that there are great handicaps for the issue of equal distribution, which is encountered in almost every field. In this issue, which is led by food inequality, there will be socio-cultural and ethical consequences in many parts such as sources of economic gain, purchasing power, property, land, etc., (Wahiba and Mahmoudi, 2023). In order to benefit from digital technologies correctly and effectively, the factors that will limit their use need to be resolved one by one. In particular, today is also called the age of computer and technology, and it is predicted that the need for energy and electricity resources for its future evolution will grow like an avalanche. They are also cited as one of the biggest obstacles to carrying out such studies in rural or far from the city center (Wei et al., 2023).

When such limitations and problems are ignored, it is seen that digital technologies are chosen and used today for the solution of many problems related to agriculture, food and the environment. Despite this, it is quite clear that there will be numerous limitations in addition to their use in solving problems. Accordingly, as an area that still needs to be developed, digitalization solutions also need more research. In particular, solutions and limitations within each area should be compared and carefully examined within the framework of potentially effective and fully sustainable rules. Thus, looking at the data to be obtained, the economic applicability of digitalization, which started in agriculture with the aim of economic gain, in other fields will also be determined. Finally, a detailed investigation of future studies in socio-cultural and ethical terms suggests that it will be of great importance to eliminate or reduce the limitations and problems in this context. It should also be noted that the multidisciplinary integrated use of many sustainable fields will also provide benefits to this issue (Borghi et al., 2016; Stepnov, 2021).

4. CONCLUSION AND RECOMMENDATIONS

This book chapter provides an overview of exactly what digitalization means, its effects and its future position as well as global challenges and problems with an innovative perspective in terms of sustainability of agriculture, food and the environment. In addition to the possible effects of global warming and natural evetns, fungal plant diseases also have effects on agricultural products in the form of decreases in quality and yield losses with the increase of infected plants, and also proportional decreases in plant-based food production. Thus, the inability to provide food and the increasing concerns about food threaten food security and safety, as well as agriculture. Therefore, the aim of reducing the effects of factors affecting agricultural production is the focus of the scientific community. However, this subject, which is the focal point, requires the use of techniques with critical features such as reliable, innovative and repeatable, and innovative technologies in the age of digitalization in every field, and applications that have the potential to be innovative, multidisciplinary and sustainable, are being developed by also including food in the common issues determined to protect of future. Digital agriculture applications are one of the innovative techniques and technologies that contribute to reducing the impact of agricultural problems, as well as reducing concerns and increasing plant-based nutrition due to their positive effects on food, as well as providing benefits for the sustainable management and protection of agriculture, food and the environment. Moreover, the least impact on the environment and agriculture in the protection of food safety and security offers the golden key of sustainable life to future generations. In line with this purpose, this chapter focuses on technological alternative solutions by addressing today's problems and challenges related to agriculture, food and environment in order to leave a livable world to future generations. Accordingly, it is emphasized that the idea that life will not be eternal and inexhaustible also applies to agriculture. It is obvious that the protection of the future and the multidisciplinary use of developments in line with today's sustainability goals will provide effective, fast, time-saving, cost-free, accurate and reliable solutions.

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CHAPTER X

BıOCHAR EFFECT: PLANT RESISTANCE TO BIOTIC AND ABIOTIC STRESSES

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1.INTRODUCTION

Unpredictable climate change, growing industrial sectors, excessive agrochemicals, biotic and abiotic stressors negatively affect the growth and productivity of many crops. "Sustainable agriculture" aims to find a set of conservation agricultural practices that can reduce such negative impacts. Biochar is part of sustainable agricultural practices that focus on solving global problems such as stressors, environmental pollution, soil degradation and climate change. Biochar is charred organic material produced after pyrolysis from carbon (C)-based raw material in oxygen-free conditions. It is a simple charcoal-like product consisting mostly of manure, sawdust, crop and forest waste, etc. Many studies have shown that biochar increases crop productivity under both typical and unusual circumstances adverse conditions such as salinity, drought, and heavy metals. It has been reported to significantly increase the capacity to retain and adsorb plant nutrients in the soil and reduce nutrient losses. Biochar has also been reported to suppress the growth of many plant pathogens such as *Fusarium* spp., *Verticillium* spp., *Rhizoctonia* spp., *Phytophthora* spp., *Alternaria* spp., and *Pythium* and increase the activity of beneficial microorganisms in the rhizosphere. Biochar has been applied widely to reduce abiotic and biotic stress on plants. In this review, we report the effects of biochar application under biotic and abiotic stress conditions (salinity, drought, flooding, and heavy metal stress) to increase the resistance of plants exposed to these conditions. It also emphasizes the importance of offering a different perspective on the many aspects of biochar as an alternative to sustainable agriculture.

Programs to increase food crop production are constrained by intensive farming methods and the impacts of climate change, which also jeopardize crop yields (Al-wabel et al., 2015; Hasnain et al., 2022). The consequences of climate change include melting glaciers, rising ocean and sea water levels and changes in weather patterns, soil degradation and drought, floods, and increases in plant pathogens and pests (Hasnain et al., 2022; Murtaza et al., 2023). Therefore, there is a need for a sustainable agricultural system with environmentally friendly, practical, and effective practices that can conserve and improve soil, increase agricultural yields, and mitigate the impacts of climate change in response to the food demands of a growing population (Zhang et al., 2019; Singh et al., 2022).

Biochar, known for its porous structure and efficiency in soil fertility, has emerged as a promising biomaterial for environmental management, and biotic and abiotic stress factors due to its abundant mineral and micronutrient content and strong adsorption capacity (Abhishek et al., 2022). Biochar, which contains abundant carbon (C), is obtained by pyrolysis of various feedstocks under limited oxygen conditions (Rady et al., 2016). Pyrolysis is a thermochemical technology. In other words, it is defined as the breakdown of biomass into smaller pieces and the emission of specific gases at regulated oxygen levels (Mallick, 2019). The fact that pyrolysis contains approximately 50% plant moisture and is a cost-effective and applicable method in agricultural activities are among the reasons why it is preferred (Leng and Huang, 2018). As the pyrolysis temperature increases, biochar yield decreases, and pH and ash content increase (Oh and Seo, 2019). The history of biomass (black carbon) in pyrolysis goes back many years, and evidence shows that charcoal was used in agriculture by many peoples, including the Egyptians and Greeks (Elad et al., 2011; Semida et al., 2019). In recent years, biochar has attracted attention as a potentially valuable input tool in agriculture to improve soil fertility, aid sustainable agricultural production, and mitigate the negative effects of different biotic (pathogen, pest) and abiotic (temperature, drought, salinity) stresses, improve plant growth and provide genetic diversity (Barrow, 2012; Akhtar et al., 2015; van Geel et al., 2021). Biochar provides bioavailability for crops grown in poor soil conditions (saline, arid, heavy metal, etc.) (Gasco et al., 2016). They also increase the density of beneficial microorganisms in the soil, plant growth, development, and yield (Murtaza et al., 2021). This efficiency is related to the type of biochar, pyrolysis temperature, biochar dose, and soil type (Joseph et al., 2021).

There is a growing literature on the effectiveness of biochar in sustainable agricultural practices. The overall objective of this review is to synthesize and present knowledge on biochar-soil-plant interactions, focusing on the effects of biochar on plant growth and tolerance to biotic and abiotic stresses. Furthermore, a schematic representation of biochar production and its advantages is given in Figure 1.

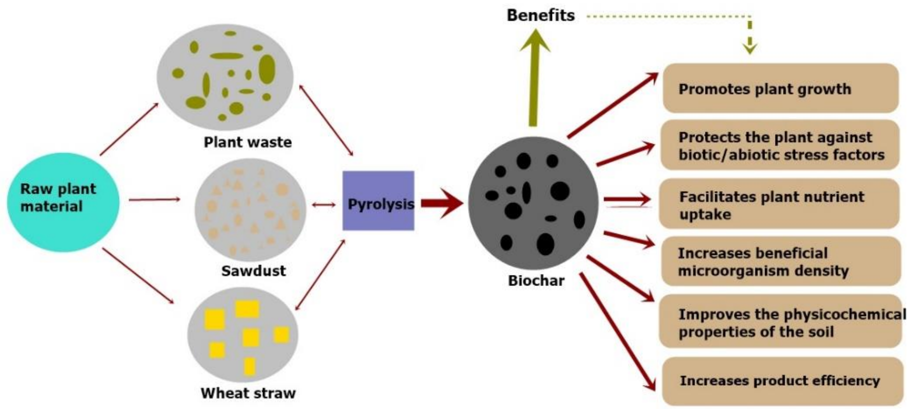

Figure 1. Schematic representation and advantages of biochar production

2. EFFECTS OF BIOCHAR ON PLANT RESISTANCE TO BIOTIC AND ABIOTIC STRESSES

Biochar (alone or in combination with live microorganisms) applied to degraded soils (saline, heavy metal-laden, inoculated, etc.) is considered to be beneficial in enhancing plant resistance to biotic and abiotic stresses (Farooq and Pisante, 2019). The use of biochar in plants under biotic/abiotic stress conditions has been shown in numerous studies to support plant development and improve plant stress tolerance (Gao et al., 2020; Gunes et al., 2023). The effects of biochar application in increasing plant stress resistance vary according to many factors. These effects are described in detail below.

2.1.Plant diseases

Many studies examining the use of biochar in plant diseases have addressed how biochar affects plant resistance to both soilborne and foliar pathogens (Elad et al., 2011). The ability of biochar to detoxify chemicals and suppress soil pathogens has been reported to depend on several mechanisms, including (Atkinson et al., 2010; Silber et al., 2010; Elad et al., 2011).

i. Provision of nutrients that help enhance plant growth and resistance to stresses caused by pathogenic soil microorganisms

ii. Stimulation of microorganisms that provide direct protection against soil pathogens through antibiosis, competition, or parasitic pathways
iii. Biochar-associated organic compounds suppress sensitive components of soil microflora and promote the proliferation of resistant microorganisms
iv. Biochar stimulates systemic plant defense mechanisms

Biochar affects microbial density as mentioned above. It responds to changes in the response mechanism by producing antibiotics, competing with or suppressing pathogens and increasing beneficial microorganisms that provide direct protection against soil pathogens (Elad et al., 2011). Bonanomi et al. (2015) recently analyzed data from 13 pathosystems examining the impact of biochar on plant diseases. Accordingly, they stated that just 3% of the studies revealed that biochar applications caused plant disease, but 12% had a neutral effect, and 85% of the studies demonstrated a favorable of biochar in reducing the impact of disease in plants. Many researchers have studied the beneficial effects of biochar in reducing major plant diseases in wheat (Tian et al., 2021; Wu et al., 2022; Murtaza et al., 2023). Especially the studies by Tian et al. (2021) and Wu et al. (2022) draw attention. Tian et al. (2021) reported that biochar reduced bacterial wilt disease in tomatoes by 75%. They reported that this may be due to changes in the composition of organic acids and amino acids in the rhizosphere region, increasing the diversity and activity of microorganisms in the rhizosphere. Similarly, Wu et al. (2022) reported that biochar from rice husks reduced the growth of soil-borne pathogens (*Fusarium solani*) and promoted the growth of plant seedlings. They also found that biochar from different plant products increased the number of beneficial microorganisms such as Rhizobacteria, Arbuscular mycorrhizal fungi, and *Trichoderma*, which promote plant growth and reduce disease severity of many plant pathogens (Gunes, 2022; Wu et al., 2022). Elmer and Pignatello (2011) reported that biochar from coconut increased AMF root colonization and reduced root lesions caused by *Fusarium oxysporum* f. sp. *asparagi* and *F. proliferatum* in asparagus compared to control. They also determined that biochar may help prevent allelopathic effects.

In pepper, biochar from corn stalks was found to increase the density of many biological control fungi like *Trichoderma* in the rhizosphere and reduce the severity of leaf blight disease by up to 50% (Wang et al., 2020; Gunes et al., 2023; Murtaza et al., 2023). Semida et al. (2019) reported in their study that high doses of biochar should not be applied against plant leaf pathogens. In this context, they stated that diseased plants are more sensitive to high biochar doses than healthy plants on the dose axis. Similarly, Jaiswal et al. (2015) described this phenomenon while investigating the effects of biochar derived from greenhouse waste and eucalyptus wood waste on beans and cucumber infected with the soilborne pathogen *Rhizoctonia solani*. In their study, they found that 3% biochar concentration gave better results on healthy plants, while 1% was most effective on diseased plants. According to Akhter et al. (2015), plant morphological parameters increased in tomato plants with 3% biochar, and disease severity caused by *F. oxysporum lycopersici* decreased at the same biochar rate. The plant hormone ethylene plays an important role at low doses, both as a plant growth promoter and as a supporter of plant defense against various stress factors. At higher concentrations, it appears to be ineffective in these roles (Kammann and Graber 2015). There is information in the literature that even low concentrations of some compounds can cause minor stresses. Such stresses and minor injuries are seen as weak points that provide favorable conditions for soil-borne pathogens to successfully attack and penetrate the mechanical defense layer of the root surface (Jaiswal et al., 2015; Frenkel et al., 2017).

2.2.Drought stress

Plants are affected by drought stress in various ways morphological to metabolic and anatomical levels (Zhao et al., 2022). In addition to accelerating leaf senescence, it significantly reduces photosynthetic and crop productivity by reducing chlorophyll synthesis (Ma et al., 2021). It also causes the formation of reactive oxygen species that damage DNA and enzymatic processes (Vijayaraghavareddy et al., 2022). Moreover, drought stress negatively affects physiological processes and leads to decreases in crop productivity, affecting agronomic traits (Zhou et al., 2007). However, there is also information that yield losses are largely dependent on the severity and duration of drought stress and plant species (Agarwal et al., 2016). It also causes a significant decrease in plant productivity by causing limiting chlorophyll synthesis and the destruction of enzymes and proteins (Mahmoud et al., 2022a; Mahmoud et al., 2022b).

As the black gold of agriculture, biochar has recently attracted great interest to offset the negative effects of drought stress. Biochar application generally favored growth in many plants subjected to the drought test (Wu et al., 2023). Additional increases in photosynthetic activity, water use, stomatal conductance, and photosynthetic rates were also observed in these plants (Haider et al., 2015; Batool et al., 2015). In 2018, Rizwan et al. revealed that biochar (wheat straw at 450 °C) applied to rice under drought conditions increased leaf chlorophyll value highly (78%-96%). Farhangi-Abriz and Torabian (2017) reported that biochar (20% maple) applied to beans under limited water conditions decreased enzyme activities. Lyu et al. (2016) found that biochar (5%) applied to pear wood significantly reduced superoxide dismutase activity, peroxidase, and malondialdehyde concentration.

In other studies where biochar was applied, it was reported that it reduced membrane damage, leaf-proportional water content, lipid peroxidation, and increased drought tolerance in barley plants (Hafez et al., 2020). Biochar improves the nutritional status of the plant, increases potassium (K) uptake, and enhances stress resistance (Mannan et al., 2021). Haider et al. (2015) found that biochar application improved leaf-proportional water content in sandy soils, while Lyu et al. (2016) found that biochar application improved antioxidant activities and plant water relations; however, the response of biochar to drought stress varied by plant species, soil, and biochar type. Biochar can mitigate the detrimental effects of dryness on plant growth, and ROS that inhibits plant growth can be lower. The strategic use of biochar during drought is of paramount importance to sustain plant functionality and ultimately crop productivity in arid regions (Hasnain et al., 2023).

2.3.Salt stress

Salt stress is another abiotic factor that affects global agricultural productivity (Abdelaal et al., 2020). Soil salinity, which limits crop production in arid and semi-arid regions, may be pre-existing due to the mineral structure of the soil (primary salinity) or may develop later due to natural processes or human impacts (secondary salinity) (Acosta-Motos et al., 2020; Gomes et al., 2021).

In other words, saline areas are reported to result from climate change, low rainfall, high evaporation, irrigation with saline water, and improper cultural practices (Abidalrazzaq Musluh Al Rubaye et al., 2021). Salinity stress negatively affects the physical and chemical properties of the soil. It causes an imbalance in the uptake of water and nutrients, an increase in soil Na^+ and pH, osmotic-ionic-oxidative stress, a decrease in hydraulic conductivity, and other effects (Akladious and Mohamed, 2018). Soil salinity has a negative impact on almost all aspects of plant growth and development, including germination, vegetative growth, reproduction, yield and physiology (Isayenkov and Maathuis, 2019). As a consequence of salt stress, excessive amounts of ROS are produced, which disrupt the ionic balance in cells, leading to oxidation of important components such as proteins, lipids and carbohydrates. Inhibiting nitrogen uptake prevents plant growth while simultaneously increasing electrical conductivity and MDA buildup (Sultan et al., 2021). To this end, strategies to promote greater plant growth and production under salt stress conditions should be proposed to address the global food security challenge (Hernández-Herrera et al., 2022).

Biochar is a highly important strategy as a common product of today's innovative perspective and sustainability that can be used to reduce the impact of salinity on agricultural productivity, facilitate the development and utilization of saline soils, and increase plant tolerance to salt stress (Choudhury et al., 2021). In particular, it is reported to increase plant growth, yield, nutrient uptake, soil cation exchange capacity, water holding capacity, enzyme activities, and density of beneficial microorganisms (Egamberdieva et al., 2022). Biochar is an environmentally friendly biostimulant that increases crop production and reduces the negative effects of different abiotic stresses. Its recent popularity is due to its ability to improve the physio-biochemical and biological properties of soil (Imran et al., 2022). Gunes et al. (2023) reported that the application of 4% biochar (poplar wood) produced at 400 °C at different salt concentrations increased plant growth parameters (shoot length, root length, leaf area, shoot diameter) of pepper plants. Similarly, In another application under salinity stress, they discovered that 5% (w/w) wheat waste reduced Na^+ uptake by up to 11.8 dS/m (Akhtar et al., 2015). Therefore, different biochar species have the potential to reduce salinity-induced Na^+

uptake. In a study by Demir (2018) it was reported that biochar (pyrolyzed from sheep manure and corn cobs) mixed into saline soil had a positive effect on the mineralogical structure and clay species in the soil.

Abd El-Mageed et al. (2020) investigated the effects of sulfur and biochar (citrus wood at a ratio of 5:100 (w/v)) on soil properties, growth, yield, and salinity damage of pepper under salt stress. Within the scope of these treatments, they found that it increased dehydration tolerance, nutrient uptake, plant growth, yield, and some nutrient concentrations (N, P, K, Fe, Mn, Cu, Zn, and Ca2) while significantly decreasing sodium and cadmium (Na and Cd) concentrations. They also reported that the interaction of sulfur (S) and biochar showed beneficial effects on pepper plants at high salt concentrations. In another study, they investigated the effect of different biochar rates (0, 2.5, 5, and 10%) on sorghum (*Sorghum bicolor* L.) grown under different salt stress conditions (0.8, 4.1, and 7.7 dS/m). They mainly analyzed plant growth parameters. As a result of the study, they found that the interaction between biochar and salinity was significant, and 5% biochar applied had a greater effect on reducing salt stress. With these findings, they proved that an appropriate amount of biochar can reduce the effects of salt stress (Ibrahim et al., 2021).

2.4.Flood

Flooding, one of the abiotic stresses, negatively affects the performance and survival rate of plants (Tian et al., 2020). As a result of floods, soil organisms use up all of the oxygen available and produce various harmful substances (Kaur et al., 2020). In flooded paddy soils, wheat straw biochar applications were found to increase crop yields by up to 14% (Zhang et al., 2010). Hardwood biochar varieties from yellow poplar, walnut, and oak can be used to regularise sandy soil left after flood events. It has also been reported to increase soil nutrient content and crop productivity (Basiri Jahromi et al., 2020). Biochar improves poor soil properties of inundated sandy soils in terms of soil water, nutrient density, and surface area (Cui et al., 2017). Biochar in irrigated paddy soil is a promising method for plant growth and production and has been reported to have several effects on greenhouse gas emissions (Hasnain et al., 2023).

2.5.Heavy metal

Human activity-related heavy metal contamination in the soil causes an excessive buildup of trace elements in the soil. Due to crops being grown in the soil heavy metals tend to collect in the soil and even change into dangerous methyl compounds in human bodies. This is because soil microorganisms cannot easily break down heavy metals.

Biochar, a plant biostimulant for sustainable development, is an environmentally friendly, cost-effective, and available material in phytoremediation (Murtaza et al., 2023). Chen et al. (2018) found that biochar mixed with soil reduced heavy metal pollution such as Zinc (17%), Copper (25%), Lead (39%), and Cadmium (38%) in plant tissue. Lei et al. (2019) revealed that biochar derived from manure has higher Ca content than plant-based biochar so it can immobilize Cu^{2+} and Cd^{2+} through ion exchange.

Biochar with high P content can immobilize lead (Pb) through the formation of β-$Pb_9(PO_4)_6$ (Li et al., 2016). According to research by Xiao et al. (2018), biochar produced at medium and low temperatures generally has a higher capacity to adsorb cation heavy metals. Li et al. (2022) explained that the effect of biochar leads to ion exchange of charged metals, physical trapping on biochar surfaces, and changes in soil chemistry.

Biochar is a possible strategy to reduce heavy metal contamination in crops as it can increase agricultural productivity and promote plant growth. However, the effectiveness of this biochar depends more on the plant species, the biogeochemical characteristics of the soil, and its exposure to specific trace metals. Therefore, future strategies require a thorough analysis to identify the best processes for biochar production, the best biochar species, and the best plant species, to disseminate biochar and to highlight the suitability, adsorption, and sustainability of biochar as an ideal means of regulating against heavy metals while maintaining food quality (Murtaza et al., 2023).

2.6.Pollutants in the soil

Trace elements reduce plant growth, water uptake, and photosynthesis (Duruibe et al., 2007). Some studies have reported that the use of biochar can reduce the impact of certain toxic metals and may be effective in reducing the impact of contaminated soils by providing plants with balanced mineral nutrition. The effect of biochar on metal adsorption varies depending on the surface structure, biomass type, and pyrolysis temperature (Saletnik et al., 2019). Carbon (C) in biochar is highly effective in reducing the heavy metal damage of zinc (Melo et al., 2016). Xu et al. (2013) found that biochar obtained from dairy animal manure immobilized Zinc (Zn) as Zinc phosphate ($Zn_3(PO_4)_2$) and Zinc carbonate ($ZnCO_3$). Similar results were found in the studies of Wagner et al. (2015) and Nzediegwu et al. (2019). Within the scope of the studies, they determined the effects of banana peel biochar for Zn immobilization in sewage soils and Cd and Zn immobilization in potatoes (Solanum tuberosum). Gliricidia sepium biochar (5%) mixed into tomato plant soil significantly increased plant growth and reduced the damage of pollutants such as Nickel (Ni), Chromium (Cr), Manganese (Mn), and serpentine by 93-97% (Herath et al., 2015).

In some studies, it has been shown that biochar application to contaminated soils can increase plant growth and the same time increase plant nutrition (Kavitha et al., 2018). Biochar, together with its water retention capacity, can absorb the damage of pollutants in the soil, regulate soil pH and provide essential plant nutrients to plants (Qian et al., 2016). Biochar has minus charged carboxyl (-C(=O) OH), hydroxyl (OH-), and phenolic functional groups on its surface that bind effectively with pollutants, giving it an excellent absorbency property for pollutants (organic and inorganic) in soil (Hasnain et al., 2023).

2.7.Climate Change

Plant development, soil characteristics, and crop productivity are all severely impacted by climate change (Palanivelu et al., 2020). Agricultural practices such as pesticides, improper and unconscious tillage, and stubble burning reduce carbon and nutrient storage in the soil and negatively affect the diversity of beneficial microorganisms. In addition to being an organic material, when added to soil, biochar raises carbon (C) levels, the density of advantageous microbes in the rhizosphere, and plant productivity in a sustainable manner (Feizi and Razavi, 2020; Sundberg et al., 2020). Wheat straw biochar applied to sandy soil increases organic carbon (C) by about 76%. This combination also promotes C uptake by increasing the percentage of macro aggregates (El-

Naggar et al., 2018; H. Huang et al., 2018). They reported that biochar from corn stalks significantly reduced CO2 emissions (Yang et al., (2017).

Singh and Cowie (2014) found that biochar from the eucalyptus tree (*Eucalyptus saligna*) applied to clay soil stimulated soil organic carbon mineralization. Zhang et al. (2017) found that 8 tons/ha biochar (wheat straw) increased soil organic carbon by 34-80%, microbial biomass carbon by 19-47%, and microorganism density by 8-38%.

3.BIOCHAR FOR SUSTAINABLE AGRICULTURE

Some eco-friendly biostimulants can help produce food with resistance to biotic and abiotic challenges. Among the options, the most potential candidates include humic acids (Li et al., 2021), organometal fertilizers (Liu et al., 2020), and biochar (Mona et al., 2021; Liu et al., 2023). These additions not only aid to improve soil fertility but also hasten plant growth and promote plant resistance to harsh environments (Liu et al., 2023).

Nowadays, biochar, as a potentially valuable agricultural input method, is attracting attention for improving soil fertility, assisting in the production of new agricultural systems, and mitigating the adverse effects of biotic and abiotic stresses (Xiao et al., 2017). Biochar is hydrophobic, making it an attractive adsorbent for post-combustion CO2 capture (Zhou et al., 2021). Biochar fertilizer, which is effective in increasing soil fertility and contains abundant mineral substances, and mimics soil conditions, has recently attracted attention in the world (Liu et al., 2020b).

Biochar is created using organic matter, agricultural and forest residues, and fertilizers as source materials (Kavitha et al., 2018). Pyrolysis, the most common method used for biochar production, generally uses thermochemical decomposition methods such as hydrothermal carbonization, gasification, and baking (Tan et al., 2017; Liu et al., 2023). Biochar has been shown to have significant potential to improve soil health, and plant growth, increase crop yields, reduce the use of chemical fertilizers, and thus improve sustainability in agriculture. The following criteria should be considered for the application of biochar to soil and to guide future research:

1. Before use, the toxicity of biochar as a soil conditioner should be established.

2. Biochar applied to alkaline soils may not be as successful according to crop yield as biochar applied to acidic soils. The pH level of low pyrolyzed biochar is usually low. Therefore, it is important to consider the pyrolysis temperature of the biochar as well as the type of soil. In addition, biochar needs to work well with fertilizers such as humic acid. Future studies should focus on via means of functional biochar in calcareous and sandy soils in arid regions; the choice of feedstock and preparation temperatures are crucial when creating functional biochar.

3. The recommended proportions to maximize the advantages of biochar under specific conditions are not yet fully established. Small-scale farmers typically can't imagine using biochar in significant volumes. So various farming patterns should be included in cost-benefit analyses of the usage of biochar. Applying biochar to pots when growing seedlings could be a cost-effective way for small-scale farmers to pursue biochar technology.

4. The combination of biochar with beneficial microorganisms such as rhizobacteria, mycorrhiza, and *Trichoderma* can promote plant growth and improve nutrient utilization efficiency.

5. Laboratory research should be synchronized with field trials. Differences in soil and environmental conditions can create inconsistencies in laboratory and field trials. Hence, extensive field trials over a long period are necessary.

CONCLUSION

Since the Palaeolithic period, biochar has been associated with human civilization and food gathering. Biochar increases nutrient mineralization by altering biotic-abiotic stress and microbial activity in the rhizosphere. Due to accelerated microbial activity, organic matter cycling in the soil increases, which improves nutrient availability. The type of plant used and the pyrolysis temperature affect the structure of the biochar. Biochar applied at optimum rates regulates soil structure, inhibits pathogen development, and facilitates plant uptake by regulating nutrient and limited water conditions. Therefore, soil pH, nutrient availability, and the selection of suitable feedstocks are important for a clear understanding of every aspect of biochar in soil and plant systems.

There are still many unanswered questions about the physicochemical properties of biochar. It will be determined how biochar affects carbon sequestration, plant cultivation, sustainable soil management, and the management of harmful biotic and abiotic pressures. Therefore, disciplinary and new methodological transformations are needed. Shortly, biochar will be used in carbon trading. This is a consequence of the widespread use of biochar as a soil conditioner in other land-based activities such as forestry, agriculture, and ecological restoration.

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