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Inferences Regarding the Usage Areas and Climate Effects of Similar Medicinal Plant Species in Nairobi and Sivas Museums

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Abstract: From ancient times to the present day, many cultures worldwide have long used medicinal plants for their therapeutic benefits. Members of Lamiaceae and Fabaceae are among the most popular therapeutic plants because they contain a wide range of secondary components, especially essential oils. However, they are in danger of extinction due to recent climate changes, global warming, and the uncontrolled consumption of these plants. Understanding how climate change affects medicinal plants can help us create plans to preserve them for future generations. This study discusses climate change impacts on similar medicinal plants in Sivas (Türkiye) and Nairobi (Kenya), regions known for their great biodiversity and long history of medicinal plant use. Both cities host a rich biodiversity of medicinal plants integral to their respective regions' culture and history. The study covers several plant families, such as Lamiaceae and Fabaceae, common to both regions. These plants are used for their healing properties, particularly for treating bacterial infections in Kenya and as part of traditional cuisine in Sivas. This study highlights the need for further research on the sustainable use of medicinal plants and their potential role in the effects of climate change.

Keywords: Climatic conditions, Nairobi National Museum, SCU Natural History Museum, Fabaceae, Lamiaceae

Nairobi ve Sivas Müzelerindeki Benzer Tıbbi Bitki Türlerinin Kullanım Alanları ve İklim Etkilerine İlişkin Çıkarımlar

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Araştırma Makalesi

Öz: Antik çağlardan günümüze kadar dünya çapında birçok kültür, şifalı bitkileri tedavi edici faydaları için uzun süredir kullanmaktadır. Lamiaceae ve Fabaceae üyeleri, başta uçucu yağlar olmak üzere çok çeşitli ikincil bileşenler içerdikleri için en popüler tedavi edici bitkiler arasındadır. Ancak, son iklim değişiklikleri, küresel ısınma ve bu bitkilerin kontrolsüz tüketimi nedeniyle yok olma tehlikesiyle karşı karşıyadırlar. İklim değişikliğinin şifalı bitkileri nasıl etkilediğini anlamak, onları gelecek nesiller için koruma planları oluşturmamıza yardımcı olabilir. Bu çalışma, büyük biyolojik çeşitlilikleri ve uzun tıbbi bitki kullanım geçmişleriyle bilinen Sivas (Türkiye) ve Nairobi'deki (Kenya) benzer tıbbi bitkiler üzerindeki iklim değişikliği etkilerini tartışmaktadır. Her iki şehir de kendi bölgelerinin kültürü ve tarihi ile bütünleşmiş zengin bir tıbbi bitki biyoçeşitliliğine ev sahipliği yapmaktadır. Çalışma, her iki bölgede de yaygın olan Lamiaceae ve Fabaceae gibi çeşitli bitki familyalarını kapsamaktadır. Bu bitkiler, özellikle Kenya'da bakteriyel enfeksiyonların tedavisinde ve Sivas'ta geleneksel mutfağın bir parçası olarak iyileştirici özellikleri için kullanılmaktadır. Bu çalışma, şifalı bitkilerin sürdürülebilir kullanımı ve iklim değişikliğinin etkilerindeki potansiyel rolleri konusunda daha fazla araştırma yapılması gerektiğini vurgulamaktadır.

Anahtar Kelimeler: İklim koşulları, Nairobi Ulusal Müzesi, SCÜ Tabiat Tarihi Müzesi, Fabaceae, Lamiaceae

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Introduction

In recent years, factors such as increasing desertification, melting glaciers, climate changes, and global warming have been associated with an increase in carbon dioxide emissions (Karl and Trenberth, 2003). Consumption of natural resources due to urbanization and industrialization, which are the needs of the global world, poses a threat to living ecosystems and causes a decrease in living spaces. Accordingly, our Earth faces dangers such as the extinction of some living species or a decrease in living diversity. It is very important to protect these species and pass them on to future generations.

Natural history museums play a crucial role in preserving and displaying the Earth's biodiversity. These institutions house specimens representing millions of years of our planet's history (Biodiversity | Natural History Museum, n.d.). These establishments function as knowledge repositories, keeping a variety of collections of plants, animals, fossils, and cultural items.

This study discusses the properties, areas of use, and requirements for protection against climate change of some medicinal plants that have been used in medical treatments throughout human history and are still used today. The existence and well-being of humans depend on medicinal plants (Ghorbanpour et al., 2017). Concerning, extreme weather and climate change are becoming major dangers to the variety and long-term usage of medicinal plants (Robiansyah et al., 2023). For millennia, the utilization of therapeutic plants has been fundamental to human well-being; over 80% of the global populace still depends on conventional plant-based remedies (Izah et al., 2023).

In the study, similar plant species exhibited at the Nairobi National Museum in Kenya and Sivas Cumhuriyet University Natural History Museums in Türkiye were preferred (Figure 1). We shall pay particular attention to the genera of two families the Fabaceae and Lamiaceae that are well-known for their therapeutic qualities. These plants are vital to ecosystems because they support pollinators, provide food, and maintain healthy soil (Odongo et al., 2022). In Sivas, the genera of Lamiaceae most commonly used for medicinal purposes are Salvia, Sideritis, Stachys, Thymus, and Origanum. The correlation between these two museums transcends geographical boundaries. As stewards of our planet's natural heritage, they inspire us to appreciate the interconnectedness of ecosystems and their role in shaping climate patterns.

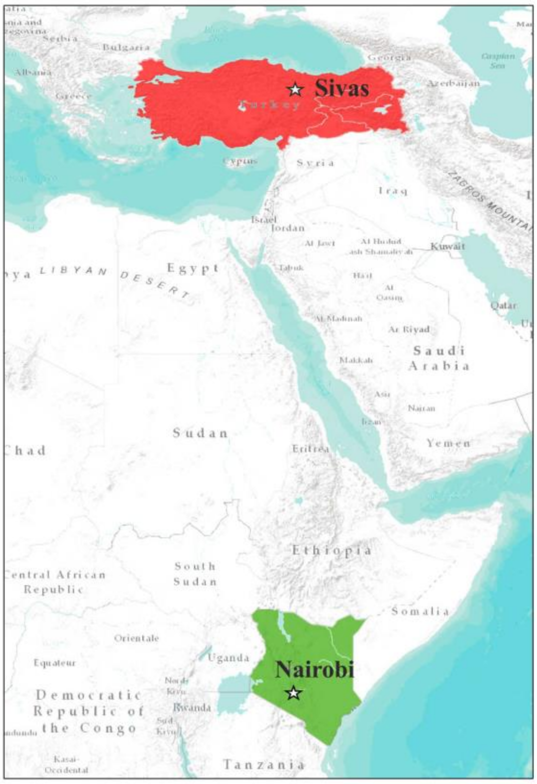

Figure 1. Location map of the museums.

Museums

The Nairobi National Museum (Kenya)

In Kenya, the management of museums, landmarks, and state corporations is under the purview of the Nairobi National Museum, a state corporation. It was established in 1910 by the East Africa Natural History Society, primarily to conduct scientific research on the natural characteristics of the East African environment (Nairobi National Museum – National Museums of Kenya, n.d.). The Nairobi National Museums serve as sites for exploration, reflection, and education (Figure 2). The four pillars that support the Institution of National Museums of Kenya are culture, history, the arts, and nature(Nairobi National Museum – National Museums of Kenya, n.d.). The competence of the museum is broad and includes studies on biodiversity, archeology, paleontology, and ethnography. There is a sizable collection of specimens in the museum, both transient and permanent (Nairobi National Museum Kenya, n.d.). The museum offers tourists and researchers the opportunity to view and investigate exhibits highlighting the region's diverse ecosystems, fauna, and geological history (Nairobi National Museum Kenya, n.d.).

The Nairobi National Museum advances knowledge on climate change by examining the relationships among ecosystems, climate, and human activity. It clarifies how local and global temperatures are impacted by changes in habitats, deforestation, and species extinction. Since healthy ecosystems are essential for carbon sequestration and climate management, conservation actions started by the museum can have a direct impact on climate resilience (Nairobi National Museum Kenya, n.d.) (Nairobi National Museum: Tours and Tickets - Tripadvisor, n.d.). Due to its vast geographic disperse, varied climatic conditions, and various soil types, Kenya, an African nation with significantly higher plant variety, also has a matching diversity of plant relationships and circumstances.

Figure 2. Views of the Nairobi National Museum. (a) Entrance of the museum, (b) Herbal Garden at Nairobi National Museum, (c-d) Learning about medicinal plants with the TICAH (Trust for Indigenous Culture and Health) herbalist at the Medicine Shield Garden at NMK

Sivas Cumhuriyet University Natural History Museum

Its significant geographic location in the Central Anatolian, Eastern Black Sea, and Eastern Anatolian regions, along with its diverse cultures, climates, and values, make it an important place. Sivas, a city of science and culture with its renowned madrasas, ruins, and historic buildings, is situated on the shore of Kızılırmak in eastern Central Anatolia (Türkiye: Madrasas of Sivas National Geographic, n.d.). Sivas has hosted significant civilizations.

Located in Sivas, Türkiye, the Cumhuriyet University Natural History Museum was established in 2022 to serve as a hub for scientific research, education, and public engagement (Figure 3). Its mission includes preserving and showcasing Türkiye's natural heritage, emphasizing the importance of biodiversity conservation (Özgen Erdem and Canbaz, 2023) (Pehlivan, 2023) (Sivas Cumhuriyet University, n.d.). The museum houses an array of specimens, from fossils and minerals to botanical samples. These collections provide valuable insights into the region's geological history and ecological dynamics. Researchers at the museum contribute to studies on climate change adaptation, habitat restoration, and sustainable land use practices. The museum actively plans to collaborate with local communities, policymakers, and scientists to address climate-related challenges. By promoting awareness and advocating for conservation, the museum aims to build climate-resilient ecosystems in the Sivas region.

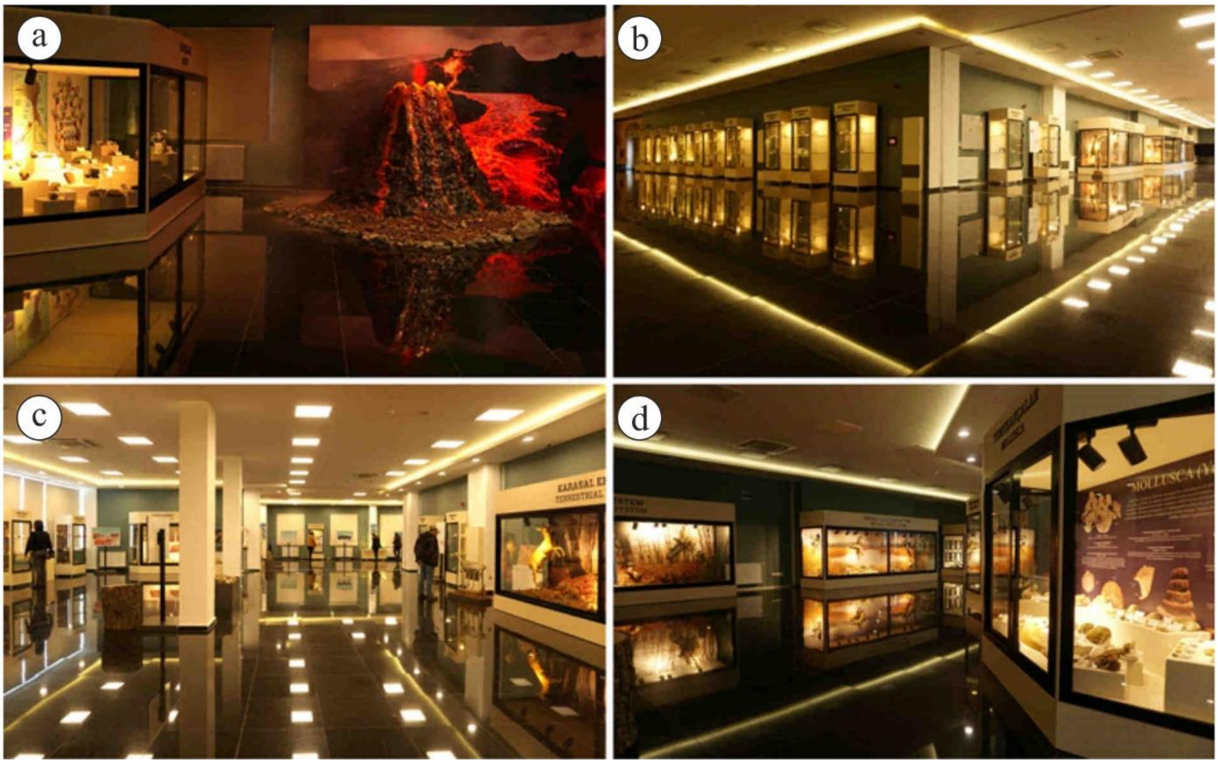

Figure 3. Views of the Sivas Cumhuriyet University Natural History Museum. (a) a volcanic model, (b-d) general views.

Material and Methods

The data for the Sivas Cumhuriyet University Natural Museum was directly collected from the Museum while the Nairobi National Museum data on fauna was obtained from the relevant museum website. The Sivas Cumhuriyet University Natural History Museum houses a total of 127 species which are divided into 36 families. Kenya has a wide variety of 105 plant species which are divided into 43 families.

Rich medicinal plant biodiversity is ingrained in the history and culture of both organizations' respective locations. Both locations have large populations of the Lamiaceae family, often known as the mint family, and the Fabaceae family, commonly known as the bean family. These families are well-known for their wide range of therapeutic qualities, which include antioxidant, anti-inflammatory, and antibacterial effects (Rao and Rao, 2015; Maroyi, 2023).

These therapeutic plants are essential for regulating climate variation (Cammarano et al., 2023). They improve soil health, aid in the sequestration of carbon, and serve as a habitat for a variety of creatures, all of which support biodiversity. The necessity for their conservation and sustainable use is highlighted by the way that their sustainable use can support policies aimed at mitigating climate change (Alahmad et al., 2023). Additionally, these areas have a long history of transferring information about the uses of these plants from one generation to the next, underscoring the significance of these plants in the cultures in which they are found (Hardy, 2020; El Sheikha, 2017).

Results

Within the Nairobi National Museum, there is a significant representation of Lamiaceae (*mint family)* and Fabaceae (*legume family*) plants. These families are vital for ecosystems due to their roles in supporting pollinators, providing food, maintaining healthy soil, and also used in healing practices. Aloe secundiflora is a drought-tolerant plant mostly found in the arid and semi-arid areas of Kenya. The species is locally used as a medicine for humans and livestock, a fermenting agent in local beers, and a border plant (Kokwaro, 1976). The Aloe is famous for its medicinal and cosmetic properties and has a long history of use in Kenya. Many species of aloes are threatened with extinction, especially in the current climate change scenario, and thus the a need to keep knowledge about their use for sound conservation strategies (Bjora, et al, 2015).

Fuerstia africana is a genus of plants in the family Lamiaceae, first described in 1929 and it is native to Eastern and Southern Africa. An infusion of the leaves of Fuerstia africana T.C.E. Fr (Lamiaceae) is used to treat genital and oral thrush (Matu, et al., 2008) while Sericocomposis hildebrandtii Schinz (Amaranthaceae) roots juice is drunk for purgative effect and to treat dysmenorrhea (Kokwaro, 1993; Kipkore, et al., 2014)).

Olea africana is a small to medium-sized hardy tree with a rounded dense spread. It has narrow glossy grey-green leaves with silvery undersides and its fragrant flowers are greenish-white or cream which develop into fruits that ripen to purple-black (Bussmann, et al., 2020). Traditional remedies prepared from this plant serve as eye lotions and tonics, lower blood pressure, improve kidney function, and deal with sore throats. The early Cape settlers in South Africa used the fruits to treat diarrhoea. Frost-, drought- and wind-resistant, the wild olive has beautiful wood for furniture, and is regarded as a small-fruited subspecies of the commercial olive. This tree occurs throughout South Africa in various habitats and displays some growth forms from multi-stemmed shrubs to stately trees up to 18m tall (Orwa, et al., 2009)

On the other hand, Sivas province, located in central Türkiye has a rich history of traditional medicine. Indigenous knowledge about medicinal plants has been passed down through generations. The Lamiaceae family is particularly relevant for medicinal purposes in Sivas. Genera such as *Salvia, Sideritis*, *Stachys, Thymus*, and *Origanum* are commonly used. These plants have diverse therapeutic properties and are integral to local healing practices (Table 1).

Efforts to conserve these valuable plant resources are essential. Sustainable practices, including cultivation and responsible harvesting, can ensure their availability for future generations. In summary, both Nairobi and Sivas museums recognize the importance of preserving medicinal plant diversity. By understanding their unique contexts and leveraging traditional knowledge, we can promote sustainable use and protect these valuable natural assets.

Table 1. Similar Plants remedies in Sivas (Türkiye) and Nairobi (Kenya)

No.	Family and species name	Parts used	Use and administration
1	*Thymus/Thyme* **Lamiaceae**	Leaves	- It boosts the general immunity of the body as it contains vitamin A and Vitamin B (*Thyme: 12 Health Benefits and More*, n.d.). - It is used in disinfecting as it contains antiseptic properties e.g. mouthwashes, medicated bandages, or fungal creams(*Antiseptics and Disinfectants | MSF Medical Guidelines*, n.d.). - It's also effective against mold, a common indoor pollutant(*Reduce Your Exposure to Mold in Your Home | Mold | CDC*, n.d.) - It also impacts the mood positively hence referred to as aromatherapy to boost spirits and create a pleasant environment(*Everyday Aromatherapy for Enhancing Calm and Well-Being | Psychology Today*, n.d.)

			- Apart from its medicinal benefits, thyme remains a culinary staple due to its distinctive taste when added to the dishes and potential health perks (*Thyme: 12 Health Benefits and More*, n.d.)
2	*Rosmarinus officinalis* (Rosemary leaf) **Lamiaceae**	Leaves	- It is used to cure headaches, dysmenorrhea, stomachache, epilepsy, rheumatic pain, spasms, and nervous agitation (Rahbardar and Hosseinzadeh, 2020; Vieira et al., 2022). - It also helps in the improvement of memory, hysteria, depression, as well as physical and mental fatigue (Vieira et al., 2022; Rahbardar and Hosseinzadeh, 2020)
3	*Salvia officinalis* (sage herb) **Lamiaceae**	Aerial parts	- Adds vibrant color to landscapes (*27 Vibrant Color Choices for the Fall Landscape | Gardener's Path*, n.d.)**.**
4	*Mentha Spicata* (Mint) **Lamiaceae**	Leaves	- Mint is extensively utilized as a culinary herb in cooking flavor and aroma to dishes such as salads, sauces, and beverages (*Cooking With Mint: The Dos And Don'ts*, n.d.). - It is used in creams, lotions, shampoos, and conditioners to soothe irritated skin, reduce oiliness, and promote scalp health(*How to Improve Your Skin with Mint | HowStuffWorks*, n.d.).
5	*Salvia officinalis* (sage) **Lamiaceae**	Leaves	- Its fragrant leaves are prized for their savory flavor and are often used to season meats, poultry, soups, and stews (*Thyme: Exploring Its History, Flavor, And Culinary Uses*, n.d.). - It is believed to possess various therapeutic properties, including antimicrobial, anti-inflammatory, antioxidant, and cognitive-enhancing effects (Mitropoulou et al., 2023).
6	*Cassia* (sinameki) **Fabaceae**	Leaves and pods	- Used to relieve constipation and promote bowel movements(*Constipation - Symptoms and Causes - Mayo Clinic*, n.d.) (*Fruits for Constipation Relief: 16 Fruits That Can Resolve Your Stomach Issue*, n.d.).
7	*Ceratonia siliqua* (carob) **Fabaceae**	Pods	- They can be consumed fresh or dried, and are often processed into various products such as carob powder, carob syrup, and carob chips (*The 5 Best Things About Carob*, n.d.). - Carob syrup is sometimes used as a natural remedy for digestive issues such as diarrhea and indigestion (*CAROB: Overview, Uses, Side Effects, Precautions, Interactions, Dosing and Reviews*, n.d.)**.**
8	*Glycyrrhiza glabra* (meyan) **Fabaceae**	Roots	- It is primarily known for its sweet-tasting root, which contains bioactive compounds with various pharmacological effects(Kumar et al., 2021).
9	*Lavandula stoechas* (karabash herb) **Lamiaceae**	Flowers and Leaves	- Prized for its aromatic qualities, with fragrant flowers and foliage that are used in potpourris, sachets, and aromatherapy products (*Lavandula x Intermedia SENSATIONAL!® (Lavandin)*, n.d.). - Used in traditional medicine for various therapeutic purposes(*Traditional Medicine Has a Long History of Contributing to Conventional Medicine and Continues to Hold Promise*, n.d.).
10	*Lamiumga leodolon (crantz) Alibaba* **Lamiaceae**	Leaves and Aerial Parts	- Used to treat respiratory ailments such as coughs, colds, and bronchitis (*Mullein: A Powerful Herbal Remedy for Respiratory Health — Medicinal Backyard*, n.d.)**.** - Used to support digestive health and alleviate gastrointestinal discomfort. (*Your Digestive System: 5 Ways to Support Gut Health | Johns Hopkins Medicine*, n.d.)

11	*Melissa officinalis* (lemon one) **Lamiaceae**	Leaves	- It is renowned for its calming and soothing properties, making it a popular herb for alleviating stress, anxiety, and insomnia(*Can Herbs Help You Alleviate Stress and Anxiety? | Psychology Today*, n.d.)**.**
12	*Lavandula intermedia* (lavender) **Lamiaceae**		- Contributes to perfumes and skincare products(*Lavandula x Intermedia SENSATIONAL!® (Lavandin)*, n.d.)**.**
13	*Acacia* (Acacia tree Resin) **Fabaceae**		- Useful for covering wounds and cuts, providing a protective barrier against infection, and promoting faster healing (Han, 2023).
14	*Astragalus tragacantha* (kitre Zamki) **Fabaceae**	Roots	- It is often used as a herbal remedy to alleviate symptoms and promote respiratory wellness(*Breathe Easy: Herbs to Improve Respiratory Health Amidst Delhi's Air Pollution | OnlyMyHealth*, n.d.). - Support digestive health and aid in gastrointestinal issues such as indigestion, bloating, and diarrhea (*Foods That Help Digestion: What to Eat and Avoid*, n.d.).
15	*Lavandula steochas* (karabas herb) **Lamiaceae**	Leaves	- Used in traditional medicine for its therapeutic properties (*Who Global Report On Traditional And Complementary Medicine 2019*, 2019). - The plant possesses aromatic qualities and is often used for fragrance or as incense(*A Field Guide To Aromatic Plants: Lavender, Rose, Jasmine*, n.d.).
16	*Salviamulticaulis vahl* **Lamiaceae**	Leaves	- The leaves contain bioactive compounds such as phenolic acids, flavonoids, and terpenoids, which contribute to their pharmacological activities (Kumar et al., 2021).
17	*Sileneruscifolia(Hub.-Mor.and Reese)* **Lamiaceae**	Leaves and Roots	- The plant may be used to alleviate symptoms of respiratory disorders such as coughs and bronchitis (Mailu et al., 2020). - To aid digestion and alleviate gastrointestinal discomfort(*7 Foods To Alleviate Digestive Discomfort*, n.d.).
18	*Nepeta betonifolia C.A.Mey* **Lamiaceae**	Aerial parts	- It is used to alleviate symptoms of conditions such as headaches, fever, and gastrointestinal disorders(*Migraine > Fact Sheets > Yale Medicine*, n.d.) (*Headaches > Fact Sheets > Yale Medicine*, n.d.).
19	*Scutelliana orientalis* L. *subsp, bicolor* (*Hochst*) *J.R Edm* **Lamiaceae**		- Beneficial for conditions such as arthritis and other inflammatory diseases.
20	*Thymus pectinatus Fisch and Mey. var. pectinatus* **Lamiaceae**	Leaves	- Used as a culinary herb, imparting a distinctive flavor and aroma to various dishes. It is often used to season meats, soups, stews, and sauces. - It is believed to have antiseptic, antimicrobial, and antioxidant properties, making it useful for treating respiratory ailments, digestive issues, and minor skin infections.
21	*Salviacryptantha Montbret* and *Aucher ex Benth* **Lamiaceae**	Leaves and Aerial parts	- Used in traditional herbal remedies to treat various ailments, including digestive disorders, respiratory conditions, and skin ailments (Chaachouay et al., 2024).

22	*Ebenus laguroides Boiss. var. laguroids* **Fabaceae**		- It is often utilized for its medicinal properties in treating various ailments such as gastrointestinal disorders, respiratory problems, and skin conditions, - The plant's antimicrobial properties may also contribute to its efficacy in wound management.
23	*Salvia hypargeia Fisch Mey* **Lamiaceae**	Leaves	- Some cultures incorporate Salvia hypalgesia leaves into culinary dishes for flavoring and aroma, particularly in traditional cuisines of regions where the plant is native (*A Guide to Common Medicinal Herbs - Stanford Medicine Children's Health*, n.d.). - Treating various ailments, such as respiratory infections, gastrointestinal disorders, and skin conditions (*A Guide to Common Medicinal Herbs - Stanford Medicine Children's Health*, n.d.).
24	*Astragalus microcephalus will* **Fabaceae**	Roots	- To boost the immune system and enhance overall health and vitality(*6 Ayurvedic Herbs To Enhance Your Immunity - Tata 1mg Capsules*, n.d.). - Treating conditions such as colds, flu, allergies, and respiratory infections(*A Guide to Common Medicinal Herbs - Stanford Medicine Children's Health*, n.d.).
25	*Teucrium chamaedrys* L. *subsp. chamaedrys* **Lamiaceae**		- To alleviate skin conditions such as wounds, cuts, and insect bites(*The Best Healing Herbs for Skin - Spices and Herbs Guide*, n.d.) - To treat various ailments such as indigestion, liver disorders, and urinary tract infections (Kaushik et al., 2021).
26	*Astragalus xylobasis Freyn* and *Bornm* **Fabaceae**	Roots	- To treat respiratory ailments, such as coughs, bronchitis, and asthma, due to its expectorant and bronchodilator effects(*10 Natural Herbs for Bronchitis Relief and Healing | MedShun*, n.d.).
27	*Astragalus cymbibracteatus Hub.-Mor.* and *Chamb* **Fabaceae**		- Boosting the immune system's function and aiding in the treatment of certain immune-related disorders(Dabas et al., 2023). - Used to treat conditions such as respiratory infections, fatigue, gastrointestinal disorders, and immune system weaknesses(*Herbs for Respiratory Health - CNM College of Naturopathic Medicine*, n.d.)(Dabas et al., 2023).
28	*Hedysarum pestalozzae Boiss* **Fabaceae**		- Potential therapeutic applications, such as antimicrobial, anti-inflammatory, antioxidant, or anti-cancer properties(Jongrungraungchok et al., 2023)(Mashabela et al., 2022).
29	*Nepeta congesta Fisch. Et. Mey* **Lamiaceae**	Leaves	- used to relieve digestive discomforts such as indigestion, bloating, and stomach cramps(*10 Herbs for Healthier Digestion - The Nutrition Insider*, n.d.). - Used to alleviate symptoms of respiratory conditions such as coughs, colds, and bronchitis(*10 Natural Herbs For Bronchitis Relief and Healing | MedShun*, n.d.).
30	*Oregano* [*Origanum vulgare* L.]	Leaves	- Used as a culinary herb, adding flavor to a variety of dishes, including pasta sauces, pizzas, salads, soups, and meat marinades(*Mediterranean Flavors: Herbs and Spices Used in Mediterranean Cuisine.*, n.d.). - It has been used traditionally in herbal medicine to treat respiratory infections, digestive issues, and skin conditions (Chaughule and Barve, 2024).

Discussion

Climate Change Mitigation and Medicinal Plants

Medicinal plants, especially those from the Fabaceae and Lamiaceae families, have enormous potential to contribute to climate change mitigation (Bussmann and Sharon, 2007). Beyond their traditional uses in health and livelihoods, they play a crucial role in carbon sequestration, biodiversity conservation, and ecosystem resilience. Below, we discuss their multidimensional roles in responding to climate change and highlight regional insights from Sivas and Nairobi.

Carbon Sequestration

Carbon sequestration, the process by which plants absorb atmospheric carbon dioxide during photosynthesis (Kumar et al 2014), and it is pivotal in mitigating global warming. Medicinal plants, like other plants, store carbon within their tissues and release oxygen back into the atmosphere. Over time, this sequestered carbon can contribute to soil organic carbon (SOC) through the decomposition of plant matter, enhancing the soil's carbon-holding capacity (Sanderman et al., 2017).

Medicinal plants have been shown to act as carbon sinks. The rate of sequestration by various species, suc h as Amla, Bahera, and Harar, has been found to be 1, 2.64, and 1.42 tC ha^{-1} yr^{-1}, respectively, in Sikkim, India (Lis-Balchin et al., 1998). Such observations suggest that medicinal plants, if integrated into carbon forestry initiatives, could yield economic dividends through carbon credits under plausible scenarios of \$5/tCO_2 (Aggarwal and Chauhan, 2014).

However, carbon storage is not permanent, as the decay of plants releases stored carbon into the soil and atmosphere. Therefore, such sustainable practices and conservation efforts are important in maintaining such benefits herein (Baltes and Voytas, 2015).

Biodiversity Conservation

Medicinal plants are important in the conservation of biodiversity in that they provide food, habitat, and ecosystem services.

Food Source

Many medicinal plants provide necessary inputs in terms of nectar, pollen, seeds, and leaves that provide various organisms such as insects, birds, and mammals with shelter (Tohidi et al., 2019).

Habitat

Medicinal plants are complexly structured; hence, the form in which they exist provides shelter to the microorganisms, insects, and sometimes the bigger animals. The root structure, stem, and the leaves will give a niche environment for the micro-ecosystem (Oremland, 2003).

Ecosystem Services

Medicinal plants contribute to provisioning (e.g., food, medicine), regulating (e.g., climate regulation), supporting (e.g., nutrient cycling), and cultural services (e.g., spiritual, recreational) (Soliveres et al., 2016). These ecosystem services improve overall health and resilience in ecosystems, which are key factors for adapting to climate change.

Resilience to Climate Change

Medicinal plants are part of healthy ecosystems that are more resistant to climatic changes. Plants stabilize soils, prevent erosion, sequester carbon, and act as a buffer for extreme weather events. However, Aggarwal and Chauhan, 2014; Yu et al., 2023, present the challenges of conservation: habitat loss, overharvesting, and climate chance. For medicinal plants, strategies need to be implemented to preserve the biodiversity and ensure sustainability (Applequist et al., 2020; Xia et al., 2022).

Livelihoods that are Sustainable

Medicinal plants cultivation can provide sustainable livelihoods and reduce dependence on activities like deforestation and fossil fuel use. In addition, communities are able to conserve forest ecosystems and improve their carbon sequestration potential through sustainable cultivation. This is according to Scherr and McNeely, 2007.

Adaptation and Climate Resilience

Some medicinal plants are quite resistant to severe climatic conditions and may contribute to land restoration. For example, several species can be grown in arid or semi-arid regions, which could help in reducing the heat island effect of cities and store carbon in urban green areas (Howden et al., 2007).

Regional Insights: Sivas and Nairobi

The climates of Sivas and Nairobi represent two extremes in the impact on medicinal plants, considering temperature, precipitation, and seasonal changes.

Sivas has a cold temperate climate, classified as Dsb, with an average annual temperature of 8.1°C. Precipitation is moderate, averaging 467 mm per year, with the highest in April at 67 mm and the lowest in August at 6 mm. The cold winters and unpredictable precipitation make the growth and distribution of medicinal plants difficult and require adaptive conservation methods (Sivas Climate, n.d.). Nairobi has a moderate, warm climate, with the temperature classified as Cfb. The city's average annual temperature is 18.8°C, and it has an annual rainfall of 674 mm. Its relatively stable climate supports various medicinal plants; however, increasing urbanization and changes in land use threaten biodiversity (Climate Nairobi, n.d.).

Effects on Medicinal Plants

Climate change affects the geographical boundaries within which medicinal plants grow. Changes in temperature and rainfall might make certain habitats unfavorable and shift the distribution of the species (Wink, 2015). Changes in climate affect the timing of plant life-cycle events, such as flowering and fruiting, potentially reducing reproductive success and medicinal compound availability (Hedhly et al., 2009). Variations in temperature and rainfall can impact plant growth and the production of medicinal compounds, such as essential oils in Lamiaceae species (Kreuzwieser and Gessler, 2010).

Preservation of the Medicinal Plant Diversity in Sivas and Nairobi

In-situ conservation: Establish reserves and protected areas for native flora.

Ex-situ conservation: Maintain botanical gardens and seed banks to preserve the genetic material.

Sustainable practices: The cultivation of medicinal plants using environmentally friendly methods.

Public awareness: Educate people in all sectors on the importance of biodiversity conservation and sustainable use.

As medicinal plants have a considerable scope to contribute to lessening climate chance, they cannot stand on their own. Dealing with climate change demands an integrated approach to mitigation of emissions, restoration of ecosystems, and sustainable development. Given effective conservation and sustainable use strategies, medicinal plants can contribute significantly to such efforts, playing a diverse ecological role. Cases in Sivas and Nairobi point out that local adaptations and global cooperation are crucial in using medicinal plants in the interest of mitigating climate chance and preserving biodiversity.

Conclusion

Through numerous efforts and programs, Nairobi and Sivas Museums have both significantly contributed to the attainment of the Vision 2030 SDGs. It's crucial to remember that reaching these objectives calls for a coordinated effort from every sphere of society. As SDG 2 (Zero Hunger), SDG 3(Good Health), and SDG 13 (Climate Action) both Nairobi and Sivas museum plays a crucial role as they both provide education and exhibit the importance of sustainable agriculture and food security, promote public health awareness and the well-being and this has led to improve access of quality healthcare services and lastly the two museums has played a major role in raising awareness about the climate change impacts and its resilient adaptive measures through various exhibitions, educational programs and community engagement as shown in Figures 2 and 3.

Lastly, this study demonstrates the similar medicinal plant species in Nairobi and Sivas alongside justifying the use of these plants in traditional medicine. It may serve as a starting point of research geared towards the similar medicinal species of these plants. In conclusion, despite their differences in geography and culture, Kenya and Sivas, Türkiye, use therapeutic herbs in similar ways. There is a long-standing custom in both areas to use the medicinal plants' diverse range of uses for health benefits. This common history emphasizes the value of therapeutic plants everywhere and the necessity to value and conserve this botanical. Also, both Nairobi (Kenya) and Sivas (Türkiye) ethnobotanical archives are further encouraging in that, although living in cities for a long time, the people there continue to use the knowledge passed down from their ancestors. Therefore, the results of this ethnobotanical survey were important to find out the present situation of traditional knowledge in the two countries.

Additional Information and Declarations

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Wheat and Barley Cultivated Area Determination Using NDVI Threshold Values and Google Earth Engine

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Abstract: This study aims to determine the optimal imaging time for detecting wheat and barley (W-B) cultivated areas using Sentinel-2 images and NDVI-based threshold values (December 2018-June 2019) via Google Earth Engine (GEE). The study was conducted in Mahmudiye village, situated to Çanakkale province, Türkiye. Randomly selected parcels (RSP) were determined through ground surveys were used to obtain monthly minimum and maximum NDVI thresholds ($NDVI_{min}$ and $NDVI_{max}$). Monthly NDVI threshold-based W-B maps were produced. In addition to the month-based maps, the areas that meet all the threshold conditions for all months at once were also mapped. The predicted and actual inventory of W-B areas were compared for identification of the most appropriate imaging time within the growing season. Findings have shown that using the image acquired in April gave the most satisfactory W-B area prediction with an overestimation of only 53 pixels. Use of $NDVI_{min}$ and $NDVI_{max}$ thresholds for prediction of W-B cultivated areas and yield predictions considering imageries acquired in April strongly suggested for more precise estimations under similar climate conditions, whereby the method provides more time and labor-effective investigations in comparison with land use land cover classification methods.

Keywords: GEE, imaging time, NDVI threshold values, Sentinel-2, Wheat-Barley

NDVI Eşik Değerleri ve Google Eart Engine Kullanılarak Buğday ve Arpa Yetiştirilen Alanların Belirlenmesi

Makale Geçmişi
Geliş: 14/02/2025
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Öz: Bu çalışma, Sentinel-2 uydu görüntüleri ve NDVI tabanlı eşik değerler kullanılarak (Aralık 2018-Haziran 2019) buğday ve arpa (B-A) ekim alanlarının tespiti için en uygun görüntüleme zamanını belirlemeyi amaçlamaktadır. Çalışma, Türkiye'nin Çanakkale iline bağlı Mahmudiye köyünde gerçekleştirilmiştir. Rastgele seçilen parseller (RSP), arazi çalışmaları ile belirlenmiş ve aylık en düşük ve en yüksek NDVI eşik değerleri ($NDVI_{en\ düşük}$ ve $NDVI_{en\ yüksek}$) elde edilmiştir. Bu eşik değerler kullanılarak her ay için B-A alanı tahmin haritaları üretilmiştir. Ayrıca, tüm aylara ait eşik koşullarını aynı anda sağlayan alanlar da haritalandırılmıştır. Tahmin edilen ve gerçek B-A alan envanter değerleri karşılaştırılarak yetiştirme sezonu içinde en uygun görüntüleme zamanı belirlenmiştir. Bulgular, Nisan ayında elde edilen görüntünün kullanımının, sadece 53 piksel fazla tahmin ile en tatmin edici B-A alanı tahminini verdiğini göstermiştir. Benzer iklim koşulları altında, arazi kullanım ve arazi örtüsü sınıflama metotlarına göre daha zaman- ve emek efektif incelemeler sağlayan $NDVI_{en\ düşük}$ ve $NDVI_{en\ yüksek}$ eşikleri metodu göz önüne alınarak B-A yetiştirilen alan ve verim tahminlemelerinde, daha hassas tahmin eldesi için Nisan ayında alınan görüntülerin kullanımı önerilmektedir.

Anahtar Kelimeler: Buğday-Arpa, GEE, görüntüleme zamanı, NDVI eşik değer, Sentinel-2

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Introduction

Agricultural activities play a key role in Türkiye's socio-economic status since the suitability of climate, soil and topographic conditions enable the growth of various agricultural products. Identifying cultivation areas for specific products is important for future planning and management strategies, such as crop rotation decisions, yield and production estimates. There is a great variety of products, whereas wheat and barley (W-B) production constitute a considerable part of the cultivation areas. According to Turkish Statistical Institute (TSI) data, the total agricultural areas cover approximately 240 million hectares, whereby 42.37% of the areas consisted of W-B cultivated areas (TSI, 2023). On the other hand, Food and Agriculture Organization (FAO) reported that national and global events together with the impacts of changing climate, led to a reduction in W-B production in Turkey in 2022 and 2023, as well as in many other countries (FAO, 2024). However, W-B products still known to have a key role in nutrition; thus, production and demands should be well-evaluated to ensure balance. Hence, identification of production areas and spatio-temporal changes presents a priority for forecasting yield (Campos et al., 2019; Ayub et al., 2022), import and export amounts in specified regions (Balambar et al., 2021).

Remote sensing imageries with different spatial, spectral and temporal resolutions have long been used for identification of W-B production areas (Gumma et al., 2022). The use of different techniques, algorithms, and indices are well documented in the literature (Meraj et al., 2022; Wang et al., 2022). Recent improvements in cloud-based applications for image processing, namely Google Earth Engine (GEE) have accelerated the number of studies due to the advantages of time-effective processing and reduced requirements of data storage (Tian et al., 2019; Cheng et al., 2022). Plant indices are important parameters in crop monitoring and agricultural practices (Qiao et al., 2024). Moreover, among the various indices for investigating specific characteristics of plants, Normalized Difference Vegetation Index (NDVI) is known to be one of the most widely used vegetation indices (Rouse et al., 1973). The sensitivity of shortwave and near-infrared bands for identification of vegetation has yielded successful results for determining wheat yield over large areas (Wu et al., 2020; Zhang et al., 2023). Qi et al. (2022) achieved a high accuracy (92%) in classification model for detecting wheat areas in the Shandong region of China. Shin et al. (2022) developed crop (W-B) classification models based on Sentinel-2 data in the southern part of the Republic of Korea using Deep Neural Networks (DNN), Machine Learning (ML) regression approaches, and five different indices, including the NDVI index, and achieved an accuracy of 89% for barley, and 45% for wheat. However, more time- and labour-effective methods are required since the classification procedures are laborious and time consuming. A simple and easy-to-understand model using minimum and maximum NDVI threshold ($NDVI_{min}$ and $NDVI_{max}$) values were used in different studies. For instance, Toscano et al. (2019) and Bouras et al. (2023) used NDVI values collected from reference parcels considering W-B phenological stages in the southern region of South Korea to identify the optimum time for W-B monitoring and yield estimation.

This study aims to determine the appropriate image timing for identifying W-B cultivation areas based on $NDVI_{min}$ and $NDVI_{max}$ threshold values collected from randomly selected parcels (RSP), which were sampled during ground surveys, using GEE. The study was conducted within the boundaries of Mahmudiye village, Çanakkale province, Türkiye. Data were collected using Sentinel-2 images from the RSP. The NDVI maps for each month were produced, monthly $NDVI_{min}$ and $NDVI_{max}$ threshold-based W-B prediction maps were obtained, and consistency between actual and predicted values were evaluated to highlight the optimum imaging time for W-B prediction under similar conditions.

Materials and Methods

Materials

Study Area

The study was conducted in Mahmudiye village, located in Ezine District of Çanakkale province (39° 51′ 52.92″ N - 26° 14′ 39.66″ E) (Figure 1). The survey area covers approximately 3200 hectares. The study area is under the impact of typical Mediterranean climate whereby the average temperature and precipitation range between 15-16°C and 500-700 mm, respectively, enabling the growth of several agricultural products. A major part of the study area is covered by agricultural lands, whereby the most widely cultivated agricultural products are wheat, barley, tomatoes, and paddy rice.

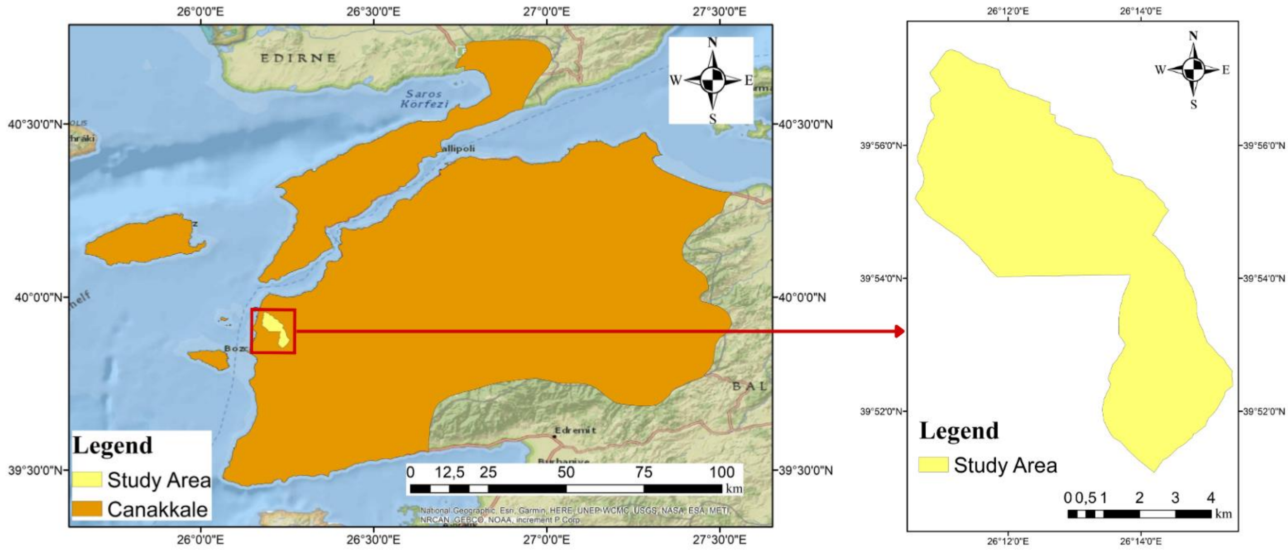


Figure 1. Location of the study area.

Data Processing

Sentinel-2 satellite collect data with an optical sensor via 13 spectral bands, with spatial resolution ranging between 10 and 60 m (Zhang et al., 2023). In present study, red (band 4) and near-infrared (band 8) bands with 10 m spatial resolution were used for NDVI calculation. The acquisition dates of imageries were selected depending on cloud cover threshold (under 10%) and growth stages of the W-B. Depending on the criteria, the images of December 17, 2018; January 06, 2019; February 05, 2019; March 17, 2019; April 26, 2019, May 28, 2019, 2019, and June 07, 2019 were used to achieve the aims.

The Sentinel-2 data were processed using the GEE open-source cloud-based platform, which provides computation and analyzing geospatial data easily, without requiring user preprocessing (Aghlmand et al., 2021). The GEE platform enables rapid computation of various processes, thus, commonly preferred to be used for environmental monitoring and modelling through remote sensing data.

Methods

The study was completed in three stages (Figure 2), and the methods are detailed below. In the first stage, NDVI of each pixel were calculated, and the NDVI maps were generated. The second stage involved the determination of monthly NDVI maximum and minimum thresholds, and the creation of monthly W-B maps depending on determined NDVI thresholds. Finally, the third stage included validation and the identification of the best image timing.

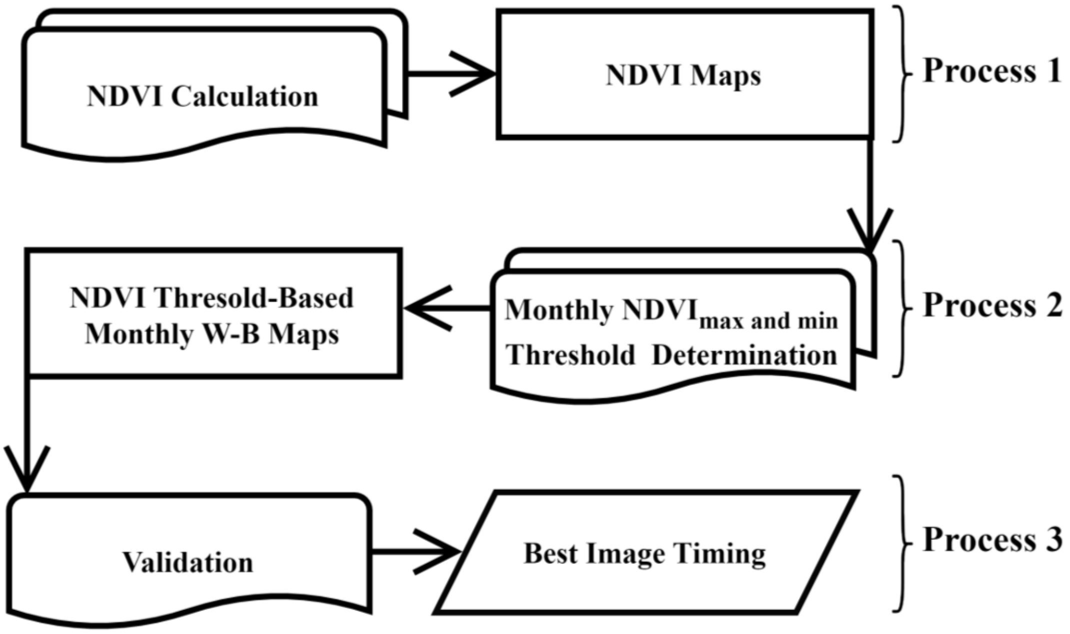


Figure 2. Flow chart of the study.

Generation of NDVI Maps

The NDVI maps of the study area were composed using red and near-infrared bands of each date through the following equation (Eq. 1). The NDVI values range between -1 and 1 whereby higher values represent dense vegetative cover.

$$NDVI = \frac{NIR-RED}{NIR+RED} \tag{1}$$

Producing NDVI Threshold-Based W-B Prediction Maps

Among the cultivated parcels, 20 parcels were randomly selected and digitized into a vector layer using ArcGIS (10.7). After the digitizing process, the vector layer overlapped with NDVI maps and randomized training polygons, which consisted of at least 9 pixels, were collected from each parcel vector. The average NDVI values of training polygons were calculated to ensure capture of the variability. Finally, the maximum and minimum thresholds from NDVI values of training polygons were identified ($NDVI_{min}$ and $NDVI_{max}$) for each month. The threshold values of $NDVI_{min}$ and $NDVI_{max}$ were used to obtain prediction maps for W-B cultivated areas for each month depending on the formula. Accordingly, if a pixel (*p*) has a value ranging between $NDVI_{min}$ and $NDVI_{max}$, the pixel (*p*) acknowledged as W-B, otherwise, other land use or land cover type (*O*). In addition to monthly maps, pixels that meet the threshold requirements in all months were presented within an individual map (Eq. 2).

$$f(NDVI) = \begin{cases} W, \ NDVI_{max} \geq p \geq NDVI_{min} \\ O, \ otherwise \end{cases} \tag{2}$$

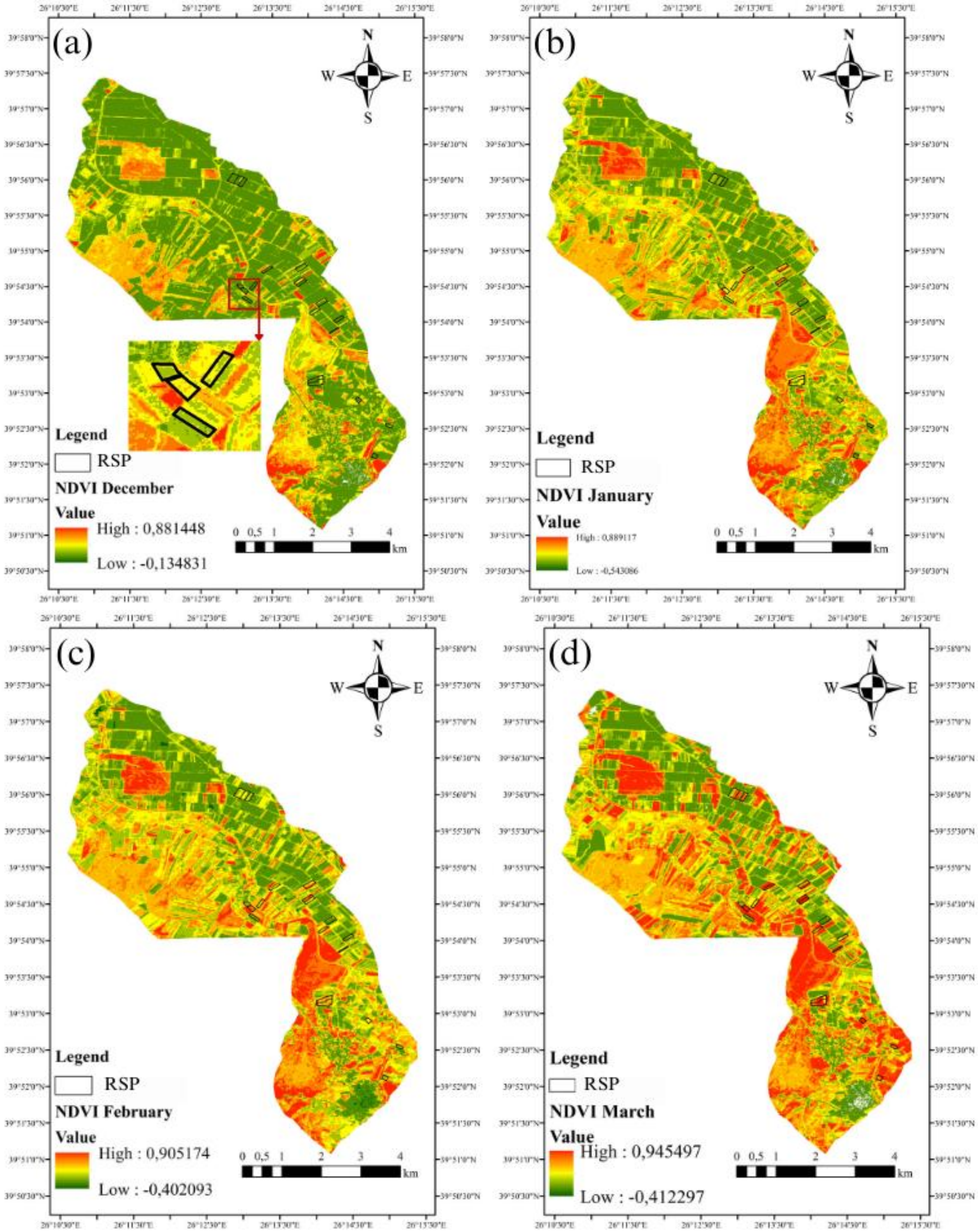
Reliability of Prediction Maps

The reliability of threshold-based prediction maps was assessed depending on the coherencies between actual inventory records of 2019 and predicted W-B areas. Village-level inventories were obtained from the Çanakkale Provincial Directorate of Türkiye Ministry of Agriculture and Forestry (ÇPDAF, 2019).

Results and Discussion

The NDVI maps of each month are given below, whereby black squares represent RSP depending on ground surveys for collecting NDVI threshold values (Figure 3 a-g). As it can be seen, $NDVI_{min}$ and $NDVI_{max}$

values in the study area range between 0.12 and 0.36 in December (2018), 0.15 and 0.39 in January (2019), 0.20 and 0.74 in February (2019), 0.52 and 0.85 in March (2019), 0.52 and 0.85 in April (2019), 0.16 and 0.77 in May (2019), and 0.20 and 0.59 in June (2019), respectively. Previous studies have shown that, phenological stages of W-B can be determined using NDVI with higher accuracy in comparison with other vegetation indices (Yang et al., 2019). Therefore, monthly monitoring of NDVI values provides valuable information on the maturity level of plants and became an important indicator.



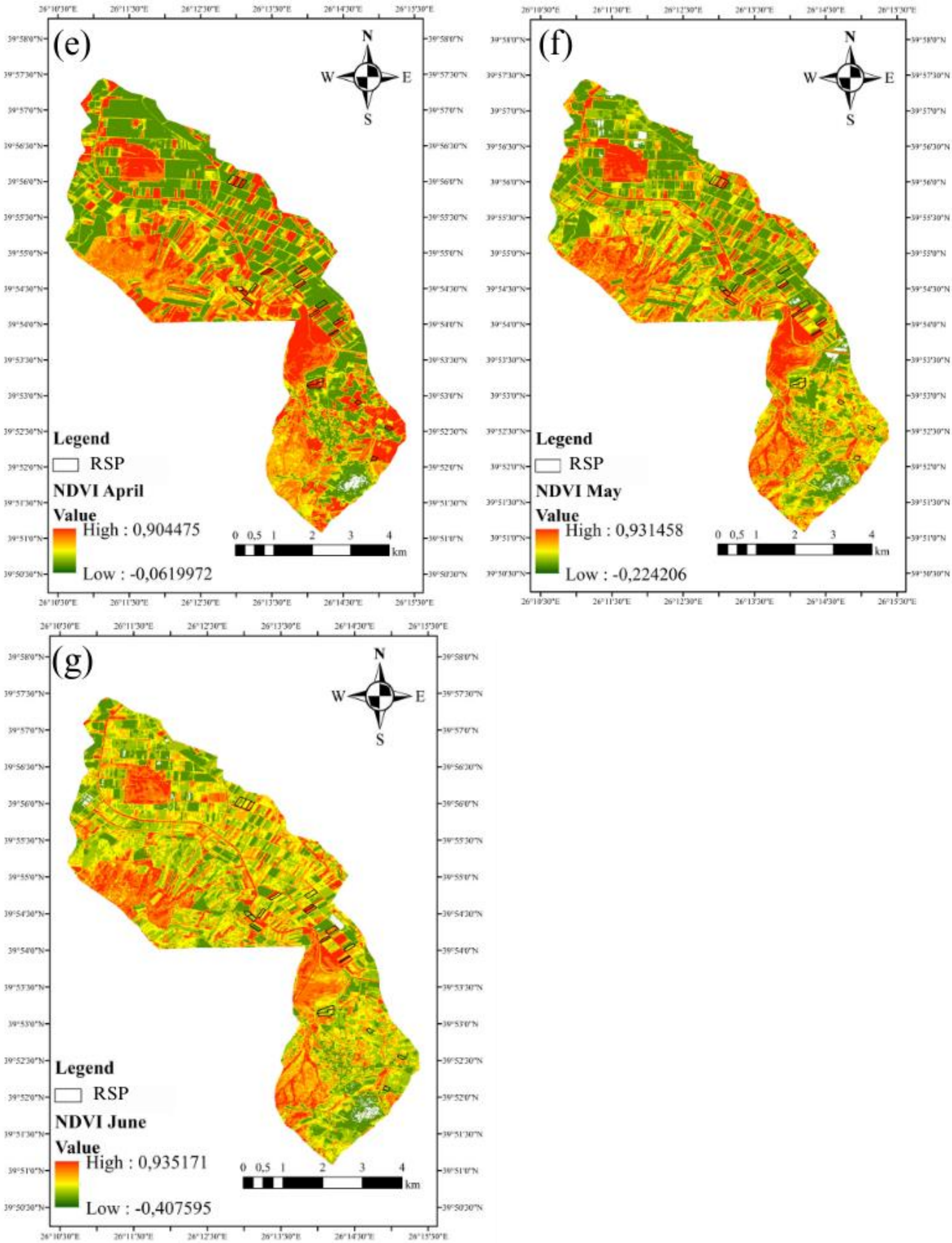


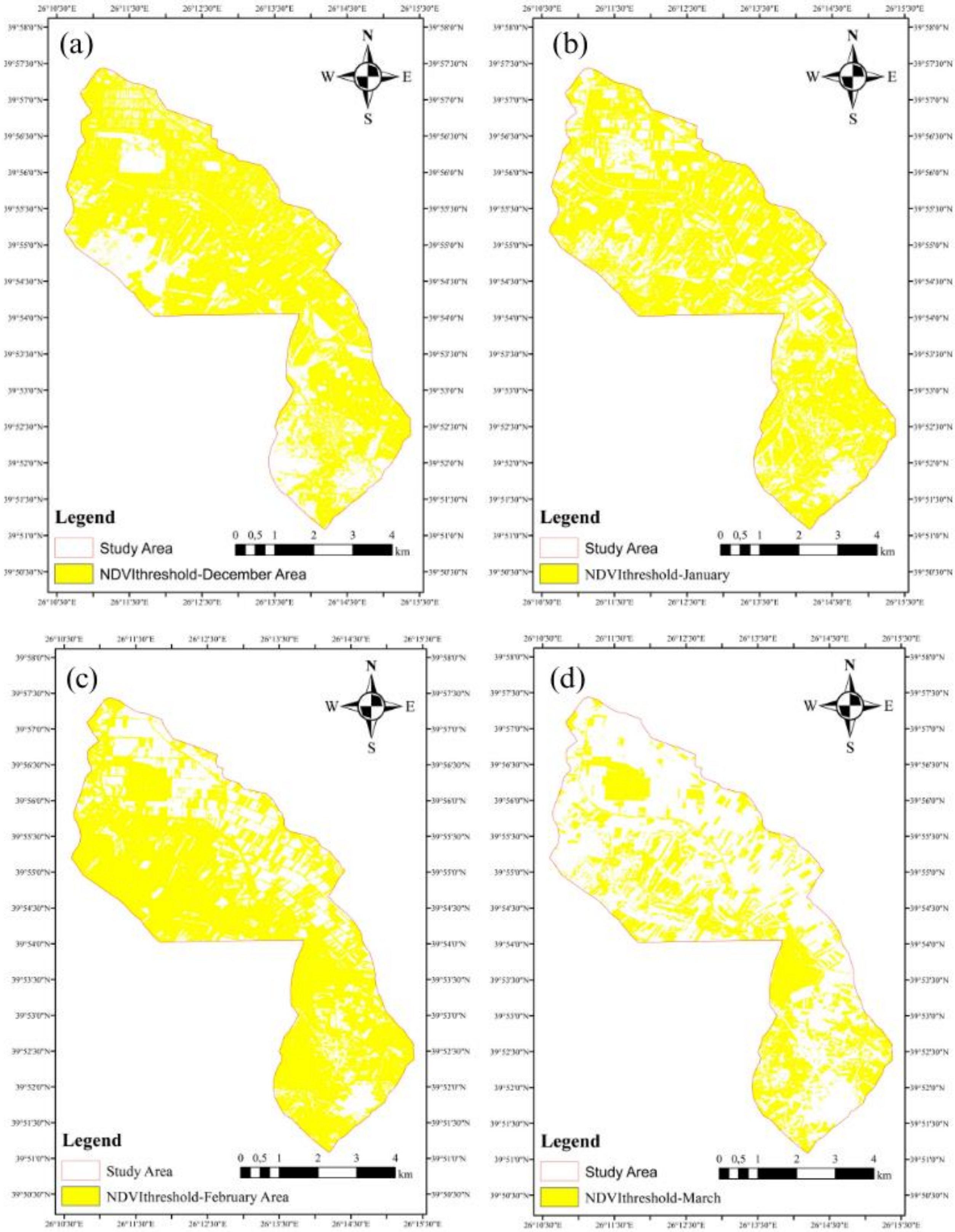
Figure 3. Randomly Selected Parcel (RSP), Normalized Difference Vegetation Index (NDVI), (a) $NDVI_{min}$ and $NDVI_{max}$ values in December, (b) $NDVI_{min}$ and $NDVI_{max}$ January, (c) $NDVI_{min}$ and $NDVI_{max}$ February, (d) $NDVI_{min}$ and $NDVI_{max}$ March, (e) $NDVI_{min}$ and $NDVI_{max}$ April, (f) $NDVI_{min}$ and $NDVI_{max}$ May and (g) $NDVI_{min}$ and $NDVI_{max}$ June.

Threshold methods are commonly used for determination of specific crops in many areas of the world, and the main issue is known to be the determination of the accurate thresholds. The parameters are usually manually prepared depending on the phenological stages of the considered plant (Wang et al., 2015; Wang et al., 2019; Li et al., 2021). There are different methods for identifying the more appropriate threshold values. In the present study, $NDVI_{min}$ and $NDVI_{max}$ reference threshold values were collected from overlay analysis using NDVI maps and RSPs that were defined during ground surveys (Table 1). Accordingly, $NDVI_{min}$ values ranged between 0.12 (December 2018) and 0.73 (May 2019), while $NDVI_{max}$ values seemed to change from 0.36 (December 2018) to 0.88 (May). Similar results were found for winter wheat in the Thessaly plain, central Greece, between 2018 and 2019 growing season, whereas the highest NDVI values were obtained from the image acquired in April (Cavalaris et al., 2021). Moreover, the findings of the study were also coherent with the NDVI values mentioned by Yang et al. (2019); the minimum and maximum NDVI values of different months were ranged between approximately 0.18 and 0.80, respectively.

Table 1. Monthly $NDVI_{min}$ and $NDVI_{max}$ threshold values.

Years	Months	$NDVI_{min}$ Threshold Value	$NDVI_{max}$ Threshold Value
2018	December	0.12	0.36
2019	January	0.15	0.39
	February	0.20	0.74
	March	0.52	0.85
	April	0.73	0.88
	May	0.16	0.77
	June	0.20	0.59

Considering these predetermined thresholds from the individual images, W-B and barley parcels were predicted and mapped, namely $NDVI_{threshold-December}$ (Figure 4 a), $NDVI_{threshold-January}$ (Figure 4 b), $NDVI_{threshold-February}$ (Figure 4 c), $NDVI_{threshold-March}$ (Figure 4 d), $NDVI_{threshold-April}$ (Figure 4 e), $NDVI_{threshold-May}$ (Figure 4 f) and $NDVI_{threshold-June}$, (Figure 4 g). Furthermore, a single map has been created that separately satisfies the $NDVI_{min}$ and $NDVI_{max}$ threshold conditions for each month at once ($NDVI_{threshold-combined}$) (Figure 4 h).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NDVIthreshold-March

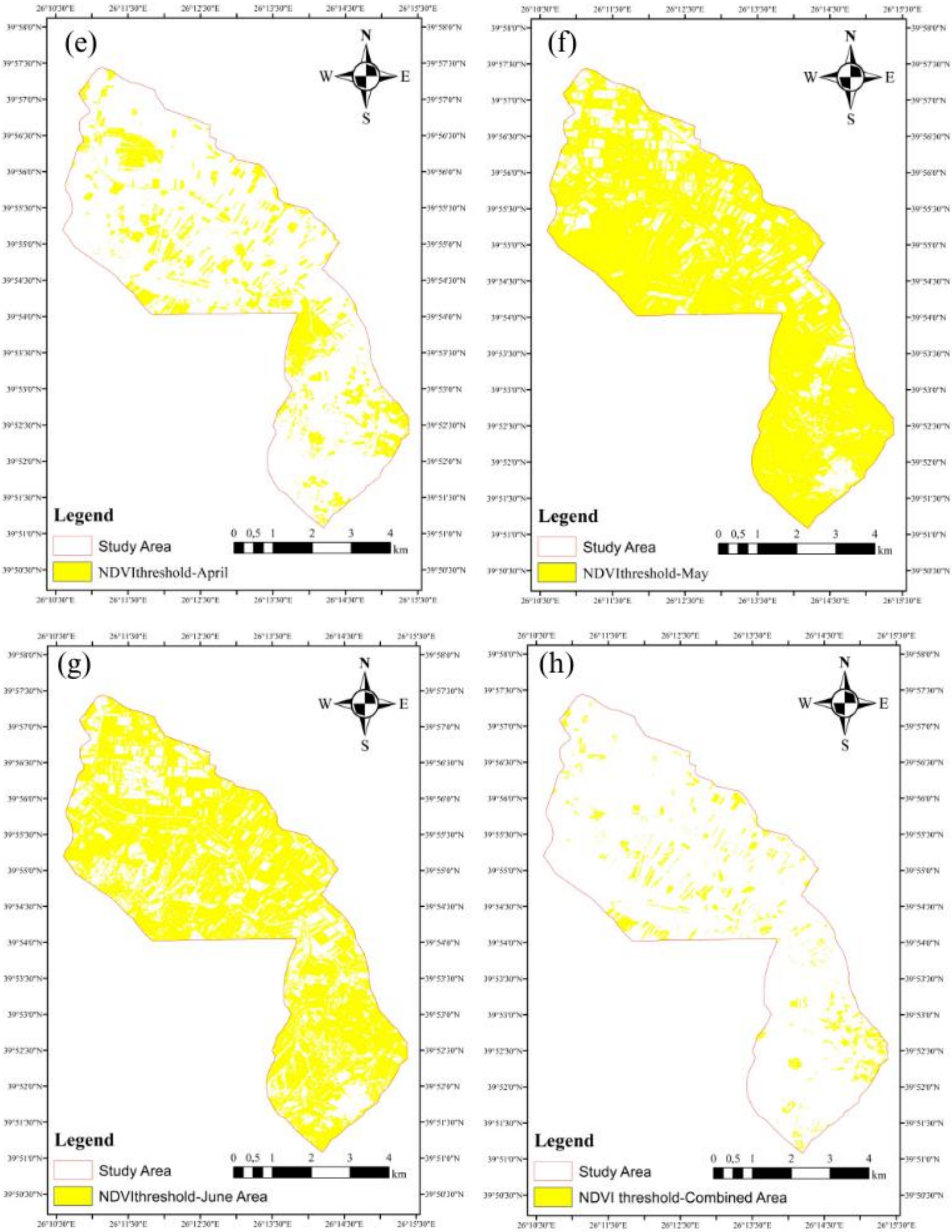

Figure 4. W-B areas determined according to $NDVI_{min}$ and $NDVI_{max}$ threshold values. (a) $NDVI_{threshold\text{-}December}$, (b) $NDVI_{threshold\text{-}January}$ (b), (c) $NDVI_{threshold\text{-}February}$, (d) $NDVI_{threshold\text{-}March,}$ (e) $NDVI_{threshold}$, (f) $NDVI_{threshold\text{-}May}$ and (g) $NDVI_{threshold\text{-}June}$, (h) $NDVI_{threshold\text{-}Combined}$.

Depending on the monthly and combined prediction maps, W-B cultivated areas were calculated (da), and compared with actual inventory data of ÇPDAF to evaluate coherency between actual and predicted values (Tablo 2). Inventory data has shown that W-B cultivated parcels cover 5510 da area. Examination of NDVI threshold-based maps has shown that W-B cultivation areas were predicted as 21964 da depending on the December (2018) image, 18350 da depending on the January (2019) image, 22749 da depending on the February (2019) image, 11668 da depending on the March (2019) image, 6041 da depending on the April (2019) image, 25328 da depending on the May (2019) image, and 21593 da depending on the June (2019) image. Briefly, use of month-based NDVI thresholds lead mostly to exceed overestimation of W-B areas, except $NDVI_{threshold\text{-}April}$. Moreover, use of $NDVI_{threshold\text{-}combined}$ values resulted in underestimation of W-B areas (2363 da).

Table 2. $NDVI_{min}$ and $NDVI_{max}$ based W-B areas (da).

	NDVI Threshold							
W-B Area (da)	**December**	**January**	**February**	**March**	**April**	**May**	**June**	**Combined**
	21.964	18.350	22.749	11.668	6.041	25.328	21.593	2.363

The cultivation area of a specific product that is calculated through remotely sensed data usually differs from official inventories at national- or regional-level (Li et al., 2021), due to cumulative effects of spatial resolution-related issues. Therefore, the study focused on a small-scale evaluation of the method. The method provided reliable results at village-level coherency between Sentinel-2 derived NDVI threshold-based cultivated area and the local inventory records in April, answering the research question on selection of the optimum imaging time for W-B area determination within a growing season.

Conclusion

The optimal imaging time for identifying W-B areas in a growing season was investigated through $NDVI_{min}$ and $NDVI_{max}$ threshold values. For this purpose, monthly NDVI thresholds were obtained from selected W-B parcels identified during ground surveys in 2019. NDVI threshold-based monthly prediction maps, as well as the combined NDVI thresholds map that meets all months NDVI threshold requirements at one query, were generated in GEE. The predictions for W-B cultivated areas were compared to actual W-B cultivation areas using inventory records to identify more appropriate acquisition time for Sentinel-2 images to perform more realistic W-B predictions. Findings of the study revealed that the use of NDVI thresholds mostly resulted in extremely overestimated W-B areas. Depending on these findings, it can be clearly seen that the image acquired in April gave the most coherent value with actual W-B cultivation areas with a difference of approximately 53 pixels. Moreover, the study provided a simpler identification of W-B areas in comparison with land use land cover classification, which is a more time consuming and laborious method. Therefore, the study is believed to serve as a baseline for future research, which may be conducted under similar climate conditions and growth periods.

Additional Information and Declarations

Authors' Contributions: N.C. collected the data, conducted the analysis, performed the calculations, and developed the model, while writing the manuscript with support from M.I. and L.G.
M.I. contributed to the data analysis, assisted in the development of the model, and wrote the main manuscript with support from N.C. and L.G
L.G. designed the proposed idea, developed the theory, contributed to the creation of the model, contributed to the data analysis, and wrote the main manuscript with support from N.C. and M.I.
Conflict of Interests: The authors declare that there are no conflicts of interest among them.

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Performance Evaluation of Snapdragon (*Antirrhinum majus* L.) Cultivars in the Dry Temperate Climate of Northern Balochistan

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Abstract: Snapdragon (*Antirrhinum majus* L.) is an ornamental plant widely grown as a cut flower worldwide because of its aesthetic appeal and adaptability to diverse climatic conditions. This study evaluated the performance of various *Antirrhinum* cultivars under the dry temperate climatic conditions of northern Balochistan, Pakistan. Three varieties—Sonnet, Shower, and Majus - and four cultivars - Yellow, White, Pink, and Purple were selected for field trials. The study examined morphological parameters, such as including plant height, number of leaves, leaf area, and number of branches, along with reproductive parameters such as the number of flowers and seeds. Seed germination tests were conducted under controlled conditions to determine germination rates and efficiency. The results showed significant variations among the cultivars in terms of growth, flowering, and germination. The findings indicated that *A. majus* can be successfully grown in dry temperate climates, offering potential for expanding the diversity of cut flowers in Pakistan's floriculture industry. The study highlights the effect of environmental factors such as temperature and photoperiod on plant development, contributing to the optimization of *A. majus* cultivation in regions with similar climatic conditions.

Keywords: Snapdragon, ornamental plant, growth, seed germination, Balochistan

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Introduction

Snapdragon (*Antirrhinum majus* L.) is a perennial, winter flowering plants, belongs to family Plantiginaceae. It is an herbaceous annual flowering plant which is originated in the Mediterranean region (Oyama and Baum. 2004). Later on, it has been introduced to different areas around the world. The Snapdragon is grown as a cut flower worldwide and it is estimated that, there are more than 20,000 cultivars are grown as commercial cut flowers worldwide (Ahmad. et al., 2020). *A. majus* is extensively used as an ornamental plant and is one of the model species in genetic science (Mateu-Andres and De Pacol, 2005). Snapdragons are known as 'cool season' or 'low temperature' crops (Miller, 1962). However, lowering temperature from 25 to 5 °C increased the flowering time in Snapdragons (Maginnes & Langhans, 1961). Plants at 21°C required 84 days for initiation and 109 days for the anthesis, whereas plants at 4.5°C required 124 days for initiation and 148 days for the anthesis (Maginnes & Langhans, 1961). On the other hand, fresh weight, number of flowers, number of leaves, stem and inflorescence length increased as the temperature was lowered from 25 to 10 °C (Maginnes & Langhans, 1961).

This plant used as a cut flower due to its showy petals. Flower petals are characterized by a variation in morphological characteristics, manifested in a variety of shapes, sizes and a series of colors. It is thought that this diversity develops as an adaptation to biotic pollinators, especially insects (Glover, 2011). *A. majus* when grown in warm regions exhibit a perennial behavior, however it is mostly grown as a winter annual, and used in flowering beds, mainly as short cultivars, or as a green background of flower beds, as tall varieties (Ball, 1991). Moreover, seed germination, growth and flowering of *Antirrhinum* are greatly influenced by various environmental conditions. The optimum temperature required for growth decreases with crop age, while seedlings require 20°C night temperature. Plants near to flowering grow best at 13 °C night temperature. Higher temperature adversely affects growth and flower quality (Bhargava, et al., 2016). Originally, Snapdragon is a summer flowering perennial in Mediterranean region. However, with the passage of time different hybrids were introduced which flower even in winter. Initially, Snapdragons were used only in landscape parks and gardens for flowering beds or borders. Recently, Snapdragon cultivars are classified into four different response groups because of their growth and flowering response in relation to temperature and day length (Ball, 1991). Recently, Snapdragon has become very popular in different gardens around the world and there is a high demand for this ornamental plant as cut flower. Therefore, the production of Snapdragon plant has been increased in recent years (Çelikel et al., 2010).

It is suggested that temperature photoperiod also plays an important role to determine the rate of growth and development in plants (El-Keblawy et al., 2015.). Temperature has a direct influence on the rate of many chemical reactions, including respiration that is the process responsible for growth and development of plants and photosynthesis. It showed that to have different effects on the flowering and budding time of genotypically different inbred lines of *Antirrhinum* sp. and most of the cultivars a temperature of 25 °C almost halved the flowering time compared to a 12 °C temperature (Edwards & Goldenberg, 1976). However, different plant sizes or plant growth stages were behavior in relation with optimum temperatures (Miller, 1962). Moreover, it is observed that, as the size of Snapdragons increased, the optimum temperature for dry weight accumulation decreased. Ethnobotanically, Snapdragon is also considered an important plant, flowers and leaves of Snapdragon have been used as traditional herbal medicine for treating several symptoms and diseases, including watery eyes, gum scurvy, hemorrhoids, ulcers, liver disorder, and tumors (Al-Snafi, 2015). The flowers of Snapdragon are among the most popular edible flowers and frequently introduced in different preparations of foods and drinks, such as salad, desserts, soups, teas, and liquors, for decorative and flavor-enhancing purposes (Rop et al., 2012).

Despite rich uses of the flower in medicinal and food products, only a few of studies have reported its antioxidant, antimicrobial, hemolytic, and wound-healing activities (Al-Snafi, 2015).

Although *A. majus* is among one of the major flowers of this plant are grown for its wide range of uses in the world, unfortunately trend of *Antirrhinum* growing has not yet been established in Pakistan. Pakistan only produced roses, gladiolus and tuberose as cut flower (Shafique et al., 2011). The study was conducted to increase the diversity of cut flowers in Pakistan and checked the efficiency of *Antirrhinum* cultivars at different times of the year. The seeds of different *Antirrhinum* cultivars were imported from the USA. Moreover, checked their field performance as cut flower under dry temperate climatic conditions of northern Balochistan.

Materials and Methods

Snapdragon Seed Collection

Three varieties i.e., Sonnet, Shower, Majus and four cultivars, Yellow, White, Pink, and Purple were collected from Directorate of Floriculture Department, (Agriculture Research Institute) Quetta in 2021. These seeds were transferred to Agriculture Plant Protection Lab, Agriculture Research Institute Quetta for further study.

Field Experiments

The field experiment was conducted at the Agriculture Research Institute (ARI) Sariab Road Quetta during growing season of 2021. The environmental conditions of Quetta are described as dry temperate zone with freezing temperatures during winter and mild weather in summer. The soil type described acidic with lower pH, and low organic content.

The following parameters were studied which are subdivided into morphological and reproductive parameters.

Morphological Parameters: The following parameters were measured weekly until the final harvest.

(i) Plant height, (ii) Number of leaves, (iii) Leaf area (leaf length x leaf width) and (iv) Number of branches.

Reproductive Parameters: The following reproductive parameters will be measured weekly when flower clusters appeared until the final harvest. (1) Number of flowers, (ii) Number of seeds.

Seed Germination Test

Twenty seeds of each variety were placed in a Petri dish with double-layered Whatman N°1 filter paper moistened with 10 ml of distilled water were used for germination test and stored at 20-25ºC in a germination. There were three replicates for each variety and cultivars were used for this experiment. Germination counts were made every day for 21 days or until all seeds germinated. Seeds was considered germinated when the tip of the radicle (2 mm) had grown free of the seed. The experimental design was described as Completely Randomized Design (CRD) with three replicates.

Environmental Data

The local environmental data were obtained from ARI, Quetta for experimental seasons. The environmental data were included relative humidity, maximum and minimum temperature and precipitation.

Soil and Water Analysis of Experimental Fields

The soil and water quality of both experimental fields were analyzed at the Directorate of Soil Fertility Research Centre, ARI Quetta.

Germination Index (GI)

The germination parameters used in this experiment are as follows:

(a) Final Germination Percentage (FGP): The FGP defined as the number of seeds germinated of an *Antirrhinum* variety during four days multiplied by 100. The higher FGP value indicates the greater seed germination of an *Antirrhinum* variety.

(b) Mean Germination Time (MGT): MGT defined as follows

MGT= Σ f.x./Σf

Where f = Seeds germinated on day x

It is described that the lower the MGT, the faster the seeds of *Antirrhinum* variety germinated.

(c) First day of Germination (FDG): Day on which the first seed germination of an *Antirrhinum* variety occurred. Lower FDG indicates less dormancy of seed in an *Antirrhinum* variety.

(d) Last Day of Germination (LDG): The day on which the last seed germination event occurred in an

Antirrhinum variety. It is described that lower LDG values indicate the faster ending of germination.

(e) Coefficient of Velocity of Germination (CVG): It is defined as follows:

CVG =N1 +N2+…..+ Nx/100 x N1T1+….+ NxTx

Where N = Number of seeds germinated each day

T = Number of days from seed germinated corresponding to N

The CVG is described as an indicator of rapidity of seed germination in *Antirrhinum* varieties. Similarly, CVG increases when the number of germinated seed increases and the days (Time) required for germination decreases. The maximum CVG is 100 when all seeds germinated on the first day.

(f) Germination Rate Index (GRI/day): Germination Rate Index defined as follows:

GRI = G1/1 +G2/2…. + Gx/x

Where G1 = Germination percentage multiplied by 100 at the first day after incubating seeds in an oven.

G2 = Germination percentage multiplied by 100 at the second day after incubating seeds in an oven.

The higher GRI percentage indicates the higher germination rate in an *Antirrhinum* seed variety.

(g) Germination Index (GI): Germination Index described as follows:

GI = GI= (4 x n1) + (3 x n2) …… + (1 x n4)

Where n1, n2… n4 = Number of germinated seeds on the first, second and subsequent days until the final day. However, 4, 3 …1 are weights given to the number of germinated seeds on the first, second, and final days respectively. From this model it is postulated that maximum GI obtained when a seed germinated on the first day first compared with the subsequent days. Therefore, the less dormant seeds of *Antirrhinum* varieties showed higher GI values compared with those which showed higher dormancy tendencies.

(h) Time Spread of Germination (TSG day): It is defined as the time in days between first and last germination events occurring in an *Antirrhinum* seed variety. The higher TSG indicates greater differences in germination tendencies between ‘fast’ and ‘slow’ germinating *Antirrhinum* varieties.

Statistical Analysis

The effects of *A. majus* varieties on morphological and reproductive parameters were statistically analyzed by using modified analysis of variance (ANOVA) procedure in which heterogeneity of variances and lack of independence over time (from the first week of emergence to final week of yield harvested) were taken into consideration. For statistical analysis temporal repeated measures of individual *A. majus* varieties were used with the help of SPSS® version 16 (IBM® Inc.). The modified univariate ANOVA was used in a way that time effects plus all interactions to the terms of ordinary the ANOVA model along with the REPEATED statement of the GLM procedure (SPSS® version 16). The difference in mean value were calculated by using LSD (Least Significant Differences) at $P < 0.05$ with the help of SPSS® version 16. The graphs were constructed with the help of Sigma Plot® version 2000 (Sigma® Inc.).

Results and Discussion

Statistical Analysis of Seed Germination

The effect of innate seed dormancy on three Snapdragon seed varieties (Sonnet, Shower and Majus) and four cultivars (Yellow, White, Pink and Purple) was studied. The results of univariate ANOVA showed that there were no significant differences found among three varieties ($P < 0.138$) and cultivars ($P < 0.154$) of Snapdragon (Table 1). Similarly, the interaction between cultivars and varieties also showed non-significant differences ($P < 0.865$). It is mostly due to uniformity that prevailed among cultivars and varieties of Snapdragon. Although the effect of different temperature regime did not study in this experiment, but the results of experiments conducted by Silva et al. (2013) showed that effect of temperature regime significantly affected the seed germination of *A. viridis*.

Moreover, the results of temporal effects on seed germination revealed that there was a significant effect of time on seed germination of different varieties and cultivars of Snapdragon ($P < 0.001$, Table 1). The temporal repeated measures ANOVA is a comparatively advanced analysis of variance in which the effect of time on seed germination taken into consideration. Therefore, to adjust these effects G-G (Greenhouse-Geisser) and H-F (Huynh-Feldt) must be adjusted. In G-G (Greenhouse-Geisser) and H-F (Huynh-Feldt) the number of degrees of freedom of the F-test for time-related effects are reduced in order to take the autocorrelation and heteroscedasticity over time into account. Therefore, the adjusted values of G-G and H-F Epsilon are separately measured in Temporal Repeated Measures ANOVA are as follows: G-G = Greenhouse-Geisser Epsilon = 0.455 H-F = Huynh-Feldt Epsilon = 0.812 (The G-G and H-F Epsilon can be used to adjust the degrees of freedom for the averaged tests of significance). This test is used to correct for violation in the within subject effect factor. Within the subject degree of freedom is adjusted into 1 ($P < 0.001$, Table 1 & 2). The Epsilon values (G-G= 0.455 and H-F= 0.812) are the results of Mauchly's Test of Sphericity, where, tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix (Footnote, Table 1). It is defined as used to be adjust the degrees of freedom for the averaged tests of Significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table (Dutilleul, 1998). Furthermore, the within the subject effects of Time interaction with Variety also showed non-significant effects ($P < 0.568$) and similar trends observed in case of their adjusted values carried out by G-G (0.964) and H-F (0.994). Similarly, the interaction between Time and Cultivar also showed non-significant difference and same goes in case of interaction between Time x Variety x Cultivar (Table 2).

The results of LSD Test are presented in Figures 1, and 2. Temporal effect on seed germination of three Snapdragon varieties revealed that “Shower” comparatively higher rate of seed germination (18.16 ± 0.34) compared with Sonnet (17.33 ± 0.39) and Majus (17.50±0.31). However, these differences statistically were non-significant (Figure 1). Similarly, cultivars yellow (17.88±0.26), white (17.66±0.33), Pink (17.00±0.40) and Purple (18.11±0.56) were also showed non-significant differences (Figure 1).

Table 1. Univariate ANOVA for seed germination index for three Snapdragon varieties (Sonnet, Shower and Majus) and four cultivars (Yellow, White, Pink and Purple).

Source	Df	Sum of Squares	Mean Square	F	Significance
Variety	2	0.467	0.233	2.154	0.138
Cultivar	3	0.622	0.207	1.915	0.154
Variety*Cultivar	6	1.711	0.285	2.632	0.865
Error	24	2.600	0.108		0.042

Table 2. Summary of temporal repeated measure ANOVA for seed germination index for three Snapdragon varieties (Sonnet, Shower and Majus) and four cultivars (Yellow, White, Pink and Purple).

Source	DF[1]	F-value	Probability	Adjusted Pr>F	
				G-G[2]	H-F
(a) Between subject effects					
Variety	2	2.154	0.138	---	---
Cultivar	3	1.915	0.154	---	---
Variety*Cultivar	6	2.632	0.042	---	---
Error	24	------	------	---	---
(b) Within subject effects					

Time (Days)	1	0.00	0.001	0.001	0.001
Time*Variety	2	0.58	0.568	0.964	0.994
Time*Cultivar	3	3.752	0.24	0.184	0.127
Time*Variety*Cultivar	6	2.31	0.067	0.263	0.209
Error	24	---	---		

1DF = degrees of freedom
2In G-G (Greenhouse-Geisser) and H-F (Huynh-Feldt)
Mauchly's test of sphericity,
G-G = Greenhouse-Geisser Epsilon = 0.455
H-F = Huynh-Feldt Epsilon = 0.812

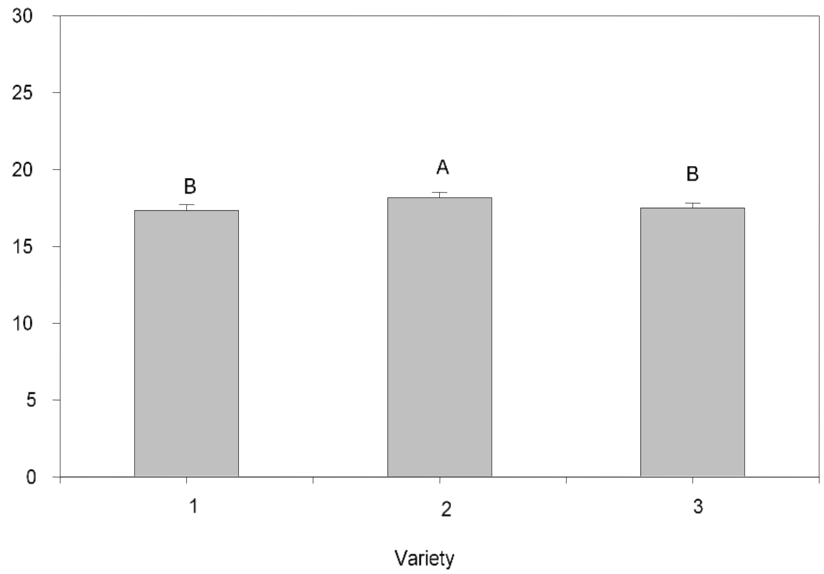

Figure 1. Seed germination (%) for three Snapdragon varieties (Sonnet, Shower, Majus). The arrows on the bar represent SE. The alphabets on the bar showed LSD ($p < 0.05$).

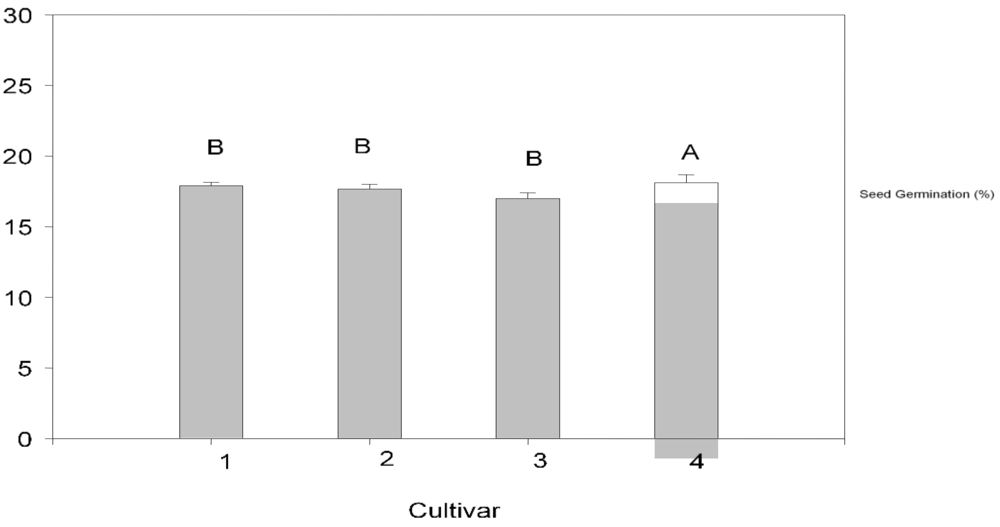

Figure 2. Seed germination (%) for four Snapdragon cultivars (Yellow, White, Pink and Purple). The arrows on the bar represent SE. The alphabets on the bar showed LSD ($p < 0.05$)

Seed Germination Index (SGI)

The result of SGI describes the effect of different parameters on seed germination (Kader, 2005). The results revealed a wide variation between germination data founded on the time spread of germination as well as its final percentage (Figure 3 & 4). The Final Germination Percentage (FGP), which reflects the final percentage of germination showed that the germination percentage appeared uniformly among three Snapdragon seed varieties. For instance, Snapdragon variety "Sonnet" showed 87.08 ± 1.78, Shower 87.50 ± 1.56 and Majus 87.50 ±1.56 (Figure 3). Similarly, the FGP of four cultivars of Snapdragon are as follows: Yellow showed 88.88 ±1.61, White 88.33±1.66, Pink 84.44±1.75 and Purple 91.11±2.46 (Figure 3). In general, there was a homogeneity prevailed among all varieties and cultivars, however, cultivar Purple showed highest FGP (91.11±2.46) compared with Sonnet which showed (87.08 ± 1.78).

The First Day of Germination (FDG) is described as the day on which the first germination event occurred (Kader, 2005). The results of FDG for three Snapdragon variety are as follows: Sonnet showed 4.91 ± 0.14, while Shower 4.75 ± 0.31and Majus 4.83 ±0.11. Moreover, the FDG of four cultivars of Snapdragon are as follows: Yellow showed 5.00 ± 0.00, White 4.77 ± 0.14, Pink 4.88 ± 0.20 and Purple 4.66 ± 0.16 (Figure 3 & 4). Based on these results it is observed that cultivar Yellow showed highest FDG (5.00 ± 0.00) compared with Shower (4.75 ± 0.3). Similar trend also observed in case of FDG, where, homogeneity prevailed among all varieties and cultivars.

The Last Day of Germination (LDG) is described as the day on which the last germination event occurred (Kader, 2005). The results of LDG for three Snapdragon varieties are as follows: Sonnet showed 9.83 ± 0.11, while Shower 9.91 ± 0.08 and Majus 9.66 ± 0.14. Furthermore, the LDG of four cultivars of Snapdragon are as follows: Yellow showed 10.00 ± 0.00, White 10.00 ± 0.00, Pink 9.66 ± 0.16 and Purple 9.55 ± 0.17 (Figure 3 & 4). Based on these results, it is observed that cultivar Yellow showed highest LDG (10.00 ± 0.00) compared with Purple (9.55 ± 0.17). These results revealed similar trend of homogeneity as observed in previous traits of germination indices.

The Coefficient of Velocity of Germination (CVG) is described as the day on which the number of seeds germinated per day (Kader, 2005). The results of CVG for three Snapdragon varieties are as follows: Sonnet showed 21.74 ± 0.88, while Shower 23.35 ± 0.74 and Majus 21.83 ± 0.91. Moreover, the CVG of four cultivars of Snapdragon are as follows: Yellow showed 23.53 ± 0.61, White 22.51 ± 0.86, Pink 20.25 ± 1.02 and Purple

22.94 ± 1.13 (Figure 3 & 4). Based on these results it is observed that cultivar Yellow showed the highest CVG (23.53 ± 0.61) compared with Pink (20.25 ± 1.02). Similar trend also observed in case of CVG, where, a homogeneity prevailed among all varieties and cultivars.

The Germination Rate Index (GRI) described is calculated based on the percentage of germination per day. The results of GRI for three Snapdragon varieties are as follows: Sonnet showed 2.53 ± 0.08, while Shower 2.72 ± 0.08 and Majus 2.61 ± 0.06. Besides, the GRI of four cultivars of Snapdragon are as follows: Yellow showed 2.58 ± 0.04, White 2.59 ± 0.06, Pink 2.57 ± 0.10 and Purple 2.74 ± 0.13 (Figure 3 & 4). Based on these results, it is observed that cultivar Purple showed highest GRI (2.74 ± 0.13) compared with Sonnet (2.53 ± 0.08). Similar trend also observed in case of GRI, where, a homogeneity prevailed among all varieties and cultivars.

The results of Germination Index (GI) for three Snapdragon varieties are as follows: Sonnet showed 65.75 ± 2.83, although Shower 71.58 ± 2.54, and Majus 68.83 ± 2.21. Furthermore, the GI of four cultivars of Snapdragon are as follows: Yellow showed 66.22 ± 1.51, White 67.22 ± 1.85, Pink 68.33 ± 3.44 and Purple 73.11 ± 4.17 (Figure 3 & 4). Based on these results it is detected that cultivar Purple showed highest GI (73.11 ± 4.17) compared with Sonnet (65.75 ± 2.83). Parallel trend also detected in case of GI, where, homogeneity prevailed among all varieties and cultivars.

Based on the Time Spread of Germination (TSG) were studied among three Snapdragon seed varieties. It was observed that Sonnet showed 4.91 ± 0.14, while Shower showed 5.16 ± 0.11 and Majus showed 4.83± 0.11. Moreover, the TSG of four cultivars of Snapdragon are as follows: Yellow showed 5.00 ± 0.00, White 5.22 ± 0.14, Pink 4.77 ± 0.14 and Purple 4.88 ± 0.20 (Figs. 3 and 4). Based on these results it was observed that cultivar White showed highest TSG (5.22 ± 0.14) compared with Pink (4.77 ± 0.14). Equivalent trend also detected in case of TSG, where; homogeneity prevailed among all varieties and cultivars.

The result of Mean Germination of Day (MGD) for three Snapdragon varieties are as follows: Sonnet showed 7.21 ± 0.10 while Shower showed 7.06 ± 0.07 and Majus showed 7.06 ± 0.11. Additionally, the MGD of four cultivars of Snapdragon are as follows: Yellow showed 7.29 ± 0.05, White showed 7.19 ± 0.07, Pink showed 6.98 ± 0.16 and Purple 6.98 ± 0.12 (Figure 3 & 4). Based on these results it was observed that cultivar Yellow showed highest MGD (7.29 ± 0.05) compared with Purple (6.98 ± 0.12). Equivalent trend was also observed in case of MGD, where; homogeneity prevailed among all varieties and cultivars.

Based on the result obtained with the help of different germination models, it is clear that all varieties and cultivars followed the same trends which confirms the assumption that despite their morphological heterogeneity, their genetic behavior is the same. Similarly, the seed dormancy among all these traits behaved similarly in a newly introduced environmental conditions. However, these results were obtained in a limited time scale and more research is required to observe the actual behavior of these traits.

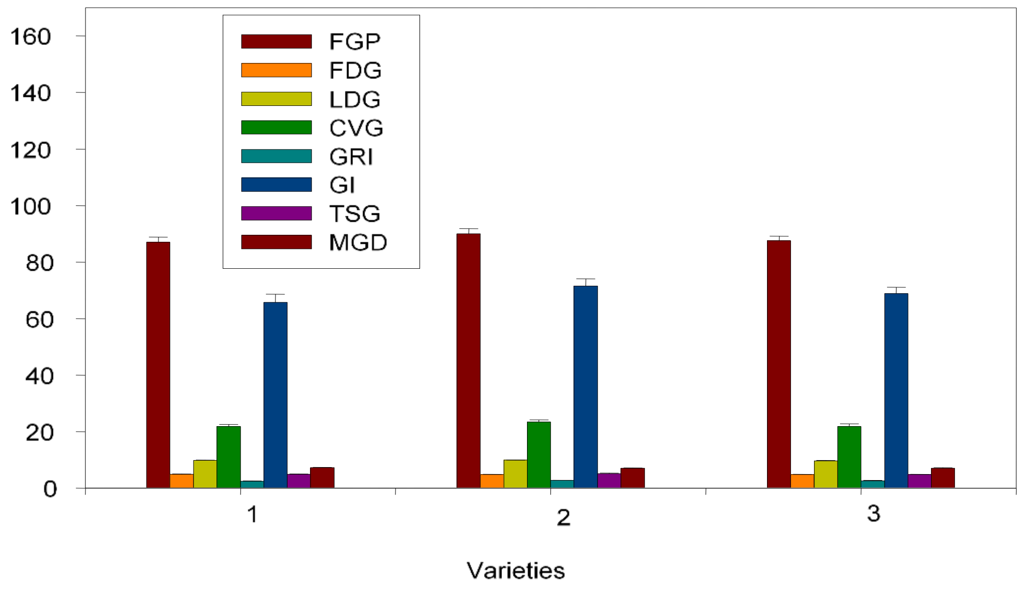

Figure 3. Germination parameters i.e., FGP (Final Germination Percentage), FDG (First Day of Germination), LDG (Last Day of Germination), CVG (Coefficient of Velocity of Germination), GRI (Germination Rate Index), GI (Germination Index), TSG (Time Spread of Germination) and MGD (Mean Germination Time) for three Snapdragon (Sonnet, Shower and Majus). The arrows on the bars represent the standard error.

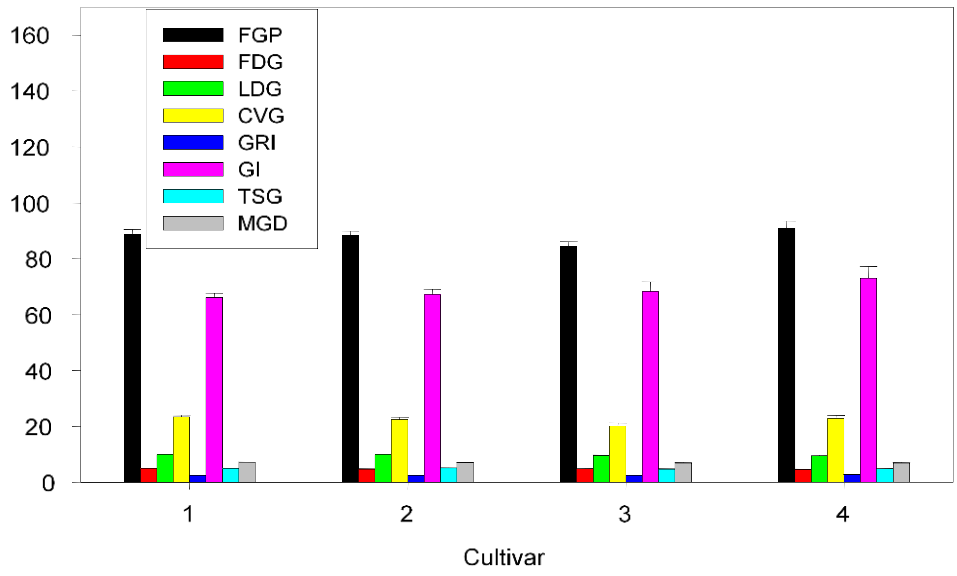

Figure 4. Germination Parameters i.e., FGP (Final Germination Percentage), FDG (First Day of Germination), LDG (Last Day of Germination), CVG (Coefficient of Velocity of Germination), GRI (Germination Rate Index), GI (Germination Index), TSG (Time Spread of Germination) and MGD (Mean Germination Time) for four Snapdragon cultivar (Yellow, White, Pink and Purple). The arrows on the bars represent the standard error.

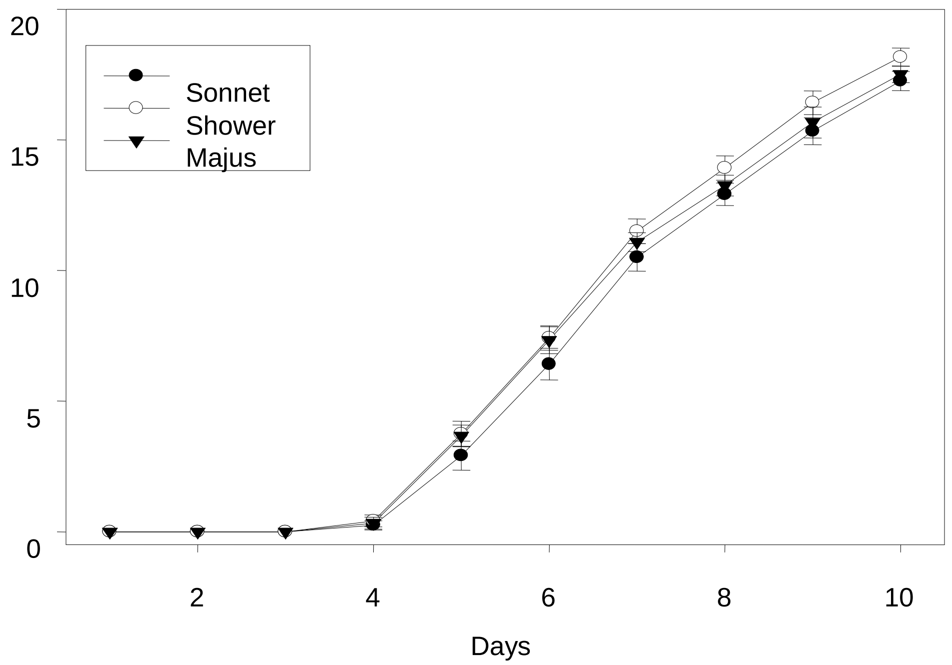

Figure 5. Cumulative Germination Index for three Snapdragon Varieties (Sonnet Shower, and Majus) for ten days. Arrows on dots are representing SE.

Conclusion

The study provides valuable insights into the adaptability and performance of *A. majus* cultivars under the dry temperate conditions of northern Balochistan. The results confirm that Snapdragon can be successfully cultivated in this region, with significant variations in morphological and reproductive traits among different varieties and cultivars. The influence of environmental factors, particularly temperature and photoperiod, plays a critical role in determining the growth and flowering patterns of Snapdragon. The findings suggest that introducing Snapdragon as a cut flower crop in Pakistan can enhance the diversity of the floriculture sector, offering economic benefits and aesthetic value. Future research should focus on optimizing cultivation practices, including irrigation management and soil fertility enhancement, to further improve the yield and quality of Snapdragon flowers in arid and semi-arid regions.

Additional Information and Declarations

Authors' Contribution: Authors declare that they have contributed equally to the manuscript.
Conflict of Interests: The authors of the manuscript declare that they have no conflict of interest.

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Investigation of Pomological and Morphological Traits of Some Peach (*Prunus persica* L.) Cultivars and Local Genotypes Grown in Çanakkale Ecological Conditions

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Abstract: The peach is a widespread and economically important fruit species all over the world. Due to its genetic diversity and the suitability of its ecological conditions, Türkiye is a leading country in the production of peaches. The temperate climate and fertile soils of Çanakkale provide an optimal environment for the cultivation of local peach genotypes. The aim of this study was to compare and evaluate the pomological and morphological traits of local peach genotypes grown in Çanakkale with the standard peach cultivars according to the criteria of UPOV TG/53/7 Rev. 2. The materials employed in this study included the standard cultivars Glohaven, Cresthaven, Şentürk, and J.H. Hale as well as the local genotypes Black Abdos and Sırrı. The analysis revealed a range of fruit width (52.17–75.64 mm), fruit weight (74.47–225.73 g), stone weight (5.56–12.28 g), flesh firmness (0.91–2.91 N), and soluble solids content (9.16%–12.16%) in the samples. The leaf areas ranged from 3672.190 to 5271.610 mm², which showed a considerable variation. In accordance with the criteria set forth by the UPOV, the leaf margins of the Black Abdos cultivar were observed to exhibit a serrated morphology, while the other cultivars displayed a crenate morphology. The nectarines of Black Abdos and Sırrı were observed to be reniform and present in two numbers. Additionally, the leaf bases of all genotypes were observed to be pointed. These findings provide invaluable insights for the conservation of genetic resources, the development of novel cultivars, and the improvement of production efficiency, while simultaneously guiding the preservation of regional diversity and the formulation of market-oriented production strategies.

Keywords: Peach local genotypes, standard cultivars, morphological traits, pomology, Çanakkale.

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Introduction

The peach (*Prunus persica* L.) is a member of the genus *Prunus*, which belongs to the subfamily *Prunoidea* of the family *Rosaceae*, within the order Rosales (Deveci, 1967; Rieger, 2007). The botanical name of the peach, *Prunus persica* L., has been attributed to its origin in Iran and the Caucasus (Gharaghani et al., 2017). Peach cultivation is practiced worldwide, both south and north of the equator, between latitudes 25 and 45 (Demirören, 1992). The diversity of our country's ecosystems, coupled with the peach's early yield, processing potential for fruit juice and canned products, and suitability for fresh consumption, renders it an important intermediate agricultural crop (Şeker & Kaya, 2024). Moreover, the considerable number of varieties and recent success in identifying suitable markets have contributed to the significance of peach production (Ekinci et al., 2024; Gür et al., 2024). The peach occupies a prominent position among fruit species, largely due to its economic value and extensive cultivation across the globe (Bayav & Çetinbaş, 2021). Given its extensive usage in both the fresh consumption and food processing industries, peaches are of great importance in Türkiye (Güneş et al., 2017). A review of the statistical data published by TUIK (2023) reveals that global peach production in 2022 was 26.354,497 tons, while Türkiye's production in 2023 was 1.076,852 tons. A further examination of export values in 2023 reveals a total of 227.106 tons. The total peach production in Çanakkale is 192.802 tons (TUIK, 2023). As a consequence of its favorable ecological conditions and genetic diversity, Türkiye is among the foremost countries in terms of peach production (Natalchuk et al., 2024). The fertile agricultural lands and microclimatic characteristics of the Marmara Region, particularly in Çanakkale, serve to further enhance the prominence of peach genotypes cultivated in this area (Yıldırım & Koyuncu, 2005; Layne & Bassi, 2008; Kaya & Şeker, 2023).

The evaluation of pomological and morphological characteristics of local genotypes is of paramount importance for both scientific research and applied agriculture (Yılmaz et al., 2017). The identification of such characteristics enables the determination of the region-specific adaptive abilities and superior traits of local genotypes (Demirel et al., 2024). This is of particular importance for the conservation of genetic resources, the breeding of new cultivars, and the optimization of cultivation practices. Furthermore, the pomological traits of local genotypes provide valuable insights into fruit quality, market value, and consumer preferences, while morphological traits provide essential information about agricultural performance, ecological adaptability, and disease resistance (Gariglio et al., 2012).

It is of the utmost importance to understand the differences between standard cultivars and local genotypes in order to enhance the competitiveness of the latter and develop appropriate cultivation strategies. Standard cultivars are usually known for their high yields, extensive geographical adaptability, and consistent quality. In contrast, local genotypes offer distinct advantages, such as greater resilience to regional environmental conditions, suitability for minimum input farming systems, and distinctive flavor profiles (Faust, 1989). Highlighting these differences enables producers to utilize genetic resources in a more effective manner, helps preserve regional diversity, and increases export potential (Reig Córdoba, 2013).

The region of Çanakkale, with its temperate climate, consistent rainfall patterns, and fertile soils, provides an optimal ecological foundation for peach cultivation (Şeker et al., 2013). Local genotypes in the region have adapted to these distinctive conditions over an extended period, resulting in a high level of genetic diversity. However, it has been observed that the pomological and morphological characteristics of these genotypes have not been sufficiently studied from a scientific perspective, thereby leaving their full potential untapped. This study aims to address this gap by revealing the superior traits of local genotypes and contributing to the genetic resources of Çanakkale in the scientific literature.

The study will inform producers of the varieties that are best suited to market demands and the most appropriate regional production strategies, by comparing local genotypes with standard varieties. In view of the growing consumer demand for environmentally sustainable, low-input, and distinctive taste profiles, it is anticipated that the results of this study will make an important contribution to both local producers and national agricultural policy.

Materials and Methods

Materials

The present study was conducted in the 2024 production season in a producer orchard in Umurbey Village, Lapseki District, Çanakkale Province (plot 285/19) (Figure 1), where peach varieties were grown under optimal conditions and harvested at the commercial maturity stage. The present study is concerned with the pomological and morphological characteristics of the following peach cultivars grafted onto GF677 rootstock: The cultivars included in the study were Glohaven, Cresthaven, Şentürk and J. H. Hale, as well as the local peach genotypes, Black Abdos and Sırrı (Figure 2). The age of the trees was 11 years. The trees were spaced 1 meter apart in each row and 3-meters apart between each row. The harvest dates of the peach cultivars and genotypes are provided in Table 1.

Figure 1. The image of the location where plant material was collected in the study.

Figure 2. Images of peach cultivars/genotypes used in the study.

Table 1. The harvest dates of the peach cultivars and genotypes.

Cultivars/Genotypes	Harvest Dates
Glohaven	28 July 2024
Cresthaven	20 August 2024
Şentürk	10 July 2024
J. H. Hale	20 August 2024
Black Abdos	25 August 2024
Sırrı	20 September 2024

Methods

Collection of Leaf Samples

Leaf samples were taken according to the following methodology, which is described in detail below. Fully developed leaves were collected from the four cardinal points of the tree. A total of 100 leaves and their petioles were taken from each tree (Figure 3). Sampling was carried out in an X-shape in the orchard in question, with one tree being omitted. The leaf samples were wrapped in aluminum foil and placed in an ice box. The name of the sample, the name of the orchard where the sample was taken, the date of sampling and the age of the tree were written on the label. The leaf samples were transported to the laboratory as quickly as possible under cold chain conditions.

Collection of Fruit Samples

Fruits were randomly selected from all four sides of the tree (X-shaped) to represent the production orchard. A total of 30 fruit samples were taken from each tree. The measurements performed on the fruits were determined in three replicates, with 10 fruits each.

Figure 3. An image of collected leaves (front and rear view).

Morphological, Physical, and Chemical Measurements

Fruit and stone weights were measured individually using a precision balance with ±0.01 g sensitivity. Dimensional measurements were performed using a caliper, with three replicates of 10 samples each. Fruit firmness was measured with a Chatillon penetrometer (9 mm tip), and color parameters (L*, a*, b*) were determined using a Minolta CR-400 colorimeter. Flesh ratio (%) was calculated by subtracting stone weight from fruit weight and expressing the result as a percentage. Titratable acidity (g/100 ml citric acid) was determined by diluting the juice with distilled water and titrating with 0.1 N NaOH to pH 8.10 using an Orion digital pH meter. Fruit juice pH was also measured using the same device. Soluble solids content (SSC) was determined using a digital Hanna refractometer and expressed as a Brix percentage. Leaf measurements were performed using a ruler and caliper, and leaf area was calculated using the Leaf Area Measurement Program v1.3. SPAD values were recorded as the mean of 10 randomly selected leaves per replicate. Nectary traits, leaf shape, margin type, hairiness, and other morphological characteristics were evaluated according to the UPOV TG/53/7 Rev. 2 guidelines.

Data Analysis

The results obtained in the study were evaluated using analysis of variance (ANOVA) with the statistical package "SAS 9.1.3 Portable". The differences between varieties and genotypes in the parameters studied were evaluated by the LSD multiple comparison test at the 0.05 significance level ($p<0.05$). For morphological data, the criteria developed by the International Union for the Protection of New Varieties of Plants (UPOV-TG/53/7 Rev. 2) for the peach species were taken into account.

Results and Discussion

Peach is a widely grown fruit with high economic value worldwide and is one of the most important fruits in Türkiye. However, the unique climate and soil conditions of each region can influence the yield and quality characteristics of different cultivars and local genotypes. In this study, the morphological and pomological traits of different fruit cultivars and genotypes were compared and their importance for commercial potential in terms of a number of parameters are elaborated. The data obtained revealed significant differences among the genotypes, which may influence the suitability of each genotype for different market requirements.

In the study, the genotype Sırrı had the widest fruit (75.64±0.26 mm) compared to the other varieties. This finding is consistent with the fruit size data for the Sırrı genotype presented in the study by Gür et al. (2020). Similarly, genotypes such as Black Abdos (71.56±2.17 mm) are also characterized by large fruit width in the literature (Gür et al., 2020). These large fruits are generally preferred due to their superior taste and market value. In this study, when compared to smaller varieties such as Cresthaven (52.17±1.31 mm) and Glohaven (59.05±2.61 mm), the larger fruit width was found to have significant advantages, particularly from a commercial perspective (Table 2).

The Sırrı and Black Abdos genotypes, with weights of 225.73±7.29g and 214.11±13.92g, respectively, had the heaviest fruit. This result is in line with findings by Gür et al. (2020), where it was also reported that the Sırrı and Black Abdos genotypes possess large fruit weights. However, in this study it was observed that the fruit weights of other cultivars such as Cresthaven (74.47±6.13 g) and Glohaven (129.86±8.81 g) were smaller, suggesting that their market value, especially for commercial production, might be lower. It has been emphasized in numerous studies that fruit width and weight are crucial parameters influencing market value (Table 2). The data on stone width and length indicate significant differences among cultivars. In particular, the stones of the Şentürk cultivar (27.88±3.86 mm) and Sırrı (23.01±0.74 mm) genotype were found to be wider and longer, whereas smaller stone widths were observed in cultivars such as Cresthaven (20.40±0.16 mm) and Glohaven (19.02±1.77 mm). This finding is consistent with Tecimer (2012), who reported that some cultivars have smaller stones, which could positively influence production processes. Peach cultivars with smaller stones may also be more attractive in terms of market and consumer demand (Table 2).

The highest stone weight value was observed in the Sırrı genotype (9.09±0.75 g). The Black Abdos genotype (12.28±1.14 g) and Şentürk cultivar (9.40±2.01 g) also exhibited high stone weights. However, high stone weight may result in increased production costs for stone fruit varieties and may not be preferred by certain markets. Consequently, varieties with lower stone weights may offer a more advantageous profile, particularly in terms of fresh consumption and overall market value (Table 2).

Stoneless fruit weight is generally important as a parameter of commercial production. The Sırrı genotype (216.64±6.61 g) had the highest value in terms of stoneless fruit weight, followed by Black Abdos (201.83±13.23 g) and Şentürk (141.36±8.48 g). Fruits with lower stone content have a higher economic value especially for fresh consumption and the processing industry. In this study, lower stone fruit weights were found in varieties such as Glohaven (124.30±8.55 g) and Cresthaven (67.68±6.16 g), suggesting that these varieties may provide lower yields in commercial production (Table 2).

The measurement of L*, a*, and b* values is of great importance for both the determination of quality and the optimization of marketing strategies. The L* value indicates the brightness of the fruit, and higher L* values are generally perceived as fresher and more attractive by consumers, which increases the market value of the fruit. The use of color measurements enables producers to accurately assess the ripeness of their peaches, thereby facilitating the optimization of harvest timing and the reduction of quality losses. Furthermore, the a* and b* values can indicate the fruit's acidic or sweet characteristics, helping in the selection of varieties better aligned with consumer preferences. In the processing industry, darker peach varieties are more commonly preferred due to their typically richer taste and texture. Consequently, the selection of appropriate fruit for processing can be made more efficiently through the use of color measurements. In addition, alterations in the fruit's peel pigmentation can be employed to ensure the maintenance of quality during storage and transportation, as color provides crucial indications regarding the freshness and quality of the peaches (Fallik & Ilic, 2018).

Table 2. The pomological traits of peach cultivars and genotypes.

Cultivar/Genotype	Fruit width (mm)	Fruit length (mm)	Fruit weight (g)	Stone width (mm)	Stone length (mm)	Stone weight (g)	Stoneless fruit weight (g)
Glohaven	59.05±2.61[d]	66.11±0.25[d]	129.86±8.81[c]	19.02±1.77[c]	35.76±1.90[cb]	5.56±0.66[c]	124.300±8.55[d]
Cresthaven	52.17±1.31[e]	54.07±2.77[e]	74.47±6.13[d]	20.40±0.16[cb]	34.01±0.76[c]	6.78±0.06[c]	67.683±6.16[e]
Şentürk	65.13±1.99[c]	70.40±3.45[cb]	150.75±7.69[b]	27.88±3.86[a]	40.34±1.49[a]	9.40±2.01[b]	141.357±8.48[c]
Black Abdos	71.56±2.17[b]	71.02±1.27[b]	214.11±13.92[a]	23.04±0.66[b]	36.66±0.72[b]	12.28±1.14[a]	201.830±13.23[b]
Sırrı	75.64±0.26[a]	77.77±0.83[a]	225.73±7.29[a]	23.01±0.74[b]	42.52±1.79[a]	9.09±0.75[b]	216.637±6.61[a]
J.H. Hale	62.36±1.21[c]	67.25±0.53[cd]	129.53±2.43[c]	21.42±0.95[cb]	37.67±0.75[b]	7.02±0.61[c]	122.507±2.64[d]
$LSD_{(0.05)}$	3.1498 **	3.4262 **	15.008 **	3.2429 **	2.3733 **	1.8824 **	14.678 **

** There are statistically significant differences among cultivars/genotypes in terms of the related trait ($p<0.05$).

The highest L* values were observed in Glohaven (48.55±2.41) and Şentürk (48.85±2.91) in this study. This indicates that the fruit peel is of a lighter hue, and these varieties are typically regarded as more aesthetically pleasing in the marketplace. It has been demonstrated that peels of a lighter hue are preferred by consumers, as they are perceived as fresher and more appealing (Minas et al., 2018). Conversely, the genotype Black Abdos (33.19±2.24) exhibited the lowest L values, indicating a darker peel color (Table 3). It has been demonstrated that peach varieties with darker hues may be more favored by the processing industry due to their superior storage and processing qualities. The significance of color in consumer preference is well documented, with associations between color and market value frequently observed, particularly in the context of fresh fruit and processed products (Christofi, 2021).

The highest values in terms of rind a* values are observed in Cresthaven (26.22±1.81) and Sırrı (30.42±1.41). This indicates that their red tones are more dominant, resulting in more vivid and remarkable colors. The studies conducted on the subject highlight red peel color as a feature that increases consumer appreciation. However, the a* values of the Black Abdos genotype (29.43±3.22) and the Şentürk cultivar (28.94±1.51) are also high, although their red color tones may be less prominent than those of Cresthaven (Table 3). Significant differences are evident between the varieties in terms of b value. It can be observed that certain genotypes, such as Black Abdos and Cresthaven cultivars, exhibit a more pronounced yellow color tone, which may be a significant factor in the visual representation of the fruit peel in the market.

The Şentürk cultivar exhibited the highest value for flesh a* with a mean of 0.91±0.51, while the Glohaven (0.39±0.99) and Cresthaven (-0.36±0.33) cultivars demonstrated lower red tones. The fruit flesh of the Şentürk cultivar is characterized by reddish tones, whereas the flesh of the other varieties exhibits more neutral hues. The flesh b* value is higher in the Black Abdos (1.68±1.89) and Sırrı (1.69±0.49) genotypes (Table 3), indicating that yellow tones are dominant. These tones may be more attractive, especially for fresh consumption.

The Şentürk cultivar exhibited the highest fruit firmness value, with an average of 2.91±0.14 N, while Black Abdos (0.91±0.29 N) and J.H. Hale (3.31±0.41 N) demonstrated notably lower firmness values (Table 3). The firmness of peach fruit is closely related to its suitability for consumption. Harder fruits are generally more durable during transport and storage, but may be less desirable for fresh consumption. Additionally, hard fruit flesh can be an important characteristic in the processing industry (Gür & Pırlak, 2011).

The genotype Sırrı (95.97±0.22) exhibited the highest value in terms of fruit flesh ratio, indicating that the fruit flesh constitutes a greater proportion of the fruit than the peel and therefore provides a higher yield. Additionally, the Glohaven (95.71±0.47) and J.H. Hale (94.57±0.51) cultivars exhibited elevated fruit flesh ratios, suggesting that these cultivars may be preferred by consumers for fresh consumption (Table 4). Similar ratios were observed in the Black Abdos genotype (94.26±0.40) and Şentürk (93.74±1.49) cultivars. The Cresthaven

(90.84±0.80) variety exhibited a significantly lower fruit flesh ratio compared to the other cultivars (Demiral & Ülger, 2021).

Table 3. The pomological traits of peach cultivars and genotypes.

Cultivar/Genotype	Fruit peel L*	Fruit peel a*	Fruit peel b*	Fruit flesh L*	Fruit flesh a*	Fruit flesh b*	Fruit flesh firmness (N)
Glohaven	48.55±2.41^{a}	21.19±4.19^{c}	30.03±4.24^{a}	69.14±5.75^{bc}	0.39±0.99^{ba}	59.86±1.76^{a}	1.96±0.37^{b}
Cresthaven	42.04±1.99^{b}	26.22±1.81^{a}	26.33±4.34^{ba}	75.10±0.60^{a}	-0.36±0.33^{b}	60.44±2.01^{a}	1.73±0.19^{b}
Şentürk	48.85±2.91^{a}	28.94±1.51^{ba}	30.68±1.81^{a}	72.73±0.39^{ba}	0.91±0.51^{ba}	57.55±1.82^{ba}	2.91±0.14^{a}
Black Abdos	33.19±2.24^{c}	29.43±3.22^{ba}	20.81±3.87^{b}	66.98±1.86^{c}	1.68±1.89^{a}	49.94±1.68^{c}	0.91±0.29^{c}
Sırrı	39.33±5.42^{b}	30.42±1.41^{a}	27.55±4.12^{a}	72.33±0.72^{ba}	1.69±0.49^{a}	56.25±2.12^{b}	1.68±0.12^{b}
J.H. Hale	38.41±0.30^{cb}	25.40±1.56^{bc}	20.26±1.36^{b}	71.89±0.72^{ba}	-0.24±0.40^{b}	54.77±0.06^{b}	3.31±0.41^{a}
$LSD_{(0.05)}$	5.2779 **	4.4721 **	6.2489 **	4.4852 **	1.6746 **	3.0599 **	0.4912 **

** There are statistically significant differences among cultivars/genotypes in terms of the related trait ($p<0.05$).

The analysis of titratable acidity values revealed that the genotype exhibiting the highest acidity was Black Abdos (0.82±0.010). The cultivar exhibiting the lowest acidity was Cresthaven, with a mean value of 0.46 ± 0.017. The remaining cultivars and genotypes fell within the intermediate group (Table 4). The determination of titratable acidity (TA) values among peach cultivars and genotypes offers significant advantages for consumers. The acidity content has a direct influence on the flavor of the peach. A higher acidity results in a more sour taste, whereas a lower acidity leads to a sweeter profile. This allows consumers to select peach cultivars that align with their personal taste preferences. Moreover, the acidic characteristics affect both the consumption of fresh peaches and the shelf life of processed peach products, such as jams, compotes, and fruit juices. Higher acidity helps maintain the freshness of fruit products and contributes to better quality in processed goods. Therefore, titratable acidity is an important quality indicator for both peach producers and consumers (Serrano & Valero, 2010).

Table 4. The pomological traits of peach cultivars and genotypes.

Cultivar/Genotype	Fruit flesh ratio (%)	Titratable acidity (g citric acid 100 ml^{-1})	Fruit juice pH	Brix (%)	SPAD
Glohaven	95.71±0.47^{ba}	0.71±0.006^{b}	3.38±0.01^{e}	10.73±0.15^{c}	42.38±1.0^{ba}
Cresthaven	90.84±0.80^{d}	0.82±0.010^{a}	3.63±0.01^{b}	10.20±0.17^{d}	41.50±1.0^{bc}
Şentürk	93.74±1.49^{c}	0.72±0.029^{b}	3.93±0.02^{a}	9.16±0.06^{e}	40.22±1.0^{c}
Black Abdos	94.26±0.40^{c}	0.46±0.017^{e}	3.62±0.01^{b}	11.73±0.12^{b}	43.50±1.0^{a}
Sırrı	95.97±0.22^{a}	0.50±0.004^{d}	3.48±0.02^{c}	12.16±0.25^{a}	43.00±1.0^{ba}
Hale	94.57±0.51^{bc}	0.65±0.006^{c}	3.42±0.02^{d}	11.86±0.42^{ba}	43.74±1.0^{a}
$LSD_{(0.05)}$	1.3629 **	0.4003 **	0.0244 **	0.4022 **	1.779 **

** There are statistically significant differences among cultivars/genotypes in terms of the related trait ($p<0.05$).

Upon analysis of the pH values, it was observed that the highest pH value was (3.93±0.02) in the Şentürk cultivar, while the lowest pH was (3.38±0.01) in the Glohaven cultivar (Table 4). The remaining cultivars and genotypes fell within the intermediate range. This indicates that the flesh has an acidic profile, resulting in a sourer flavor (Ilgın & Yüce, 2019). Low acid peach cultivars are more suitable for processing with sweeteners, generally offering a sweeter flavor profile. Cultivars with lower pH, such as Glohaven, exhibit stronger acidic characteristics and are thus suitable for use in processed food products.

The genotypes Sırrı (12.16±0.25) and Black Abdos (11.73±0.12) exhibited the highest soluble solids content (SSC) ratios (Table 4). This suggests that these varieties contain a greater proportion of soluble carbohydrates, which contributes to a more pronounced sweetness in their flavor profile. The cultivars Glohaven (10.73±0.15) and Cresthaven (10.20±0.17) exhibited lower soluble solids content (SSC) values, which may indicate a relative weakness in terms of sweetness. These findings are directly relevant to consumer taste preferences. The determination of soluble solids content (SSC) in peach cultivars and genotypes offers significant benefits to producers (Anthony & Minas, 2022). It directly influences the sweetness and overall flavor quality of the fruit. A high soluble solids content (SSC) is an essential factor in the production of sweet and flavorful peaches. By measuring the SSC values of different genotypes, producers can cultivate high-quality fruits that meet consumer demand (Lachkar et al., 2020). Furthermore, determining the SSC content provides a competitive advantage in the market, as consumers generally prefer sweet and flavorful fruits. This allows producers to offer their products to the market more efficiently, increase their income and make sustainable production.

The highest SPAD values were observed in Black Abdos (43.50±1.0) and J.H. Hale (43.74±1.0). This indicates that these genotypes and cultivars possess elevated chlorophyll concentrations, thereby conferring greater intensity of green hue (Table 4). The varieties Glohaven (42.38±1.0) and Sırrı (43.00±1.0) exhibited moderate chlorophyll content, whereas Cresthaven (41.50±1.0) and Şentürk (40.22±1.0) displayed lower SPAD values and paler green colors. This suggests that chlorophyll content is related to fruit ripeness, with high SPAD values indicating that the fruit flesh is close to reaching full maturity. Chlorophyll is a vital component of the photosynthetic process in plants and provides insights into plant health, nutritional status, and environmental stress tolerance (Ahmad et al., 2023). The use of SPAD measurements allows for the rapid and non-invasive determination of chlorophyll content in peach plants. This enables producers to obtain early warnings regarding the plant's nutritional status and health, facilitating the detection of adverse conditions such as nitrogen deficiency, water stress, or disease. Furthermore, monitoring chlorophyll levels indicates the plant's high photosynthetic capacity, which correlates with higher yield and quality potential (Wang et al., 2015). This assists producers in improving both productivity and product quality. Additionally, SPAD values are a valuable tool for determining the plant's nutrient requirements, optimizing fertilization strategies and overall nutrient management (Shah et al., 2017).

The data obtained in this study on fruit flesh ratio, titratable acidity, pH, soluble solids content and SPAD values demonstrate that there is considerable variation in the quality parameters of peach cultivars. The elevated fruit flesh ratio and soluble solids content observed in genotypes such as Sırrı and Black Abdos confer a significant advantage in terms of sweetness and productivity. The combination of high acidity and elevated pH. Şentürk may appeal to consumers who prefer acidic flavors. It is anticipated that the results of measurements of the relevant parameters may provide important insights into the commercial differentiation of fruit characteristics and the impact of peach production on marketing strategies.

The Glohaven (44.2±1.0) cultivar exhibited the widest leaf width, which may be indicative of a high photosynthetic capacity. This is due to the fact that larger and wider leaves are associated with greater photosynthetic efficiency. Additionally, the Şentürk (41.8±1.0) and J.H. Hale (41.8±1.0) cultivars exhibited relatively large leaves. The Cresthaven cultivar (38.0±1.0) and Black Abdos (35.4±1.0) genotype exhibited narrower leaves (Table 5). It has been demonstrated that there is a direct correlation between leaf width and water loss and photosynthetic efficiency. In this context, varieties with wider leaves can more efficiently utilize water and nutrients (Örs & Yıldırım, 2023).

The cultivar Glohaven exhibited the longest leaf length, while the Cresthaven and Black Abdos demonstrated shorter leaves, with lengths of 159.0±1.0 and 152.8±1.0, respectively. Similarly, the cultivars Şentürk (149.6 ± 1.0) and J.H. Hale (144.0 ± 1.0) also exhibited relatively shorter leaf lengths Longer leaves have the potential to capture more light, thereby enhancing photosynthetic efficiency, whereas shorter leaves may be associated with accelerated water loss (Derecik, 2018).

The J.H. Hale (3.37±1.0) cultivar was observed to have a significantly longer and wider petiole than other cultivars. The Şentürk cultivar (1.33±1.0) and Black Abdos genotype (1.42±1.0) were found to have narrower petioles (Table 5). The length of the petiole was found to be generally similar, with slightly longer petioles observed in the Şentürk cultivar (11.8±1.0) and the Sırrı (11.0±1.0) genotype. Petiole length has been demonstrated to affect the plant's water and nutrient transport capacity (Koçak, 2021).

Table 5. The morphological traits of peach cultivars and genotypes.

Cultivar/ Genotype	Leaf width (mm)	Leaf length (mm)	Petiol width (mm)	Petiol length (mm)	Leaf margins	Nectaries number (piece)	Nectaries shape	Angle at base	Angle at apex	Leaf area (mm^2)	Leaf hairiness	Leaf shape
Glohaven	44.2±1.0^{a}	159.0±1.0^{a}	1.56±1.0^{b}	10.2±1.0^{bdc}	crenate	0	-	acute	acute	5271.610±2.0^{a}	absent	flat
Cresthaven	38.0±1.0^{c}	152.0±1.0^{b}	1.24±1.0^{b}	9.2±1.0^{d}	crenate	0	-	acute	acute	4388.880±2.0^{d}	absent	flat
Şentürk	41.8±1.0^{b}	149.6±1.0^{c}	1.33±1.0^{b}	11.8±1.0^{ba}	crenate	0	-	acute	acute	4625.877±6.43^{b}	absent	flat
Black Abdos	35.4±1.0^{d}	152.8±1.0^{b}	1.42±1.0^{b}	9.8±1.0^{dc}	deep serrate	2	reniform	acute	acute	3672.190±2.0^{f}	absent	flat
Sırrı	38.0±1.0^{c}	160.6±1.0^{a}	1.46±1.0^{b}	11.0±1.0^{bac}	crenate	2	reniform	acute	acute	3976.050±2.0^{e}	absent	flat
J.H. Hale	41.8±1.0^{b}	144.0±1.0^{d}	3.37±1.0^{a}	12.0±1.0^{a}	crenate	0	-	acute	acute	4552.830±2.0^{c}	absen	flat
LSD$_{(0.05)}$	1.779 **	1.779 **	1.779 **	1.779 **	-	N.S.*	-	-	-	5.6878 **	-	-

** There are statistically significant differences among cultivars/genotypes in terms of the related trait ($p<0.05$).

*N.S. There are not statistically significant differences among cultivars/genotypes in terms of the related trait ($p<0.05$).

The Black Abdos (deep serrate) genotype is distinguished from the others by its distinctive leaf margin shape. The remaining cultivars predominantly display a crenate leaf margin shape (Table 5). The shape of the leaf margin is directly associated with genetic diversity, which may influence the cultivars' resilience to environmental stresses. It is hypothesized that plants with deep serrate margins may demonstrate greater resistance to water stress. The morphology of a plant's leaf margins, including the presence of crenate and serrate patterns, can be indicative of the plant's ability to adapt to specific environmental conditions. These margin types serve various functions, such as minimizing water loss, enhancing nutrient absorption, and reinforcing defensive mechanisms. The evolution of crenate leaf margins may have been driven by the need to minimize water evaporation, particularly in humid environments. The undulating structure helps retain atmospheric moisture, thereby reducing t water loss from the leaf surface. Conversely, serrate leaf margins, defined by sharp, tooth-like projections along the edge, facilitate more efficient water accumulation on the leaf surface, thus assisting the plant in maintaining a balance between water intake and output. Furthermore, these types of leaf margins may deter herbivores from feeding on the plant, thereby conferring a protective advantage. Both crenate and serrate leaf margins contribute to the plant's resistance to water stress, promoting more efficient water use and enabling the plant to better cope with environmental challenges. These morphological characteristics are critical adaptations that support plant survival in their respective ecosystems (Akbulut et al., 2017).

The number of nectaries was observed to be two in the Black Abdos and Sırrı genotypes. This indicates that the leaves of these genotypes have more nectaries, which may be associated with enhanced plant health. In other cultivars, no nectaries were observed (Table 5). Nectaries located on the petiole of peach trees serve as vital structures involved in various plant functions. These nectaries play a pivotal role in pollination. They attract bees and other pollinators, thereby facilitating pollination and potentially enhancing fruit yield. Furthermore, nectaries can attract certain pests, thereby strengthening the plant's defense mechanisms. Additionally, these structures contribute to the plant's overall defense strategies, aiding its survival and maintaining overall vitality. In this way, the nectaries on the petiole support the peach tree's adaptation to environmental factors and its survival strategies (Lim & Lim, 2012).

In all peach cultivars/genotypes identified within the scope of the study, it was determined that leaf base angles one of the UPOV TG/53/7 Rev. 2 criteria, were found to be acute (Table 5). Previous research has indicated that leaf base angles can affect plant water uptake capacity and their adaptation to environmental conditions. Additionally, different leaf base shapes have been shown to affect root architecture and the plant's hydraulic capacity.

The Glohaven cultivar (5271.610±2.0) exhibited the greatest leaf area, indicating a large leaf surface and a high photosynthetic capacity for this cultivar. The Cresthaven cultivar (4388.880±2.0) and the Black Abdos genotype (3672.190±2.0) exhibited reduced leaf area (Table 5), indicating potential limitations in their photosynthetic capacity relative to other cultivars. It can be hypothesized that larger leaves may increase light absorption and, as a consequence, result in higher yields. To assess the photosynthetic capacity and environmental responses of peach cultivars and genotypes, it is essential to determine their leaf area. Leaf area has a direct influence on water management, allowing for the assessment of the plant is resilience to water stress. Furthermore, leaf area provides insight into the overall health and developmental stage of the plant, which is associated with fruit yield and quality. The measurement of leaf area can assist in the identification of cultivars that demonstrate higher yields and superior fruit quality. Additionally, this measurement is valuable for understanding how different genotypes adapt to environmental conditions (Anamur & Türkmen, 2021). The leaf shapes of the related cultivars and genotypes were observed to be flat in form (Table 5). Previous research has indicated that leaf shape can influence water conservation and temperature regulation.

Conclusion

This study offers a comprehensive analysis of the pomological and morphological characteristics of the Black Abdos and Sırrı peach genotypes grown under the specific ecological conditions of Çanakkale, with a comparison to standard peach cultivars. The findings indicate that both local genotypes exhibit notable advantages, including a delayed harvest period, larger fruit weight, and superior fruit width compared with standard cultivars. In particular, the late harvesting nature of Black Abdos and Sırrı provides producers with a longer harvesting window, allowing for the availability of fresh fruit in the market for an extended period. This extended market presence is particularly advantageous for markets requiring a steady supply of fresh peaches, thereby conferring a competitive advantage to producers. Moreover, the augmented fruit dimensions and mass of these local genotypes contribute to the production of peaches with elevated commercial value. When compared with standard cultivars, Black Abdos and Sırrı not only exhibited superior fruit quality and size, but also demonstrated the potential for higher market demand, which translates into increased profitability for producers. This quality makes them particularly valuable for both domestic and international markets that prioritize premium fruit, thus offering significant commercial opportunities.

It is of paramount importance to integrate local peach genotypes into breeding programs. Local genotypes, being well-adapted to specific regional climatic and soil conditions, have the potential to enhance the resilience of peach production against environmental stresses, such as those posed by climate change. The integration of these local genotypes into breeding efforts can foster more sustainable and efficient peach production practices. Furthermore, the utilization of these local genotypes not only guarantees commercial profitability but also contributes to the preservation of regional genetic diversity. The Black Abdos and Sırrı genotypes, with their adaptability and high yield potential, represent a valuable resource for the development of more resilient and high-quality peach cultivars.

This study highlights the significant commercial and ecological value of local peach genotypes, such as Black Abdos and Sırrı, which offer distinct advantages over standard cultivars. Their incorporation into breeding programs can contribute to more efficient, sustainable and high-quality peach production, which benefiting both local agriculture and broader markets.

Additional Information and Declarations

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Bursa İli Karacabey İlçesine Bağlı Bazı Köylerin Mera Kullanım Alışkanlıkları Üzerine Bir Araştırma

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Öz: Bu araştırmada, Bursa ilinin Karacabey ilçesine ait 15 köyde bölge çiftçisinin mera kullanım alışkanlıklarının belirlenmesi amaçlanmıştır. Bu amaçla 2024 yılında Karacabey ilçesinde yer alan ve en fazla mera varlığına sahip olan 15 köyde (Akçakoyun, Canbaz, Dağkadı, Danişment, Eskikarağaç, Gönü, Harmanlı, İnkaya, Karakoca, Muratlı, Subaşı, Sultaniye, Tophisar, Yenikaraağaç ve Yolağzı) toplam 225 katılımcı ile bir anket çalışması yapılmıştır. Araştırma sonuçlarına göre; ankete katılan çiftçilerin %58.3'ü Mera Kanunu hakkında bilgi sahibi olmakla birlikte genellikle otlatma planının uygulanması konusunda eksikliklerin olduğu ortaya çıkmıştır. Ayrıca, çiftçilerin kış döneminde hayvanlarını ahırda beslenmelerine karşın mera bitkileri açısından kritik dönemler olarak adlandırılan zamanlarda hayvanların çoğunlukla merada otlattıkları belirlenmiştir. Sonuç olarak, meraların amenajman ilkelerine uygun kullanılabilmesi için otlatma mevsiminin dikkate alınması, erken ilkbahar, yaz ve geç sonbahar gibi kritik dönemlerde otlatmaların yapılmaması son derece önemlidir. Bu nedenle bölge üreticilerine bu konularda bilgiler verilerek meraların daha etkin kullanılması sağlanabilir.

Anahtar Kelimeler: Bursa, hayvancılık, Karacabey ilçesi, mera, otlatma planı

A Study on Rangeland Utilization Habits of Some Villages in Karacabey District of Bursa Province

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Abstract: This study aimed to determine the rangeland utilization habits of the farmers in 15 villages of the Karacabey district of Bursa province. For this purpose, a survey was carried out with a total of 225 participants in 15 villages (Akçakoyun, Canbaz, Dağkadı, Danişment, Eskikarağaç, Gönü, Harmanlı, İnkaya, Karakoca, Muratlı, Subaşı, Sultaniye, Tophisar, Yenikaraağaç and Yolağzı), which have the highest number of rangelands in Karacabey district in 2024. According to the survey results, 52.9% of the farmers who participated in the survey know about the rangeland law, but it was revealed that there are generally deficiencies in the implementation of the grazing plan. In addition, it was determined that although the farmers feed their animals in the barn during the winter period. They mostly graze their animals in the rangeland during the critical periods for rangeland plants. In conclusion, to use the rangelands by the management principles, it is very important to consider the grazing season and not to graze in critical periods such as early spring, summer and late autumn. For this reason, more effective use of rangelands can be ensured by providing information on these issues to the producers in the region.

Keywords: Animal husbandry, Bursa, grazing plan, Karacabey district, rangeland

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Giriş

Karacabey ilçesi, Marmara Bölgesinin güneyinde, Bursa iline bağlı bir ilçe olup 40. kuzey paralelinin 25 km kuzeyinde ve 28. doğu meridyeninin 20 km doğusunda yer almaktadır. İlçenin Bursa iline uzaklığı 62 km, yüzölçümü ise 1247 km² olup ilçede toplam 83 mahalle bulunmaktadır. (Anonim, 2023). İlçenin ortalama rakımı 24 m'dir. Karacabey ilçesi, tarım alanı ve çayır-mera varlığı bakımından Bursa'daki ilçeler içerisinde birinci sırada yer almaktadır. İlçede nüfusun büyük bir bölümü tarımla uğraşmakta ve ilçe ekonomisinde tarım ön planda yer almaktadır (Anonim, 2023). İlçede yer alan toplam çiftçi sayısı 4069 adet olmakla birlikte olup çiftçi kayıt sistemine (ÇKS) kayıtlı çiftçi sayısı 3152 adet, ilçenin toplam büyükbaş hayvan varlığı 54 639 adet, küçükbaş hayvan varlığı ise 147 766 adettir (Anonim, 2023; TÜRKVET, 2023).

Yeterli ve dengeli beslenme ile ilgili sorunlarımız temel olarak hayvancılığımız ve hayvansal ürün üretimimize ilişkin sorunlardan kaynaklanmaktadır (Demiroğlu & Özkan, 2017). Ülkemizde hayvan beslenmesi büyük ölçüde doğal çayır-meralara, bitki artıkları ve anızlar ile saman gibi düşük kaliteli yemlere bağlı olarak yapılmaktadır. Oysa yem bitkileri tarımı, yem temin etmenin en etkin ve ekonomik yoludur. Karacabey ilçesinde yem bitkileri ekim alanı 2022 yılı verilerine göre 519 283 da olup yem bitkileri ekiminde silajlık mısır, italyan çimi, fiğ ve yonca ilk sıralarda yer almaktadır (TÜİK, 2022). Karacabey'de 2022 yılı verilerine göre; toplam tarım alanı 616 279 da, toplam çayır-mera varlığı ise 79 056 da'dır (Anonim, 2022).

Bu araştırma ile Bursa İli Karacabey ilçesinde 2024 yılında 15 köyde, 225 katılımcı üzerinde yapılan anket çalışması sonucu, bölge çiftçisinin mera kullanım alışkanlıklarının belirlenmesi amaçlanmıştır.

Materyal ve Yöntem

Araştırma materyalini Bursa ilinin Karacabey ilçesine bağlı 15 farklı köyde (Akçakoyun, Canbaz, Dağkadı, Danişment, Eskikarağaç, Gönü, Harmanlı, İnkaya, Karakoca, Muratlı, Subaşı, Sultaniye, Tophisar, Yenikaraağaç ve Yolağzı) yaşayan toplam 225 adet çiftçi oluşturmaktadır. Her köyde 15 üretici ile anket çalışması yapılmıştır. Ankete katılan çiftçilerin yaş aralığı 18-81 arasında değişim göstermiştir. Anket formu mera kullanıcısına ait genel özellikler ve mera ile ilgili özellikler olmak üzere 2 kısımdan oluşmaktadır. Formda mera kullanıcısına ait özellikler ve mera ile ilgili özellikleri belirlemek amacıyla da toplam 34 adet soruya yer verilmiştir. Toplam 34 adet sorudan oluşan anket formu Çizelge 1.'de verilmiştir. Anket çalışması için Bursa Uludağ Üniversitesi Araştırma ve Yayın Etik Kurullarından (Fen ve Mühendislik Bilimleri Araştırma ve Yayın Etik Kurulu) etik onay belgesi (27 Mayıs 2024/2024-05) alınmıştır.

Çizelge 1. Anket formu
Table 1. Survey form

A. Mera Kullanıcısına Ait Genel Özellikler	B. Mera ile İlgili Özellikler
1. Yaş:	1. Hangi tip mera alanına sahipsiniz? a. Doğal mera b. Yapay mera c. Her ikisi de mevcut
2. Eğitim durumunuz nedir? a. Okula Gitmemiş b. İlk c. Orta d. Lise e. Üniversite	2. Merada hangi tür hayvan otlatıyorsunuz? a. Büyükbaş b. Küçükbaş c. Her ikisi
3. Çiftçilik mesleği dışında gelir getiren başka hangi işle uğraşıyorsunuz? a. Cevapsız b. İşçi c. Memur d. Esnaf e. Emekli	3. Erken ilkbahar döneminde hayvanlarınızı nerede besliyorsunuz? a. Ahırda b. Merada c. Çayır ve ekili olmayan tarla alanları
4. Kaç yıldır hayvancılıkla uğraşıyorsunuz? a. 2–3 b. 5–10 c. 10–15 d. Uzun zamandır	4. Kış döneminde hayvanlarınızı nerede besliyorsunuz? a. Ahırda b. Merada c. Çayır ve ekili olmayan tarla alanları
5. Büyükbaş hayvanınız var mı? Evet ( ) Hayır ( )	5. Yaz döneminde hayvanlarınızı nerede besliyorsunuz? a. Ahırda b. Merada c. Çayır ve ekili olmayan tarla alanları

6. 'Evet' ise kaç adet? a. 10'dan az b. 10-20 adet c. 20-30 adet d. 30'dan fazla	6. Geç sonbahar döneminde hayvanlarınızı nerede besliyorsunuz? a. Ahırda b. Merada c. Çayır ve ekili olmayan tarla alanları
7. Küçükbaş hayvanınız var mı? Evet ( ) Hayır ( )	7. Hayvanlar merada otlamaya ne zaman başlıyor? a. 15-30 Ocak b. 01-15 Şubat c. 15-28 Şubat d. 1-15 Mart e. 15-30 Mart f. 01-15 Nisan
8. 'Evet' ise kaç adet? a. 20'den az b. 20-30 adet c.30-40 adet d. 40'dan fazla	8. Merada otlatmayı yılın hangi ayında bitiriyorsunuz? a. 1-15 Kasım b. 15-30 Kasım c. 1-15 Aralık d. 15-30 Aralık e. 1-15 Ocak
9. Hayvanlar kayıtlı mı? a. Evet b. Hayır	9. Köyünüzde mera yönetim birliği var mı? a. Evet b. Hayır c. Bilmiyorum
10. Devletten yem bitkileri desteği alıyor musunuz? a. Evet b. Hayır	10. Her yıl düzenli olarak otlatma bedelleri toplanıyor mu? a. Evet b. Hayır
11. Hayvan beslemede saman kullanıyor musunuz? a. Evet b. Hayır	11. Tarım teşkilatı (tarım il veya ilçe müdürlükleri) teknik elemanlarınca size verilen otlatma planını uyguluyor musunuz? a. Evet b. Böyle bir planı duymadım c. Tam olarak değil d. Hayır
12. Tarım teşkilatı (tarım il veya ilçe müdürlükleri) teknik elemanları ile görüşme sıklığınız nedir? a. Her gün b. Haftada bir c. Ayda bir d. Yılda bir e. Hiç	12. Bölgenizdeki meraları özel mülk gibi kullanılarak (bina-ahır-ağıl-tarla vb. gibi) tecavüz edildiği oluyor mu? a. Tecavüz var b. Tecavüz yok
13. Tarım teşkilatındaki teknik elemanların çözüm önerilerinden memnun kaldınız mı? a. Her zaman b. Çoğunlukla c. Bazen d. Hiç	13. Bugüne kadar mera alanlarında bakım ve ıslah çalışması yapıldı mı? a. Yapıldı b. Yapılmadı c. Yarım kaldı d. Şuan yapılıyor
14. 4342 sayılı "Mera Kanunu ve Mera Yönetmeliğine" ilişkin bir bilginiz var mı? a. Var b. Yok	14. Mera alanlarında ot verimini ve kalitesini artırmak için ne gibi çalışmalar yapılıyor? a. Gübreleme b. Düzenli otlatma c. Dinlenmeye bırakma d. Yapılmadı
	15. Mera alanlarında hangi tip gübre kullanılıyor? a. Ahır gübresi b. Kimyasal gübre c. Gübreleme yapmıyor
	16. Otlatmayı nasıl yapıyorsunuz? a. Yarı açık sistem b. Aylara göre c. Hava şartları uygunsa her gün
	17. Hastalık durumunda merada ne yapıyorsunuz? a. Kendim müdahale ederim b. Veteriner çağırırım
	18. Köpeğiniz var mı? a. Evet b. Hayır
	19.Köpeğinizi hangi amaçla kullanıyorsunuz? a. Koruma b. Sürü kontrolü c. Zevk için d. Koruma-sürü kontrolü e. Koruma-zevk f. Sürü kontrolü-zevk g. Koruma-sürü kontrolü-zevk
	20. Hayvanlara neden çan (zil) takıyorsunuz? a. Konum bilgisi b. Sürü birliği c. Konum bilgisi-Sürü birliği

Bulgular ve Tartışma

2024 yılında yapılan bu anket çalışmasında çiftçilere yöneltilen sorular iki başlık altında değerlendirilmiştir.

Mera Kullanıcısına Ait Genel Özellikler

Karacabey ilçesine ait 15 köyde yapılan anket çalışması sonucunda ankete katılan çiftçilerin %50.2'lik kısmı ilköğretim seviyesinde öğrenim görmüş olmasına karşın orta öğretim ve lise seviyesinde öğrenim görenlerin oranı yaklaşık %47'dir. Ankete katılan çiftçilerin yaş aralığı 18-81 arasında değişim göstermiş ve genellikle 51-60 yaş aralığının oranı %35.9 olmuştur. 18-30 yaş arası gençlerin hayvancılıkla uğraşma oranı (%6.3) oldukça düşüktür (Çizelge 2). Anket için köylere farklı dönemlerde gidilmiş ve genellikle köy içerisinde gençlerin oranının daha az olduğu gözlenmiştir. Bu durum gençlerin köyden ve hayvancılıktan uzaklaşarak başka alanlara yöneldiklerini göstermektedir. Hayvancılıkla uğraşan çiftçilerin %58.4'ü 15 yıldan daha uzun bir süredir hayvancılıkla uğraşmaktadır. Hayvancılık ile uğraşmaya yeni başlayanların (2-3 yıl) oranı ise sadece %9'dur. Ayrıca, çiftçilerin büyük bir kısmı (%43.1) çiftçilik mesleğinin dışında emekli olup ankete katılanların sadece %0.9'u memur, %8'si ise ticaretle uğraşmaktadır (Çizelge 2). Karacabey ilçesinde anket yapılan 15 köyde 2023 yılı verilerine göre; toplam 9260 adet büyükbaş, 42 947 adet küçükbaş bulunmaktadır. En fazla büyükbaş-küçükbaş varlığı (6620 adet) Canbaz köyünde, en az ise 587 adet ile İnkaya köyünde yer almaktadır (TÜRKVET, 2023). Ankete katılan çiftçilerin %41.3'ü büyükbaş yetiştiriciliği, %77.9'u ise küçükbaş yetiştiriciliği yapmaktadır. Büyükbaş yetiştiriciliğinde %58.7'sinin 10 adetten daha az büyükbaşa sahip olduğu ve genellikle 31 adetten daha fazla büyükbaşa sahip olanların ise sadece %5.4 olduğu tespit edilmiştir. Küçükbaş yetiştiriciliğinde ise ankete katılanları sadece %22.1 küçükbaş yetiştiriciliği yapmamaktadır. Küçükbaş yetiştiriciliği yapanların ise %52.6'sinda 20 adetten az küçükbaş bulunurken 40 adetten fazla küçükbaşa sahip olanların oranı ise %25.7 olmuştur (Çizelge 2). Ankete katılan çiftçilerin koyun yetiştiriciliğinin yanı sıra değişen oranlarda büyükbaş yetiştiriciliği de yaptıkları gözlenmiştir. Karacabey ilçesinde yer alan çiftçilerin 2019 yılı verilerine göre %77.46'sı ÇKS'ne kayıtlıdır (Anonim, 2023). Yapılan anket sonuçlarına göre çiftçilerin yaklaşık yarısı yem bitkileri desteğinden aldığını bildirmişlerdir (Çizelge 2).

Çizelge 2. Anket çalışması yapılan mera kullanıcılarına ait genel özellikler
Table 2. General characteristics of the rangeland users surveyed

Özellik	
Eğitim durumu	Okula gitmemiş: %1.3, İlköğretim: %50.2, Ortaöğretim: %17.8, Lise: %28.9, Üniversite: %1.8
Yaş aralığı	18-30 arası: %6.3, 31-40 arası: %7.2, 41-50 arası: %26.5, 51-60 arası: %35.9, 61 ve üzeri: %24.2
Hayvancılıkla uğraşma süreleri	2-3 yıl: %9.0, 5-10 yıl: %15.8, 10-15 yıl: %16.7, Uzun zamandır: %58.4
Çiftçilik mesleği dışında gelir getiren iş	Cevapsız: %31.1, İşçi: %16.9, Memur: %0.9, Esnaf: %8.0, Emekli: %43.1
Büyükbaş hayvan varlığı	Var: %41.3, Yok: %58.7
Büyükbaş hayvan sayısı	10 adetten az: %58.7, 10-20 adet: %21.7, 21-30 adet: %14.1, 31 adetten fazla: %5.4
Küçükbaş hayvan varlığı	Var: %77.9, Yok: %22.1
Küçükbaş hayvan sayısı	20 adetten az: %52.6, 21-30 adet: %8.2, 31-40 adet: %13.5, 40 adetten fazla: %25.7
Büyük ve küçükbaşların kayıt durumu	Kayıtlı: %70.7, Kayıtsız: %29.3
Yem bitkileri desteği	Alıyorum: %56.2, Almıyorum: %43.8
Hayvan beslemede saman kullanım durumu	Kullanıyorum: %93.5, Kullanmıyorum: %6.5
Tarım teşkilatı teknik elemanları ile görüşme sıklığı	Her gün: %0.4, Haftada bir: %0.4, Ayda bir: %16.1, Yılda bir: %47.5, Hiç: %35.4
Tarım teşkilatı teknik elemanlarından memnuniyet durumu	Bazen: %43.8, Her zaman: % 4.5, Çoğunlukla: %12.1, Hiç: %39.7
4342 sayılı "Mera Kanunu ve Mera Yönetmeliği hakkında bilgi durumu	Var: %58.3, Yok: %41.7

Samanlar hayvan beslemede genellikle; kaba yem açığının kapatılmasının yanı sıra özellikle su içeriği yüksek olan yemlerin silolanmasında katkı maddesi olarak, yüksek oranda lignin ve selüloz içeriğinden dolayı hayvana tokluk hissi vermesi ve ergin ruminantlarda, kuru dönemdeki ineklerde ve atların beslenmesinde yaşama payı düzeyinde kaba yem kaynağı amacıyla kullanılmaktadır (Gürsoy, 2023). Ankete katılan çiftçilerin %93.5'i hayvan beslemede saman kullandığını belirtmişlerdir. Ankete katılan çiftçilerin %47.5'i yılda bir kez, %16.1'i ayda bir, %0.4 haftada bir tarım teşkilatı teknik elemanları ile görüşmekte olup genellikle yapılan görüşmelerden memnun olmaktadırlar (Çizelge 2).Ankete katılan çiftçilerin Mera Kanunu hakkında bilgi sahibi olup olmadıklarını belirlemek amacıyla katılımcılara "4342 sayılı Mera Kanunu ve Mera Yönetmeliğine ilişkin bir bilginiz var mı?" sorusu sorulmuş ve katılımcıların %58.3'ü bu konuda bilgi sahibi olduklarını gerek yetkililer tarafından anlatıldığını gerekse yönetmeliği okuduklarını belirtmişlerdir.

Mera ile İlgili Özellikler

Karacabey ilçesinde yer alan 15 köye ait toplam mera varlığı 38170 da olup köyler içerisinde en büyük mera alanı 4758 da olup İnkaya köyünde bulunmaktadır (Anonim, 2024). Ankete katılan çiftçilerin %93.2'si doğal meraya sahip olduklarını, %6.8'i ise doğal meranın yanı sıra yapay meralarının da olduğunu belirtmişlerdir (Çizelge 3). Ankete katılan çiftçilerin merada genellikle karışık otlatma yaptıkları gözlenmiştir. Zira anket sonucunda katılımcıların %4.4'ü büyükbaş, %22'si küçükbaş, %73.7'si ise büyükbaş-küçükbaşların merada otlatıldığını bildirmişlerdir. "Erken ilkbahar, kış, yaz ve geç sonbahar dönemlerinde hayvanlarınızı nerede besliyorsunuz ?" sorusuna verilen yanıtlar incelendiğinde; erken ilkbahar döneminde çiftçilerin %47.0'si merada, kış döneminde %94 ahırda, yaz döneminde %53.2'si merada ve geç sonbahar döneminde ise %43.8'i ahırda ve %35.9'u merada hayvan beslediklerini bildirmişlerdir (Çizelge 3). Elde edilen sonuçlar çiftçilerin meralar açısından önemli olan ilkbahar, yaz ve sonbahar kritik dönemlerini çok fazla dikkate almadıklarını göstermektedir. Ülkemiz meraları için en uygun otlatma mevsimi, ilkbahar duyarlı döneminin sonu ile sonbahar duyarlı döneminin başı arasında kalan süredir (Altın ve ark., 2011). Bu açıdan ele alınan 15 köye ait meralardaki otlatmaya başlama tarihleri incelendiğinde; katılımcıların büyük çoğunluğunun (%71.2) otlamaya 15 Mart-15 Nisan tarihleri arasında başladığı, ancak daha az oranlarda da olmakla birlikte otlatmanın 15 Ocak-15 Mart tarihleri arasında da başlatıldığı tespit edilmiştir. Çiftçilerin %34.6'sı otlatmaya 1-15 Kasım tarihleri arasında son verdiklerini belirtirmiş, buna karşılık verilen cevaplar değerlendirildiğinde otlamanın 15 Ocak tarihine kadar da devam edildiği tespit edilmiştir (Çizelge 3). Bitkilerin yeterli yedek besin madde biriktirebilmeleri için otlatmaya belirli bir dönemde son vermek son derece önemlidir. Genellikle sonbaharda toprak yüzeyinde ilk hafif donların görülmesi ile birlikte otlatmaya son verilmelidir (Altın ve ark., 2011). Ancak yapılan anket çalışmasında hem otlatmaya başlama hem de bitirmede çiftçilerin büyük bir bölümünün bu gerçeğe uygun olarak otlatma yapmadıkları ortaya çıkmıştır.

Çizelge 3. Meraların kullanım durumlarına ait özellikler
Table 3. Characteristics of the utilization status of rangelands

Özellik	
Mera tipi	Doğal mera: %93.2, Doğal-yapay mera: %6.8
Otlatılan hayvan türü	Büyükbaş: %4.4, Küçükbaş: %22, Her ikisi: %73.7
Erken ilkbahar döneminde hayvanların beslendiği yer	Ahırda: %23.0, Merada: %47.0, Çayır ve ekili olmayan tarla alanları: %4.6, Ahırda-Merada: %6.9, Ahırda- Çayır ve ekili olmayan tarla alanları: %0.9, Merada-Çayır ve ekili olmayan tarla alanları: %17.5
Kış döneminde hayvanların beslendiği yer	Ahırda: %94.0, Merada: %3.2, Çayır ve ekili olmayan tarla alanları: %0.0 Ahırda-Merada: %1.8, Ahırda- Çayır ve ekili olmayan tarla alanları: %0.9
Yaz döneminde hayvanların beslendiği yer	Ahırda: %16.7, Merada: %53.2, Çayır ve ekili olmayan tarla alanları: %6.4 Ahırda-merada: %5.9, Ahırda- Çayır ve ekili olmayan tarla alanları: %1.5, Merada-Çayır ve ekili olmayan tarla alanları: %15.3, Ahırda-Merada- Çayır ve ekili olmayan tarla alanları: %1.0
Geç sonbahar döneminde hayvanların beslendiği yer	Ahırda: %43.8, Merada: %35.9, Çayır ve ekili olmayan tarla alanları: %2.8 Ahırda-merada: %8.3, Merada-Çayır ve ekili olmayan tarla alanları: %8.3, Ahırda-Merada-Çayır ve ekili olmayan tarla alanları: %0.9
Merada otlatmaya başlama zamanı	15-30 Ocak: %9.9, 01-15 Şubat: %2.6, 15-28 Şubat: %0.5, 1-15 Mart: %15.7, 15-30 Mart: %31.9, 01-15 Nisan: %39.3
Merada otlatmayı bitirme zamanı	1-15 Kasım: %34.6, 15-30 Kasım: %23.6, 1-15 Aralık: %7.9, 15-30 Aralık: %16.8, 1-15 Ocak: %17.3
Mera yönetim birliği hakkında bilgi durumu	Evet: %52.0, Hayır: %26.2, Bilmiyorum: %21.8
Otlatma bedelini toplanma durumu	Evet: %2.3, Hayır: %97.7
Otlatma planının uygulanma durumu	Uygulanıyor: %4.9, Otlatma planını duymadım: %39.0, Tam olarak değil: %30.5, Uygulanmıyor: %25.6
Meraların özel mülk gibi kullanıma durumu	Tecavüz var: %43.8, Tecavüz yok: %56.3
Meralarda ıslah çalışmalarının yapılma durumu	Yapıldı: %5.8, Yapılmadı: %91.5, Yarım kaldı: %1.3, Şu an yapılıyor: %1.3
Otlatma durumu	Yarı açık sistem: %10.3, Aylara göre: %24.1, Hava şartları uygunsa her gün: %65.5
Hastalıklara müdahale	Kendim müdahale ederim: %62.1, Veteriner çağırırım: %37.9
Köpek kullanım durumu	Var: %87.4, Yok: %12.6
Köpek kullanım amacı	Koruma: %47.0, Sürü kontrolü: %17.2, Zevk için: %15.7, Koruma-sürü kontrolü: %16.7, Koruma-zevk: %2.0, Sürü kontrolü-zevk: %0.5, Koruma-sürü kontrolü-zevk: %1.0
Çan kullanım durumu	Konum bilgisi: %20.8, sürü birliği: %26.1, Konum bilgisi-sürü birliği: % 53.1

Köylerde mera yönetim birliklerinin kurulması özellikle meralardan daha iyi faydalanılmasını sağlamaktadır (Demiray, 2013). Bu çalışmada anket yapılan 15 köyden sadece 5 köyde (Akçakoyun, Dağkadı, Yolağzı, Gönü ve Harmanlı) mera yönetim birliği bulunmaktadır. Anket çalışması kapsamında değerlendirilen köylerde ankete katılan çiftçilerin %52'si köyde mera yönetim birliğinin bulunduğunu, %26.2'si ise bulunmadığını bildirmiştir. Ayrıca, ankete katılanların %21.8'i köyde mera yönetim birliğinin olup olmadığı konusunda bilgi sahibi değildir (Çizelge 3). Otlatma bedellerinin aktif olarak toplanıp toplanmadığını belirlemek amacıyla sorulan soruya ankete katılan çiftçilerin büyük çoğunluğu (%97.32) otlatma bedellerinin toplanmadığını bildirmişlerdir (Çizelge 3). Ankete katılan çiftçilerin %39.3'ü otlamaya 1-15 Nisan tarihleri arasında başladıklarını, %34.6'sı ise otlatmayı 1-15 Kasım tarihleri arasında sonlandırdıklarını belirtmelerine karşın "Tarım teşkilatı (tarım il veya ilçe müdürlükleri) teknik elemanlarınca size verilen otlatma planını uyguluyor musunuz?" sorusuna sadece %4.9 oranında olumlu cevap verilmiştir (Çizelge 3). Bu durum aslında çiftçilerin meranın sağlıklı bir şekilde gelişmesi, bol ve kaliteli bir ot üretebilmesi açısından otlamaya başlama ve son verme tarihlerinin önemli olduğunu bildiklerini ancak uygulama konusunda yeterli girişimin olmadığını göstermektedir. Anket çalışmasında, çiftçilerin %56.3'ü meralara tecavüz olmadığını, fakat meraların zamansız ve ağır kullanıldığını belirtirken, çiftçilerin %43.8'i hayvancılık ile uğraşanların mera üzerinde belirli kısımları çevirerek hayvancılık yaptıklarını, çevrilen kısımlarda hayvanların yaz-kış kullanılabilecekleri barınakların yapıldığını bildirmişlerdir. 15 köyde toplam 225 çiftçinin katılımıyla yapılan anket sonucunda, köylerin büyük çoğunluğunda (%91.5) ıslah ve bakım işlerinin yapılmadığı anlaşılmıştır. Otlatmanın doğru zamanda yapılması meraların devamlılığı verim artışı açısından son derece önemlidir (Alatürk ve ark., 2018). Bu anket çalışmasında, çiftçilerin sadece %10.3'ünün meraları kullanmayarak yarı açık sistem ile hayvan yetiştiriciliği yaptıkları görülmüştür. Çiftçilerin büyük çoğunluğu (%65.5) ise hava şartlarının uygun olması durumunda hayvanları her gün meraya çıkartmaktadır (Çizelge 3). Ankete katılan çiftçilerim %62.1'i hayvan hastalıklarına müdahale edebildiğini, %37.9'u ise veteriner desteği aldığını bildirmiştir. Merada otlatma sırasında doğumlarda ise genellikle çobanın müdahale ettiğini belirtmişlerdir. Hayvancılıkta çoban köpeği hem koruma hem de sürüyü yönetme amacıyla kullanılmaktadır (Alatürk ve ark., 2018). Ankete katılan çiftçilerin büyük çoğunluğunun (%87.4) köpeği bulunmakta ve genel olarak köpekler koruma, sürü kontrolü ve zevk amacıyla yetiştirilmektedir. Çiftçilerin büyük çoğunluğu köpekleri koruma ve sürü kontrolü amacıyla kullanırken sadece %15.7'si sadece zevk amaçlı kullandığını belirtmiştir. Sürü yönetiminde hayvanlara çan takılması son derece önemli bir uygulamadır (Alatürk ve ark., 2018). Bu açıdan ankete katılan çiftçilerin %53.1'i hayvanlara çan takılmasının esas amacının hem konum bilgisi hem de sürü birliği olduğunu, %26.1'i sadece sürü birliği, %20.8'i ise sadece konum bilgisi için çan taktıklarını belirtmişlerdir.

Sonuç

Karacabey ilçesine bağlı köylerde mera kullanımını ve yönetimi konusunda yapılan anket çalışması sonuçlarına göre; çiftçilerin çoğu (%58.4) 15 yıldan daha uzun süredir hayvancılıkla uğraşmaktadır. Büyükbaş yetiştiriciliği yapanların %58.7'si 10'dan, küçükbaş yetiştiriciliği yapanların ise %52.6'sı 20'den az sayıda hayvana sahiptirler. Çiftçilerin büyük çoğunluğunun (%70.7) hayvanları kayıtlı olup yem bitkileri desteğinden yararlananların oranı ise %56.2'dir. Ankete katılan çiftçilerin %58.3'ü 4342 sayılı Mera Kanunu hakkında bilgi sahibidir. Çiftçilerin mera alanlarının kullanımı ile ilgili bir sorun yaşandığında, genellikle bu sorunlarını muhtar, tarım il ve ilçe müdürlükleri, ziraat odaları ve belediye ile paylaştıkları gözlemlenmiştir. Anketin yapıldığı köylerde genellikle mera alanları ile ilgili ıslah çalışmalarının yapılmadığı (%91.5) tespit edilmiştir. Ayrıca, kış döneminde hayvanların büyük çoğunluğunun ahırda beslenmesine karşın mera bitkileri açısından kritik dönemler olarak adlandırılan zamanlarda hayvanların çoğunlukla mera otlatılmaktadır. Ayrıca çiftçilerin çoğunluğu (%65.5) hava şartları uygun olduğunda her gün otlatma yaptıklarını belirtmişlerdir. Sonuç olarak, meraların amenajman ilkelerine uygun kullanılabilmesi için otlatma mevsiminin dikkate alınması, erken ilkbahar, yaz ve geç sonbahar gibi kritik dönemlerde otlatmaların yapılmaması son derece önemlidir. Bu nedenle bölge üreticilerine bu konularda bilgiler verilerek meraların daha etkin kullanılması sağlanmalıdır.

Ek Bilgiler ve Beyanlar

Araştırmacıların Katkı Oranı: Yazarlar makaleye eşit oranda katkı sağlamış olduklarını beyan eder.

Çıkar Çatışması Beyanı: Makale yazarları aralarında herhangi bir çıkar çatışması olmadığını beyan ederler.

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New Approaches in Agriculture and Food Industry: Nanoparticles and their Potential Uses

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Abstract: The aim of this study is to provide a comprehensive review of the innovative solutions offered by nanotechnology in the agriculture and food industry and the potential applications of nanoparticles. Nanotechnological materials, particularly in agriculture, have great potential to enhance the efficiency of pesticide use and enhance food safety. Due to their size and surface properties, nanoparticles allow the implementation of environmentally friendly practices, improve agricultural productivity, and ensure the effective release of agrochemicals. In addition to promoting plant growth and increasing soil fertility, nanoparticles have important antibacterial and antifungal properties in the food industry. These microstructures are used as an effective way of extending the shelf life of food products and preserving their nutritional value. However, the potential environmental and health risks associated with this technology should also be considered. To ensure the safe use of nanoparticles, research in this field must be carefully managed, and new strategies developed in line with sustainability principles. Therefore, given the significant potential of nanoparticles in agriculture and the food industry, research aimed at ensuring their safe and sustainable use needs to be intensified. National and international scientific studies in this area will improve the understanding of the environmental and health impacts of nanoparticles and maximize the effectiveness and safety of innovative applications.

Keywords: Agricultural sustainability, food safety, nanoparticles, nanotechnology

Tarım ve Gıda Sanayinde Yeni Yaklaşımlar: Nanopartiküller ve Potansiyel Kullanımları

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Öz: Bu çalışmanın amacı, tarım ve gıda endüstrisinde nanoteknolojinin sunduğu yenilikçi çözümleri ve nanopartiküllerin potansiyel kullanım alanlarını geniş çaplı ele alarak incelemektir. Nanoteknolojik materyaller, özellikle tarımda daha verimli pestisit uygulamaları ve gıda güvenliği konularında yüksek bir kullanım potansiyeline sahiptir. Nanopartiküller, boyutları ve yüzey özellikleri sayesinde, çevre dostu uygulamaların gerçekleştirilmesini sağlayarak tarımda verimliliği artırmak ve aynı zamanda tarım ilaçlarının etkili bir şekilde salınımını sağlamak için kullanılmaktadır. Nanopartiküller bitki büyümesini teşvik etme ve toprak verimliliğini artırma gibi avantajlarının yanı sıra, gıda endüstrisinde sağlık açısından önemli bir yer tutan antibakteriyel ve antifungal özelliklere sahiplerdir. Bu mikro yapılar, gıda ürünlerinin raf ömrünü uzatmak ve besin değerlerini korumak adına etkili bir yöntem olarak kullanılmaktadır. Ancak, bu teknoloji ile ilgili potansiyel çevresel ve sağlık riskleri de göz önünde bulundurulmalıdır. Nanopartiküllerin güvenli bir şekilde kullanılabilmesi için, bu alanda yapılan araştırmaların dikkatle yönlendirilmesi ve sürdürülebilirlik ilkeleri doğrultusunda yeni stratejiler geliştirilmesi gerekmektedir. Sonuç olarak, nanopartiküllerin tarım ve gıda endüstrilerinde sunduğu büyük potansiyel göz önüne alındığında, bu teknolojinin güvenli ve sürdürülebilir kullanımını sağlamak amacıyla yapılan araştırmaların artırılması gerekmektedir. Bu alandaki ulusal ve uluslararası alanda bilimsel çalışmalar, nanopartiküllerin çevresel ve sağlık üzerindeki etkilerini daha iyi anlayarak, inovatif uygulamaların etkinliğini ve güvenliğini en üst düzeye çıkaracaktır.

Anahtar Kelimeler: Gıda güvenliği, nanopartiküller, nanoteknoloji, tarımsal sürdürülebilirlik

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Introduction

In the context of global challenges, such as population growth, climate change, and resource depletion, sustainable agricultural practices assume paramount importance in ensuring food security and reducing environmental impacts (Amruddin et al., 2024). Agricultural production is confronted with environmental issues, particularly the degradation of soil quality, the depletion of water resources, and the excessive use of chemical fertilizers and pesticides (Adisa et al., 2024). Conventional agricultural methods have demonstrated limited efficacy in addressing these challenges, thereby necessitating the exploration of alternative solutions (Meydan, 2016). Technological innovations hold considerable potential to offer novel solutions to sustainability challenges in this field. Specifically, nanotechnology has emerged as a promising area in the agricultural sector, exhibiting significant potential to enhance environmental sustainability and improve agricultural productivity (Raliya, 2019; Sandhu et al., 2023).

The field of nanotechnology has emerged as a pivotal element in numerous applications, including the enhancement of plant growth, the reduction of pesticide usage, and the augmentation of soil health. This is achieved through the manipulation of materials at the atomic and molecular levels. The unique properties of nanotechnology, such as its high surface area, reactivity, and minute size, facilitate enhanced penetration of nanoparticles into plant root systems, thereby promoting enhanced nutrient absorption and augmented plant resistance to stress conditions (Zhao et al., 2020; Ochoa et al., 2025). In particular, applications employing nanoparticles have the potential to enhance productivity whilst concomitantly reducing environmental impacts. Nanotechnology has also precipitated significant advancements in areas such as pesticide control and fertilizer management, thereby leading to a substantial reduction in the use of chemical fertilizers and pesticides in agriculture, thus contributing to sustainable production practices (Atakan & Özkaya, 2018).

While nanotechnology offers opportunities in agriculture, it also faces several challenges that this new technology faces. Notably, uncertainties still exist regarding the environmental impacts of nanoparticles, their potential harm to ecosystems, and their effects on human health (Rana et al., 2024). Furthermore, the high production costs of nanotechnology-based products present a significant barrier, particularly for small-scale farmers in developing countries (Demirbilek, 2015). Nevertheless, for nanotechnology to be more widely adopted in agriculture, it is crucial to develop safety protocols, better understand the environmental impacts of these technologies, and provide training for farmers (Demir, 2024).

In the domain of food production, the utilization of nanoparticles has emerged as a groundbreaking approach, eclipsing conventional methodologies. This technological advancement has been identified as having considerable promise in domains such as food safety, preservation of nutritional value, and enhancement of sensory attributes (Nile et al., 2020). Nanotechnology has been demonstrated to be a highly effective instrument for enhancing the quality of food products, extending their shelf life, and reducing food wastage (Cushen et al., 2012). The use of nanoparticles has been demonstrated to enhance the bioavailability of food components, improve the effectiveness of additives, and prevent microbial contamination (Sharma et al., 2022).

The utilization of nanoparticles in food science has been shown to enhance the bioavailability of nutrients (Mallesham et al., 2025). The application of nano-carriers, in particular, has been demonstrated to facilitate the absorption of fat-soluble vitamins and minerals (Mallesham et al., 2025). These technologies ensure that dietary supplements are absorbed more efficiently by the body, while also allowing for the preservation of nutritional values. Notably, lipid nanoparticles have been shown to facilitate the delivery of vitamins and minerals to the body with greater efficiency (Afzia & Ghosh, 2025).

Another significant application of nanoparticles in the food industry pertains to active packaging systems, where nano-coating technologies are employed to protect the surfaces of food products. These technologies create barriers against moisture, oxygen, and microorganisms, thereby contributing to the maintenance of product freshness (Prasad et al., 2024). The implementation of these smart packaging solutions has been demonstrated to enhance food safety, with the capacity to prevent foodborne illnesses by inhibiting microbial growth (Devipriya et al., 2023). Furthermore, the integration of nano-sensors within packaging materials facilitates the continuous monitoring of product freshness, thereby ensuring the provision of pertinent information to consumers (Raghavan, 2017).

In the context of food additives, the role of nanoparticles is of particular significance. The use of nano-carriers facilitates the regulated release of food preservatives, antioxidants, and other additives, thereby contributing to the prolongation of food product shelf life and the maintenance of product quality (Haris et al., 2023). This development signifies a substantial innovation within the domain of food safety, with the potential to reduce food waste. From a food safety perspective, nanoparticles are used for detecting and disinfecting pathogens microorganisms. The inhibition of microbial growth by nanomaterials has been demonstrated to enhance food hygiene and thereby reduce health risks (Chadha et al., 2022). The antibacterial properties of nanoparticles offer a significant advantage, particularly in food processing and storage. This study aims to explore the potential of nanotechnology in promoting sustainability within the agricultural and food industries. To enhance our comprehension of nanotechnology's contributions to enhancing productivity, reducing environmental impacts, and improving food safety, it is imperative to augment both national and international research in these areas.

Applications of Nanotechnology in Agriculture

Nanotechnology is a field of science that involves the design, production, and application of materials at the atomic and molecular level (Ormanoğlu et al., 2021). This technology has significant potential, particularly in sectors such as agriculture, where natural resources are limited and environmental pressures are high (Yonat & Kolören, 2022). Nanotechnology can enhance the properties of materials used in agriculture, improving plant health, increasing yields and productivity per unit area, and reducing environmental impact (Demirel, 2020). Additionally, this technology promotes efficient use of water and soil, offering innovative, micro-level solutions for sustainable agriculture. (Gökdemir et al., 2023).

Nanofertilizers and Plant Nutrition

Nanotechnology plays a crucial role in providing plant nutrition and optimizing the usage of fertilizers in agriculture. Conventional fertilizers dissolve quickly after being applied to the soil, and only a limited amount of nutrients are absorbed by plants (Dağhan, 2017). This leads to environmental pollution and loss of productivity over time. However, nanofertilizers have the potential to solve these problems by delivering nutrients to plants more efficiently (Demirci, 2023). Nanofertilizers produced using nanotechnology can reach plant root systems faster and more effectively. Nanoparticles slow down the dissolution process in the soil, allowing nutrients to remain in the soil for longer, allowing plants to absorb nutrients more efficiently (Ranjan et al., 2021). In addition, these fertilizers help to minimize the loss of essential nutrients such as nitrogen and phosphorus (Sedef, 2018).

Another advantage of nanofertilizers is their ability to increase agricultural productivity without harming the environment. Excessive use of traditional fertilizers can lead to contamination of water resources and excessive accumulation in the soil. In contrast, nano-enriched fertilizers deliver nutrients to plants with minimal environmental impact and without damaging soil structure. This contributes to improving the sustainability of agriculture while promoting environmentally friendly practices (Şahin, 2017). In addition, nano-fertilizers can be equipped with systems that control the rate at which nutrients are delivered to the soil and plants. As a result, plants receive the nutrients they need on a regular basis, improving crop health and quality (Dağhan, 2017).

Water Management and Irrigation Technologies

Nanotechnology includes various applications that ensure the efficient use of water resources (Kuhn et al., 2022). Water is one of the most important resources for agriculture, so its efficient management is crucial. Water filtration systems developed through nanotechnology help to ensure that water used for irrigation is cleaner, thereby contributing to more sustainable agricultural practices (Amdeha, 2021). By using nanofilters, contaminants in irrigation water can be effectively removed, protecting plants from harmful substances and allowing them to grow and develop in a healthy manner (Saleem & Zaidi, 2020). Nanotechnology also helps irrigation water penetrate the soil more effectively. Nanoparticles optimize the distribution of water in the soil, reducing evaporation and promoting water conservation (Spanos et al., 2021).

Agricultural Monitoring with Biosensors

One of the most significant benefits of nanotechnology in agriculture is the development of biosensors (Kirsch, 2013). These sensors continuously monitor plant health and can detect disease or pest problems at an early stage. Nanobiosensors identify microorganisms and plant diseases in their early stages, preventing the spread of diseases and providing quick solutions for affected plants (Ghanbari et al., 2024). The sensing technologies provided by nanotechnology help to reduce the unnecessary use of pesticides while effectively maintaining plant health. In addition, these sensors monitor soil conditions and environmental variables, helping growers make more informed decisions (Nikolelis & Nikoleli, 2018). Nanotechnological biosensors can increase agricultural productivity and minimize the use of chemicals for pest control (Upadhyyay et al., 2024).

Pest Control with Nanomaterials

In agriculture, traditional pest control methods often require chemical pesticides, which can harm the environment and lead to imbalances in agricultural ecosystems (An et al., 2022). Nanotechnology offers effective alternatives to overcome this problem. Nanoparticles can target pests and have properties that can harm them (Cao & Wang, 2022). In addition, nanoparticles can attach to the bodies of harmful organisms and disrupt their biological functions, thereby reducing the need for pesticides. As this method is environmentally friendly, it helps to protect ecosystems (Jiang et al., 2024).

Quality Control in Agricultural Products with Nanotechnology

Nanotechnology is also used to improve the quality control of agricultural products (Mohammad et al., 2022). Nanoparticles can detect harmful pathogens on food products and prevent contamination (Samal, 2017). Antimicrobial nanoparticles prevent spoilage and ensure that food stays fresh for longer (Thiruvengadam et al., 2018). These innovative applications help reduce food waste and contribute to safer food supply chains. In addition, nanoparticles can be incorporated into the packaging of agricultural products, ensuring freshness while using environmentally friendly packaging materials (Sekhon, 2010).

Management and Recycling of Agricultural Waste with Nanotechnology

Agricultural production generates a large amount of waste, the efficient management of which is critical for environmental sustainability (Chandrika et al., 2018). Nanotechnology offers significant solutions for the recycling and management of agricultural waste (Pramanik et al., 2020). Nanoparticles can accelerate the biological degradation of agricultural waste and can be used to convert this waste into organic fertilizer. Similarly, nanoparticles play an effective role in wastewater treatment, making it suitable for reuse in irrigation, thereby contributing to water conservation (Giri et al., 2023).

Nanotechnology systems also offer significant opportunities for the reuse of organic waste. Nanoparticles accelerate the biological degradation of pesticides used in agriculture, preventing these harmful chemicals from contaminating the environment (Jha et al., 2011).

Compared to traditional methods of processing agricultural waste, nanotechnology offers much more efficient and effective properties. In particular, nanoparticles can act as carriers for enzymes or microorganisms that biodegrade organic waste at a faster rate (Ouda et al., 2023). By accelerating the degradation process, nanoparticles increase the biological degradation rates. Nanotechnological solutions are also being used to convert agricultural waste into energy. In the processing of biomass for biofuel production, nanoparticles improve the fuel production process, promoting the production of renewable energy. Nanotechnology increases the efficiency of the organic waste recycling process and reduces its environmental impact (Chellasamy et al., 2022).

The recycling of agricultural waste is not limited to biological processes; nanotechnology also plays an important role in the recycling of inorganic waste. Pesticides, chemicals, and other substances used in agriculture can contaminate soil and water sources. Nanomaterials can facilitate the safe handling of these chemicals (Corsi et al., 2023). Nanofilters and nanoparticles can effectively remove pollutants from water and soil, minimizing the environmental damage caused by agricultural waste. This application not only improves the sustainability of agricultural production but also helps to prevent environmental pollution (Goh et al., 2022).

Nanotechnology solutions can also enable the conversion of agricultural waste into valuable products. Organic agricultural waste can be transformed into biological fertilizer using nanotechnological methods. These fertilizers improve the nutrient content of the soil, resulting in healthier plants, while reducing the use of chemical fertilizers. Nanomaterials speed up such conversion processes, allowing waste to be recycled quickly. In addition, the agricultural waste recycling reduces the need for resources in agricultural production, thereby increasing sustainability (Mustapha et al., 2024).

Reducing the Impact of Microplastics in Agriculture through Nanotechnology

Reducing the impact of microplastics in agriculture through nanotechnology. In recent years, microplastics have become a major concern due to their environmental pollution and harmful effects on ecosystems. The degradation of plastic materials used in agriculture, such as plastic sheeting, packaging, and agricultural tools, leads to the leaching of microplastics into soil, water, and the food chain (Sekar et al., 2024). The accumulation of microplastics in agricultural areas can disrupt the physical structure of the soil, reduce water quality, and adversely affect plant health. Nanotechnology has an important role to play in addressing this problem. Nanotechnological solutions are being used to limit the harmful effects of microplastics, prevent their accumulation in soil, and promote their biodegradation (Sharma et al., 2024).

One of the key contributions of nanotechnology in the fight against microplastics is the ability of nanoparticles to effectively remove these pollutants. In particular, nanoparticles can be used to prevent the accumulation of microplastics in soil and to remove them without harming the environment. Nanomaterials can adhere to the surfaces of microplastics, making it easier to collect and bind them. As a result, microplastics can be removed from environments such as soil and water before they accumulate (Das et al., 2024).

Recent studies on this topic have demonstrated the efficacy of magnetic nanoparticles in the collection of microplastics. The attraction of microplastics to the surface of magnetic nanoparticles facilitates their collection and removal from the environment. When placed in soil or water, magnetic nanoparticles adhere to microplastics, and by employing a simple magnetic field, they can be extracted from the environment (Sajid et al., 2023). This method has the potential to be an effective solution for environmental cleanup, especially in areas where microplastics are concentrated. In addition, certain nanoparticles have properties that can contribute to the biodegradation of microplastics. Nanoparticles can accelerate the biological processes of microorganisms or enzymes, helping microplastics to naturally decompose in an environmentally friendly way. The integration of nanomaterials with bacteria capable of altering the chemical structure of microplastics facilitates their biodegradation through natural processes (Nene et al., 2025). Such biological degradation processes contribute to the elimination of environmental damage caused by microplastics, while concurrently supporting the ecological balance of agricultural areas.

Microplastics in agricultural water can reduce irrigation water quality, which is critical for the growth of healthy plants and the safety of food production. Nanotechnology offers a promising solution to prevent microplastic contamination in irrigation water. (Liu et al., 2024). In particular, nanomaterials have been shown to play a key role in filtration processes that prevent microplastics from entering water sources.

The employment of nanotechnological filters has been demonstrated to yield a significantly enhanced level of effectiveness in the process of water purification when compared with conventional methodologies. The compatibility of nanoparticle size with microplastics allows for the efficient capture of these harmful pollutants from water. The utilization of these filters has been demonstrated to expedite the purification process whilst concurrently attenuating environmental impacts. Several nanofilters have been shown to remove microplastics from water while also eliminating heavy metals and other harmful substances, thereby contributing to improved water quality (Sekar et al., 2024). Such systems have the potential to enhance the efficiency of irrigation systems and promote the sustainability of agricultural production.

The accumulation of microplastics in the soil can disrupt soil structure and impede plants' ability to absorb essential nutrients. The application of nanotechnology can play a pivotal role in mitigating the accumulation of microplastics in soil, thereby preserving its quality. The use of nanoparticle-based solutions has been shown to be effective in preventing the accumulation of microplastics in soil and in the effective removal of existing microplastics (Kumar, 2023).

The ability of nanoparticles to separate plastics from the soil surface prevents damage to the soil structure. This approach prevents microplastics from penetrating deeper into the soil, thereby maintaining soil health. Furthermore, certain nanotechnological solutions have been shown to modify the chemical properties of microplastics in the soil, rendering them less susceptible to absorption by plants (Kumar, 2023). These approaches are of particular significance in the context of preventing the accumulation of plastic materials utilized in organic farming (Sajid et al., 2023).

Agricultural Bioenergy Production with Nanotechnology

The potential of nanotechnology to transform bioenergy production from agricultural waste, biomass, and organic matter is significant (Arya et al., 2021). However, when bioenergy production processes are inefficient, these resources can be processed using unsustainable methods. The utilization of nanotechnology offers a number of advantages, including the potential for faster and more efficient conversion of biomass into energy, whilst concomitantly reducing environmental impacts and improving energy efficiency (Joshi and Arora, 2023). Biomass, which is derived from agricultural plants and animal waste, is a vital raw material for bioenergy production. However, the process of converting biomass into energy is often lengthy, costly, and complex (Chettri et al., 2024).

The application of nanotechnology has the potential to streamline these processes. The integration of nanomaterials enhances the effectiveness of enzymes or microorganisms employed in biomass processing, thereby facilitating a more expeditious and efficient conversion process. Nanoparticles interact with the cellular structure of biomass, thus enabling the more facile and efficient breakdown of organic materials. Nano-enzymes accelerate the hydrolysis of lignocellulosic biomass, which is particularly abundant in agricultural waste, by catalyzing the breakdown of cellulose and lignin components, thereby optimizing the bioenergy production process (Mehejabin et al., 2024).

This integration of nanotechnology into agricultural bioenergy production processes has the dual benefits of improving efficiency and supporting the development of more sustainable and environmentally friendly energy solutions.

Another advantage that nanotechnology offers in the field of biomass processing is its capacity to expedite the disintegration of chemical bonds within biomass. This is particularly significant for materials such as agricultural waste, which is characterized by elevated levels of lignin and cellulose. The utilization of nanomaterials in this context has been shown to facilitate the breakdown of these bonds, thereby accelerating the processing of biomass and, consequently, enhancing energy production. In addition, nanohydrogenation processes have been shown to enhance the efficiency of biomass in oil production (Hussain et al., 2024).

The role of enzymes and catalysts in this process is critical. The efficiency of enzymes is a critical factor in various bioenergy production processes, including fermentation of biomass, biodiesel production, and gasification. The potential of nanotechnology to enhance enzyme efficiency and thereby increase energy production is significant. The use of nanoparticles has been shown to enhance enzyme activity, thereby facilitating more efficient biomass processing. Additionally, nanocatalysts enable processing at lower temperatures and shorter durations, thus optimizing energy production (Patil et al., 2025).

Specifically, nanotechnological catalysts have the potential to be used in the anaerobic conversion of biomass into methane gas, thereby increasing the efficiency of biogas production. This process offers an environmentally friendly method of converting agricultural waste into energy. The acceleration of biochemical processes by nanotechnological catalysts has been demonstrated to enhance methane production efficiency. Furthermore, these technologies used in biogas production can improve energy conversion rates, significantly enhancing the efficiency of agricultural bioenergy production (Khan et al., 2022).

The application of nanotechnology has the potential to enhance the design of materials employed in the conversion of biomass into energy. The utilization of nanostructured materials can facilitate the efficient combustion or gasification of biomass. The properties of nanomaterials enable the effective conversion of biomass into energy. These materials possess the capability to conduct heat more efficiently, thereby increasing energy production during biomass combustion (Dehhaghi et al., 2019). Furthermore, these materials enable biomass processing at reduced temperatures whilst demanding less energy than conventional methods. The employment of nanotechnological materials in bioenergy production has been demonstrated to engender a reduction in environmental impacts. The greenhouse gases emitted during biomass combustion are minimized when nanotechnological materials are used, thereby enhancing environmental sustainability. Specifically, Nanofilters and nanocatalysts help reduce carbon emissions, making processes more eco-friendly. (Abdelsalam & Samer, 2018).

Nanotechnological Solutions for Climate Change Mitigation in Agriculture

Climate change is a phenomenon that significantly impacts the agricultural sector and will continue to manifest its effects in the future. Increasing temperatures, water shortages, extreme weather events, and changing rainfall patterns can negatively affect productivity, thereby threatening agricultural production and food security, as well as agricultural economies. Nanotechnology plays a crucial role in offering innovative solutions to combat these challenges. Nanotechnology can enhance agricultural productivity and offer sustainable solutions to climate change. (Dasgupta et al., 2017).

Nanotechnology can improve water management in agriculture by enabling more efficient use of water resources. The use of nanomaterials can ensure more effective water purification and more efficient use in irrigation systems. The employment of nanofilters can remove contaminants and harmful substances in irrigation water. Furthermore, nanotechnological materials that facilitate the retention of water in the soil for extended periods can reduce the necessity for irrigation, thereby conserving water (Hamad et al., 2020). This offers a substantial benefit, particularly in regions afflicted by drought, and assists in mitigating the repercussions of water scarcity on agricultural production. Additionally, nanotechnology is being employed to enhance the resilience of agricultural products to diseases and pests. Genetic interventions in plants or protective coatings enhanced with nanomaterials can improve plant resilience to environmental stresses (Pramanik et al., 2020). Furthermore, nanotechnological pesticides can be used in lower doses to combat targeted pests, providing effective control without harming the environment. Additionally, nanotechnological materials can reduce the water requirements of plants, enabling higher yields with less water.

The field of nanotechnology has also made significant contributions to the enhancement of soil health. A range of nanotechnological solutions has been developed to enhance the breakdown of organic matter in the soil and to facilitate more efficient nutrient uptake. The application of nanoparticle technology has been demonstrated to have the capacity to prevent soil degradation, enhance the soil's water retention capacity, and facilitate enhanced nutrient access for plants (Ahmed et al., 2024). This contributes to the enhancement of agricultural sustainability and the mitigation of deleterious effects associated with climate change, such as soil erosion.

The potential of nanotechnology in addressing climate change in agriculture is considerable. Solutions offered in areas such as water management, pest and disease control, soil health, and fertility can help make agriculture more resilient to the effects of climate change. Nevertheless, it is imperative to undertake further research to ascertain the applicability, safety, and environmental impact of these technologies. The widespread adoption of nanotechnological solutions has the potential to be a significant step towards sustainable agricultural practices (Wang et al., 2024).

Applications of Nanoparticles in Food Industry

In recent years, nanotechnology has gained significant importance in the food industry, particularly concerning food production, processing, preservation, and packaging. The application of nanoparticles has been shown to enhance product quality, extend shelf life, and ensure food safety (Biswas et al., 2022). The larger surface area of nanoparticles allows them to enhance the functionality of materials used in the food sector. The potential of nanoparticles in the food industry is extensive, ranging from enhancing nutritional value to ensuring food safety and generating positive health effects (de Sousa et al., 2023).

Nanoparticles are employed to enhance the efficiency of food processing. They function as carriers, facilitating the absorption of food materials and enabling nutrients to bind and be utilized more rapidly and efficiently in the body. Additionally, nanoparticles can enhance the effectiveness of food components, optimizing their nutritional value. For instance, nanoparticles can be employed to enhance the preservation and absorption of food additives, such as vitamins or minerals, thereby addressing nutrient deficiencies, a particularly salient issue in developing countries (Peidaei et al., 2021).

Additionally, nanotechnology holds considerable promise in ensuring food safety. Nanoparticles can be utilized to detect and disinfect pathogens in food products with high efficiency. Nanotechnological sensors can rapidly and accurately detect bacteria, viruses, or toxins on food products, thus contributing to food safety. Furthermore, nanotechnology can be employed in food packaging to assist in protecting foodstuffs from external factors. This can be achieved by nanotechnological food packaging that inhibits the growth of microorganisms, thus extending the shelf life of products. Consequently, this can result in a reduction of food waste and enhancement of food safety (Gupta et al., 2022).

Another area of application for nanoparticles is the enhancement of the sensory characteristics of food products. Nanotechnological additives can modify sensory attributes such as taste, color, aroma, and texture. Furthermore, nanoparticles can balance the oil and water content of food products, thereby reducing their caloric content, thus aligning with contemporary trends in health-conscious eating. Furthermore, nanoparticles can enhance the appearance of food products, rendering them more visually appealing and aesthetically attractive (Neme et al., 2021). The enhancement of both the nutritional and sensory properties of food products by nanotechnology enables the creation of products that better meet market demands and improve consumer experiences (Babu, 2022).

The applications of nanoparticles and nanotechnology in the food industry are extensive, and they have the potential to shape the future of this sector. The impact of nanotechnological solutions on areas such as efficient nutrient delivery, enhanced food safety, extended shelf life, and improved sensory attributes of products is significant. However, continued research on the use of nanotechnology in the food industry is essential to gather more information on the safety and effects of these technologies (Onyeaka et al., 2022).

Nanoparticles in Food Packaging

The utilization of nanotechnology in the domain of food packaging represents a substantial advancement, not only in terms of prolonging the shelf life of products but also in enhancing food safety (Dobrucka, 2014). Nanoparticles can significantly enhance the functionality of packaging materials, with nanocomposites demonstrating particular efficacy in preserving food by protecting environmental factors such as oxygen, moisture, and light, thereby preventing food spoilage. The application of nanoparticle-based packaging has been shown to enhance the shelf life of food products by protecting them from external factors such as oxygen, moisture, and light (Aigbogun et al., 2018). Furthermore, the incorporation of nanoparticles with antibacterial and antifungal properties into food packaging can prevent the growth of microorganisms, which is particularly beneficial for perishable items such as fresh fruits, vegetables, and meat products. The efficacy of nanoparticles such as silver and zinc oxide in eradicating harmful pathogens has been well-documented (Dera et al., 2020), thereby ensuring food safety and preventing foodborne diseases.

Nanotechnology in Food Safety and Rapid Testing Systems

In the domain of the food industry, ensuring food safety is of paramount importance. In this regard, nanotechnology has emerged as a pivotal solution, offering advanced methodologies for detecting microbial contamination, toxins, and other harmful components in food products. The employment of nanotechnological sensors and testing systems has proven to be a rapid, precise, and reliable approach to ensure food safety. The surface properties of nanoparticles enhance their ability to bind to specific target components, making them an excellent tool for detecting pathogens in food products (Khan et al., 2025). Gold nanoparticles are commonly used in biosensors for pathogen detection, offering the ability to detect pathogens at very low concentrations, enabling rapid testing of food safety (Chadha et al., 2022). Furthermore, the use of nanoparticles in the detection of toxins and allergens serves to mitigate the potential health risks associated with food products.

Nanoparticles in Improving the Sensory Properties of Food Products

Nanotechnology also plays an important role in improving the sensory properties of food. Nanoparticles can change the color, aroma, texture, and flavor of food, making it more appealing and palatable. By balancing the fat and water content of food, nanoparticles enable the production of low-calorie foods. In addition, nanoparticles help to achieve better texture and appearance by ensuring the homogeneous distribution of food components. This is a significant advantage, especially for health-conscious consumers (Jagtiani, 2022).

Nanoparticles can also be used to ensure that food stays fresh for longer. Nanotechnology coatings form a protective layer on the surface of food, preventing oxidation and helping to keep food fresher for longer. These coatings can also reduce the loss of flavor and aroma, giving consumers a more satisfying experience (Berekaa, 2015).

Usage of Nanotechnology in Food Processing

Nanotechnology also has the potential to improve the efficiency of food processing. Nanoparticles can change the properties of materials used in food processing, enabling more efficient and sustainable production processes. Nanotechnological devices can reduce energy consumption by preserving the quality of food during thermal processing. In addition, nanomaterials can improve the distribution of food additives during processing, thereby improving the overall quality of products (Ali et al., 2021).

Nanotechnology solutions can also reduce the use of harmful chemicals in food processing. This helps to minimize environmental impact and adverse effects on human health. For example, nanocatalysts enable efficient reactions at lower temperatures and pressures, which saves energy and ensures that food remains more natural and healthier (He et al., 2019).

Conclusion

The rapid development of modern technologies is shaping new approaches in agriculture and the food industry. In this context, nanotechnology has emerged as a significant tool that enhances sustainability, increases efficiency, and reduces environmental impacts of these sectors. The use of nanoparticles holds great potential in various areas such as improving agricultural productivity, combating plant diseases and pests, optimizing water usage, and enhancing soil health. Similarly, the application of nanoparticles in the food industry provides robust solutions for ensuring food safety, extending shelf life, enhancing nutritional value, and improving consumer experience. Nanotechnology offers innovative solutions in food processing and packaging, significantly contributing to reducing the environmental footprint of food production.

In agriculture, the use of nanoparticles has made significant progress, particularly in areas such as water conservation, pesticide application, and soil health improvement. Nanomaterials help reduce the water requirements of plants, ensure more efficient use of water, and accelerate the decomposition of organic matter in the soil, thus supporting the adoption of more sustainable production methods in agriculture. Furthermore, the targeted use of pesticides and fertilizers through nanoparticles reduces environmental pollution while increasing agricultural productivity. Nanotechnological materials also help plants become more resistant to diseases and pests, supporting biological control methods and reducing the reliance on chemical fertilizers and pesticides.

In the food industry, nanoparticles provide revolutionary solutions, especially concerning food safety and shelf life. Nanotechnological sensors and biosensors have the ability to quickly and accurately detect pathogens, toxins, and other harmful components in food products. Additionally, nanoparticle-based food packaging helps maintain the freshness of food for longer periods, preventing waste and inhibiting the spread of microorganisms with their antibacterial and antifungal properties. The ability of nanoparticles to optimize the transport of nutrients and enhance the nutritional value of food products provides a significant advantage in promoting healthy diets.

However, there are challenges that need to be addressed for nanotechnology to be widely implemented in agriculture and the food industry. Further research on the potential environmental and health impacts of nanoparticles is critical to ensure the safe use of these technologies. Additionally, the cost of nanotechnological products is a factor that needs to be considered before they can be integrated into industrial production processes. Moreover, these technologies must be properly monitored in terms of food safety, ethics, and regulatory compliance.

In conclusion, the potential of nanoparticles in agriculture and the food industry offers significant benefits in terms of sustainability, efficiency, and environmental responsibility. Nanotechnological innovations continue to develop important solutions to improve food safety, reduce environmental impacts, and enhance agricultural productivity. However, for the effective application of these technologies, further scientific research, regulatory development, and support for industrial-scale implementations are necessary. In the future, the role of nanotechnology in agriculture and food sectors is certain to strengthen, leading to significant changes in these fields.

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