ARCHITECTURAL SCIENCES AND URBAN AGRICULTURE II

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PREFACE

In the face of burgeoning urban challenges, the call for innovative approaches that transcend traditional boundaries has never been more resounding. With immense pleasure, we present "***Architectural Sciences & Urban Agriculture II,"*** which converges various perspectives from agriculture and urban planning.

This volume ardently embraces the spirit of interdisciplinary collaboration, aiming to illuminate the intricate tapestry woven between urban landscapes and agricultural endeavors. By amalgamating agricultural sciences and urban planning principles, we envision the potential to shape cities that flourish as vibrant ecosystems, nurturing both sustenance and sustainability.

In the spirit of fostering knowledge exchange and scholarly discourse, this book extends the pioneering efforts initiated by the **"Journal of Architectural Sciences and Applications (JASA)** (https://dergipark.org.tr/en/pub/mbud)." Since its inception in 2016, JASA has provided a platform for collective studies in related disciplines. The dedicated editors of JASA have played a crucial role in curating original works and disseminating the latest developments in the field through various publications.

This book unveils a treasury of research and pioneering methodologies illuminating urban agriculture's frontiers. This volume encapsulates the essence of a burgeoning movement that seeks to rekindle the relationship between city dwellers and their sustenance.

We trust that this book shall become an invaluable asset for academics, practitioners, policymakers, and students, catalyzing fresh inquiries and propelling the advancement of urban agricultural thought.

Our heartfelt gratitude extends to the contributors who have generously shared their expertise and insights and the diligent researchers and reviewers who have dedicated their time and energy to bring this endeavor to fruition. We would also like to thank Iksad Publishing House for their contribution and support in publishing this e-book.

We invite readers to embark on a transformative journey that unravels the interconnected dynamics of urban agriculture, ultimately fostering cities that thrive as resilient and sustainable hubs of life.

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September 28. 2023

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Reflecting on Urban Agriculture and Agricultural Literacy in 12 Years of Compulsory Education in Türkiye

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1. Introduction

As a part of the natural system, humankind has been in a multidimensional, direct and indirect relationship and interaction with nature since its existence, depending on factors such as individual and social value judgments, perceptions, level of understanding and interpretation, point of view, level of satisfaction of needs, degree of importance and priority, etc. In this context, this obligatory coexistence has led to the emergence of irreversible negativities and problems as a result of human beings' tendency to destroy, exploit, change, shape, and consume nature as a unilateral commodity according to their own needs and requirements (Gül & Kurdoğlu, 2021).

Today, 55% of the world's population, which has reached 8 billion, lives in urban areas and this rate is expected to increase to 68% by 2050 (United Nations, 2023). In Turkey, the proportion of people living in provincial and district centers, which was 93.2% in 2021, became 93.4% in 2022. On the other hand, the proportion of people living in towns and villages decreased from 6.8% to 6.6% (TUIK, 2023).

As a result of social, cultural, economic, political, and technological changes, the urban population is increasing and urbanization is increasing both horizontally and vertically. As cities grow, biological reserves outside the city are decreasing and pressures on natural and rural areas are increasing. It is accepted by everyone that natural resources and ecosystems have reached an irreversible point as the multifaceted production and consumption activities of human beings gradually increase and exceed the carrying capacity of nature. In today's process, it has emerged that nature should be protected holistically, and human beings should adopt a lifestyle in harmony with nature.

For this purpose, the thought that environmental education is essential for the creation of sustainable life (Bonnett, 1999; Buckler & Creech, 2014; Farmer, Knapp & Benton, 2007; Orr, 1994; UNESCO, 2015; UNESCO, 2017) the idea of ecological literacy as a basic approach in the education system was put forward by Orr (1992) (Kujumdzieva, Nustorova & Nedeva, 2019). According to Orr (1994), he emphasized the importance of ecological literacy as a part of education, especially for living without harming the earth.

The experiences of children in their early childhood years are very important for their development and understanding for the rest of their lives. Environmental education to be provided to children in this period will enable children to gain knowledge, awareness, consciousness, and positive attitudes and behaviors about the environment and to be sustainable (Russo, 2001; Hellden & Hellden, 2008; Akbayrak & Kuru Turaşlı, 2017; Arlemalm-Hagser, 2013; Borg, Winberg & Vinterek, 2019; Buldur & Omeroğlu, 2018; Cohen & Horm-Wingerd, 1993; Evans et al, 2007; Hsiao & Shih, 2015; Kahriman-Ozturk, Olgan & Tuncer, 2012; Samur, 2018; Simsar, 2021; Soydan & Samur, 2014; Ozen Uyar & Yılmaz Genc, 2016).

Increasing environmental literacy is shown as the most effective way to deal with environmental problems (Akıllı & Genç, 2015).

In recent years, it is seen that there has been a gradual move away from organic (natural) agricultural production for many reasons such as population growth, negative consequences of climate change, approaches to reduce carbon emissions, and technological and digital developments. In particular, a dangerous process has started in which genetically modified products, artificial meats, and products are produced and encouraged for consumption. Citizens who are not informed about this issue remain unaware of the basic facts about food, agriculture, and natural resources and do not even realize that the food products they use impair their health. Because it is accepted by experts that most diseases, especially cancer, are related to the food consumed and eating habits.

Therefore, for the sustainability of life and food security and standards, it has become a necessity for everyone to understand agricultural and animal production and consumption fundamentally well and to comprehend its importance in ecological terms. In this context, it is of great importance to initiate and disseminate ecological literacy to school-age children.

Individuals can exhibit environmentally friendly attitudes and behaviors by getting to know nature from early childhood. Because the saying "he who knows, loves; he who loves, protects" proves this. To know, love and protect nature; in short, requires being "ecologically literate". In this context, the term "ecological literacy" represents the transfer of sustainable ecological relations and processes in nature to daily life in a sustainable way in terms of understanding, making sense of, internalizing, discourse, and action.

Urban agriculture, one of the environmental and nature protection actions, is directly related to the "ecological literacy" process of urban people. To become ecologically literate, especially in urban schools, it is possible to implement environmental education with appropriate programs, curricula, and learning processes. As environmental education gains importance in the world and our country, issues related to environmental education take more place in educational processes. However, it is an important deficiency that environmental education is not carried out with appropriate course materials based on a program that shows integrity from the preschool stage to the end of education life. Unfortunately, the resources on environmental education published in our country so far are far away from the ideal of raising an ecologically literate generation because they do not carry the integrity of the subject appropriate to the nature of environmental education and do not effectively guide the learning processes.

This study, it was aimed to reveal the importance of the concept of agricultural literacy within the scope of ecological literacy and to make suggestions in the context of increasing awareness of agricultural literacy in childhood by including it in the 12-year compulsory education and training curriculum in Türkiye.

2. Material and Method

In this study, the concepts of environmental literacy, ecological literacy, urban agriculture, and agricultural literacy were examined and defined within the framework of the literature. In terms of agricultural literacy, the course curriculum and content related to nature / environmental protection in the 12-year compulsory basic education and training (primary and secondary school level) of the Ministry of National Education were examined. The rates of achievements in the courses given were examined, analyzed, and interpreted. In this context, suggestions were made for reflecting the concept of agricultural literacy in the curriculum of primary and secondary school education in Türkiye.

3. Findings and Discussion

3.1. Environmental Literacy or Ecological Literacy

In its simplest form, "literacy" is defined as "the state of being literate" and "literate" is defined as "a person who can read and write, who has received an education" (TDK, 2005: 1495). Literacy refers to the minimum level of "reading and writing" skills as well as competence in a specific field (Mcbride et al., 2013). In this sense, literacy is defined as the cognitive competence needed in daily life in the form of establishing causal connections between facts, problem-solving, etc. (Michaels & O'Connor, 1990). Finally, according to the definition made by the UNESCO Education Unit (2004:13), literacy refers to the acquisitions that individuals reach to realize their goals, expand their knowledge repertoire, and participate fully in social life.

The term environmental literacy was first used by Charles Roth in 1968. According to Roth's definition; "Individuals with a basic level of knowledge about the environment are called environmentally literate individuals (Roth, 1968). The most common definition of environmental literacy was made by the North American Association for Environmental Education (NAAEE) (2004). According to this definition, environmental literacy means awareness about the environment and environmental problems, knowledge, skills, and motivation to solve environmental problems. Environmental literacy refers to cognitive, affective, and behavioral competence corresponding to all areas of human interaction with nature.

Environmental literacy is more broadly defined as the knowledge and communication necessary for environmental action strategies and the skills to use them in environmental actions and human acts related to the willingness to take action on environmental issues (Hungerford & Peyton, 1976). These include, (Disinger & Roth, 1992).

ı) The interaction between nature and the social system,

ii) Man's place in nature,

iii) Design and use of technology,

iv) Developmental learning within the human life cycle (Designer & Roth, 1992).

Basic components of environmental literacy, (Erdoğan et al., 2011; Teksöz, et al. 2010).

I) Comprehension,

ii) Attitude

iii) Reaction

iv) Interest (Erdoğan et al., 2011; Teksöz, et al., 2010).

Environmental literacy requires understanding the environment, having environmental knowledge and skills, and having environmental attitudes and behaviors. Thus, it enables the individual to establish a positive bond with the environment and to live a life respectful to nature (Roth, 2002; Koç, Çorapçıgil & Doğru, 2018).

Environmental Literacy is also expressed as perceiving, interpreting, and interpreting the functioning of the environment and showing the actions to be taken to renew and maintain these systems (Karatekin & Aksoy, 2012). The "International Working Meeting on Environmental Education in School Programmes" organized by IUCN and UNESCO in the USA was a turning point in the development of environmental education (UNESCO, 2013). In this meeting, environmental education was defined as a new field of education (Palmer, 1998: 6-7):

> *“Environmental education is the process of enabling people to understand the umbilical cord between themselves, their culture, and their biophysical environment and to understand the concepts and adopt the values related to the skills and attitudes necessary for them to understand and appreciate it. Environmental education is also necessary for making decisions about the quality of the environment and for establishing principles of individual behavior".*

With the progress of environmental protection and environmental education on the axis of "sustainability" since the 1980s, environmental literacy has undergone a terminological transformation as "ecological literacy". Therefore, in this study, environmental literacy is used synonymously with ecological literacy, which is the main vision of education for sustainable living. There is no single and unique definition of ecological literacy. The basic elements in the concept of the alternative ecological literacy model are focused on having sustainable, emotional, cognitive, and behavioral roots. These roots are considered to be two-tiered, such as ecological intelligence (social intelligence, emotional intelligence, economics) and green consumer behavior. Accordingly, ecological intelligence is one of the main components of ecological literacy. This is because the concept of ecological literacy is related to either a holistic perspective or sustainability (Kujumdzıeva, Nustorova & Nedeva, 2019). The main mission of ecological intelligence: (Kujumdzıeva, Nustorova & Nedeva, 2019).

- To develop social and environmental responsibility and awareness,
- To encourage critical thinking,
- To follow cooperative learning,
- To create behavior change in a long-term perspective.

Ecological intelligence is associated with brain regions that are responsible for cognitive and emotional reactions. Anatomically and physiologically, both parts of students' brains need to be supported.

Ecological literacy emphasizes that humans are not independent of the ecosystem by revealing that natural resources are natural, dynamic, interconnected, and not unlimited. With this approach, it reveals that humans have the role of protecting resources as well as benefiting from natural resources (Casper, Fernandez-Gimenez & Balgopal, 2020).

According to Orr (1992), ecological literacy includes "the ability to know, care and apply". According to Balgopal & Wallace's (2009) definition, "An ecologically literate person knows ecological concepts to understand human impacts on ecosystems and can recognize their relevance and application" (Casper et al., 2020). As can be understood from these two definitions, ecological literacy is a concept that defines the relationships between knowledge, beliefs, and behaviors related to human-environment interactions. Ecological literacy is about understanding how people interact with ecosystems and how this can be done sustainably and interactions between social and ecological systems (Casper et al., 2020). For this reason, education leading to ecological literacy should also be interdisciplinary and holistic and should consider humans as a part of nature (Hammarsten et al., 2019). Children need learning environments where they can interact directly with nature to make sense of the new information they acquire about nature (Ozdemir & Uzun, 2006). This education can be addressed through a program that addresses care and respect for other organisms and leads to an understanding of natural systems, starting with outdoor experiences from early years (Hammarsten et al., 2019).

Among all solutions to protect the environment/nature, educational activities are the most effective tool for society to become sensitive about the environment. To protect the environment well and develop permanent solutions, studies in the field of education and policy should be carried out simultaneously (Clayton et al., 2019; Erten, 2005; Aslan et al., 2008; Ehrlich & Ehrlich, 2013; Troy Frensley et al., 2020; Şimşekli, 2001).

An ecology-based environmental education is about learning the language of nature, ethics, and actions, and is also a way of thinking and a way of behavior (Davis, 1998; Ozaner, 2004). According to many researchers, studies in well-designed in-school and out-of-school spaces will facilitate students' understanding of the natural environment, enable them to acquire positive attitudes and values towards nature and the environment, enable them to learn about natural processes, increase their predisposition to nature, make them more sensitive and conscious, and contribute to their becoming more independent, creative and critical thinking individuals.(Demirsoy, 2004; Ozaner, 2004; Palmberg & Kuru, 2001; Phenice & Griffore, 2003; Thoe & Lin, 2006; Yanık, 2006; Ozaner, 2007).

3.2. Urban Agriculture

Urban agriculture has been defined as '...an industry that produces, processes and markets food and fuel, largely in response to the daily demand of consumers within a town, city or metropolis, on land and water dispersed throughout the urban and peri-urban area, applying intensive production methods, using and reusing natural resources and urban wastes, to yield a diversity of crops and livestock"(UNDP, 1996).

Urban Agriculture is the practice of cultivating, processing, and distributing food and other products in and around cities; it can be accompanied by a variety of complementary activities in its pre- and post-production phases, and it serves a variety of social, environmental, economic, nutritional, and recreational needs (Urban Agriculture Working Group, 2013).

Urban agricultural areas are edible urban green spaces that provide important ecological, economic, socio-cultural, and health services to the city. It is one of the sustainable development strategies for cities and offers alternative land use opportunities for planners and decision-makers (Türker & Akten, 2020). Urban agriculture can be simply defined as the cultivation of food in urban areas. Awareness of this issue is increasing day by day (Türker, 2021).

Urban agriculture has become a resource for social cohesion and eco-education, a new expression of culture and politics, and land-use fashion worldwide as a recreation activity (Camps-Calvet et al. 2015; Coles & Costa, 2018; Robineau & Dugue, 2018; Türker et al., 2021).

Until today, agricultural activities in Türkiye have only been seen as rural activity and considered a form of non-urban production. Urban agriculture has not been referred to in legislation, nor has it been included in the urban area planning system and management policies. As a result of many factors such as the increase in the urban population in Türkiye and the world, the increasing intensity of urbanization, pandemic, migration, and migrant problem, cost of living, food security, unemployment, climate change, carbon emissions, the importance and need for agricultural activities in urban areas has emerged. Thus, urban agriculture in Türkiye has been recognized by academic circles and has come to the agenda as an important form of urban land use and production, even as a means of providing income and meeting the need for urban safe food. Agricultural activities in and around urban areas in Türkiye are traditionally practiced, mostly as family enterprises and unregistered producers. For this reason, the contribution of urban agriculture to the socioeconomic and ecological structure of cities is still not fully known due to its informality. In addition, unfortunately, agricultural areas in and around cities are gradually decreasing and disappearing under the pressure of construction.

In creating a model that integrates urban agriculture, the principles that support an integrated approach are listed below (Philips, 2013).

- Promote biodiversity,
- Increasing food safety,
- Integrating education and social relations to raise awareness,
- Climate adaptation for environmental resilience,
- Maximizing water quality, accessibility, and availability,
- Maximizing waste and energy efficiency,
- Maintaining soil health,

- Develop a regionally and locally appropriate system network,
- Supporting social responsibility,
- To protect human health,
- To ensure integration with nature,
- Supporting the agricultural community,
- To develop dynamic links between people and environmental systems,
- Promote sustainable economic opportunities,
- To ensure waste management.

The unique artificial, static, and consumer society created by urban life is gradually moving away from the natural process. Urban agriculture helps to raise the interest of normally indifferent urban people in agricultural production and to raise awareness. As agricultural literacy becomes widespread, especially in schools and through after-school programs, it can serve to develop a more conscious consumer society. Thus, urban people can be summarised as knowing that watermelon does not grow on trees, that French fries come from potatoes, not from factories, or that no cow, regardless of color, produces chocolate milk.

3.3. Agricultural Literacy

In the past, efforts to define agricultural literacy have generally focused on the production and distribution of agricultural products in terms of environmental and global social importance. Today, however, agricultural literacy has become increasingly important on the public agenda and in agricultural education, where it has a significant diversity of meaning and impact. It has become a concept that agricultural literacy should be taught at the basic education level (Powell et al., 2008).

"The Committee on Agricultural Education in Secondary Schools (National Research Council, 1988) developed the idea of "agricultural literacy" and laid the foundation for a conceptual model. It defined the concept of "agricultural literacy" as follows. It is a person's understanding of the food and fiber system about its historical, economic, social, and environmental significance (Pense & Leising, 2004, p. 86).

According to Frick et al. (1991), "agricultural literacy" is "a person who has knowledge and understanding of the food and fiber system and can analyze, synthesize and communicate basic information about agriculture" (Frick et al., 1991, p. 52).

According to Meischen & Trexler (2003), agricultural literacy includes knowledge and understanding of agriculturally relevant scientific and technologically based concepts and processes necessary for personal decision-making, participation in urban and cultural affairs, and economic productivity.

Agricultural literacy involves the ability to think critically and make value judgments about the impact of agriculture as an economic and environmental activity and the concurrent social and political pressures arising from these judgments (Powell, Agnew & Trexler, 2008).

They argue that the roots of agricultural literacy began in 1821 with institutional efforts in private and public schools around the world (Birkenholz, Frick, Gartin, Hoover, Jewel, Terry, Bishop & Steward, 1992). Wright, Stewart & Birkenholz (1994) linked individuals' knowledge and understanding of agriculture with their agricultural literacy. The agricultural literacy of individuals will be effective in their attitudes and activities in the production of relevant social policies. Frick, Birkenholz & Matchmes (1995) argue that the basis of agricultural literacy is the principle that "every individual should have at least a minimum level of knowledge about the industry that will produce the food that will ensure the survival of human beings".

Frick et al., (1995) defined agricultural literacy as knowledge and perception of agriculture, food, and natural resources rather than attitudes. Philosophical, political, and epistemological differences among experts have led to the emergence of three approaches to agricultural literacy (Powell et al., 2008). These three approaches are programmed agricultural literacy (*deductive model*), emergent agricultural literacy (*inductive model*), and agricultural literate value judgments (*evaluative model*).

Most urban people do not have sufficient knowledge about safe and organic food products and agricultural production practices. It is a known fact that unhealthy eating habits such as GMOs, artificially added products, foods of unknown origin, and fast food cause or encourage many diseases. In addition, the potential and opportunity for urban people to access and purchase safe and natural food products may be insufficient. In this case, it is of great importance to put urban agriculture and agricultural literacy on the agenda.

Agricultural literacy can significantly change consumer preferences and purchasing behaviors, especially in urban areas, and can lead to correct decision-making and increase awareness of urban agriculture. Lack of knowledge, lack of interest, or global perceptual misperceptions about food and agricultural products and activities, especially in urban areas, increases the need for agricultural literacy.

There are two challenges facing agricultural literacy approaches today.

1. The increasingly powerful food industry/technology and monopolization on a global scale
2. Educating a new generation that does not understand, care about, or have an interest in natural food and farming systems (Mercier, 2015; Roberts et al., 2016).

Elementary school students need authentic learning to put into practice the topics of food, agriculture, and natural resources learned in the classroom. Teaching the subject of agriculture at the primary school age by associating it with daily life and integrating it with other fields will be directly effective in better understanding today's scientific, economic, and industrial problems (Knobloch & Martin, 2002).

Agricultural education teaches students about agriculture, food, and natural resources. Through these subjects, agricultural educators also teach students a wide range of skills, including science, mathematics, communication, leadership, management, and technology. Agricultural education consists of three interconnected components. These components are (Kendal, 2021);

- Classroom or laboratory instruction,
- Experiential learning (learning experiences that usually take place outside the classroom, supervised by the agricultural trainer),
- Leadership training (this training is provided by some private or public institutions in the agricultural context).

National Research Council (the same group that created the National Science Education Standards) established the Agricultural Education in Secondary Schools Committee to examine the status and forecast the future of agricultural education. The Committee published its findings in a report, Understanding Agriculture: New Directions for Education, and defined agricultural literacy as: "An agriculturally literate person would understand the food and fiber system and this would include its history and its current economic, social and environmental significance to all Americans" (National Research Council, 1988).

3.4. Analyzing the Primary and Secondary Education Curricula in Türkiye in terms of Ecological Literacy and Agricultural Literacy

The courses and outcomes for the year 2022 at the 12-year (primary, secondary, and high school) compulsory education and training level in Turkey were analyzed. According to this

a. At the Primary Education Level:

It is seen that only 63 outcomes (15.86%) out of a total of 397 outcomes within the scope of Life Science, Science, and Social Studies courses are courses on nature and environment (Table 1).

However, it is seen that there are only 2 outcomes related to agricultural literacy in the "Life Science" course 1 outcome in the "Science" course in 3 classes, and 1 outcome in the "Science" course in 5 classes. Thus, a total of 4 outcomes related to agriculture are achieved in the 8-year education process (Table 2). For example;

- Understands the importance of plants and animals for human life,
- Investigates the growing conditions of fruits and vegetables,
- Presents the results of observation of the life cycle of a plant.

- Question the importance of biodiversity for natural life.

Table 1. Comparison of the total number of learning outcomes and the number and percentages of environment-related learning outcomes in primary education programs by subjects

Class	Lesson	Unit Name	Total Number of Outcomes	Number of Environmental Outcomes	Percentage (%) of Environmental Outcomes
1	Life Science	Life in Nature	53	8	15
2	Life Science	Life in Nature	50	9	18
3	Life Science	Life in Nature	45	6	13
	Science	Journey to the World of Living Things	36	8	22
4	Science	Lighting and Sound Technologies & Human and Environment	46	8	17
	Social Studies	People, Places and Environments	33	6	18
5	Science	Human and Environment	36	8	22
	Social Studies	People, Places and Environments	33	5	15
6	Social Studies	People, Places and Environments	34	4	12
7	Social Studies	Global Connections	31	1	0,3
8	-	-	-	-	-
			397	**63**	**%15,86**

Table 2. Environmental outcomes in the curriculum of the primary education course

Class	Lesson	Environmental Outcomes
1	Life Science	1. Observe animals in their immediate surroundings, 2. Observe plants in their immediate surroundings 3. Takes care to protect the animals and plants in their immediate surroundings. 4. Be sensitive about keeping nature and the environment clean. 5. Observe the Sun, Moon, Earth, and stars 6. Researches the seasons and their characteristics. 7. Distinguishes the materials that can be recycled. 8. Understand the changes that occur in nature according to the seasons.
2	Life Science	1. Compares the conditions necessary for the survival of plants and animals 2. Recognizes the importance of growing plants and feeding animals 3. Gives examples of the impact of natural elements in their immediate environment on human life. 4. Contributes to the recycling of consumed materials, 5. Recognizes natural phenomena, 6. Give examples of natural disasters. 7. Explains the precautions that can be taken against natural events and natural disasters. 8. Shows the directions by observing the Sun. 9. Investigate the effects of the Earth's shape and movements on human life.
3	Life Science	1. Understands the importance of plants and animals for human life. 2. Investigate the growing conditions of fruits and vegetables. 3. Find directions by making use of nature. 4. Gives examples of the impact of humans on natural elements from their immediate environment. 5. Takes responsibility for protecting nature and the environment. 6. Gives examples of the contribution of recycling to himself/herself and the environment he/she lives in. 7. Shows the directions by observing the Sun. 8. Investigate the effects of the Earth's shape and movements on human life.
	Science	1. Classifies living and non-living things using examples from the environment. 2. Presents the results of observation of the life cycle of a plant. 3. Recognizes the environment he/she lives in. 4. Takes an active role in cleaning the environment, 5. Explains the differences between natural and artificial environment, 6. Designs an artificial environment. 7. Realize the importance of the natural environment for living things. 8. Propose solutions by researching to protect the natural environment.
4	Science	1. Question the causes of light pollution, 2. Explains the negative effects of light pollution on natural life and observation of celestial objects. 3. Produces solutions to reduce light pollution.

		4. Question the causes of sound pollution. 5. Explains the negative effects of sound pollution on human health and the environment, 6. Demonstrate conservation in the use of resources. 7. Produces solutions to reduce sound pollution. 8. Recognizes the importance of recycling and resources necessary for life.
	Social Studies	1. Makes inferences about the location of any place in the environment, 2. Sketches the places he/she uses in his/her daily life, 3. Distinguishes natural and human elements in the environment he/she lives in 4. Observe the weather events occurring around him/her and transfer his/her findings to pictorial graphs. 5. Makes inferences about the landforms and population characteristics in and around the place where he/she lives 6. Makes necessary preparations before, during, and after a disaster.
5	Science	1. Questions the importance of biodiversity for natural life, 2. Discusses the factors that threaten biodiversity based on research data. 3. Expresses the importance of the interaction between humans and the environment. 4. Provides suggestions for the solution of an environmental problem in his/her immediate environment or our country. 5. Makes inferences about the environmental problems that may occur in the future as a result of human activities. 6. Discusses benefit and harm situations in human-environment interaction on examples. 7. Explains destructive natural events caused by natural processes. 8. Expresses ways of protection from destructive natural events.
	Social Studies	1. Explains the landforms of the place where he/she lives and its surroundings on maps. 2. Explains the effects of climate on human activities in his/her environment by giving examples from his/her daily life. 3. Gives examples of the effects of natural features and human features on population and settlement 4. Questions the causes of disasters and environmental problems in his/her environment 5. Explains the effects of disasters on community life with examples.
6	Social Studies	1. Describes the geographical location of the continents, oceans, and our country using concepts related to location 2. Examines the basic physical geography features of Turkey's landforms, climate characteristics, and vegetation on the relevant maps 3. Shows the basic human geography features of Turkey on the relevant maps. 4. Makes inferences about climate characteristics based on human experiences in different natural environments of the world.
7	Social Studies	1. Develops ideas for solving global problems with their friends.
8	-	-

b. At the Secondary Education (High School) Level:

It was observed that only 25 learning outcomes (16.1%) out of 155 learning outcomes in the Geography course (Environment and Society), and Biology course (Ecosystem Ecology and Current Environmental Problems, Living Things and Environment) were related to nature and environment (Table 3). However, among these outcomes, it was observed that a total of 5 outcomes, 1 outcome in the Geography course in the 9th grade, 3 outcomes in the Biology course in the 10th grade, and 1 outcome in the Biology course in the 12th grade, were related to agricultural literacy (Table 4). For example;

- Exemplifies the ways people use the natural environment,
- Explains nutrition in living things with examples,
- Questions the importance of biological diversity for life,
- Suggests solutions for the protection of biological diversity,
- Gives examples of artificial selection practices in agriculture and animal husbandry.

Table 3. Comparison and percentage of the total number of learning outcomes and the number of environment-related learning outcomes by courses in Secondary Education (High School) programs

Class	**Lesson**	**Unit Name**	**Total Number of Outcomes**	**Number of Environmental Outcomes**	**Percentage (%) of Environmental Outcomes**
9	Geography	Environment and Society	22	2	1
10	Geography	Environment and Society	34	4	12
10	Biology	Ecosystem Ecology and Current Environmental Problems	17	10	58
11	Geography	Environment and Society	29	5	17
12	Geography	Environment and Society	24	2	0,8
12	Biology	Living Things and Environment	29	2	0,7
			155	**25**	**%16,1**

Table 4. Environmental Outcomes in the Secondary Education Curriculum

Class	Lesson	Environmental Outcomes
9	Geography	1. Exemplifies how people use the natural environment, 2. Evaluates the changes that occur in the natural environment due to human impact in terms of their consequences,
10	Geography	1. Explains the causes and characteristics of disasters 2. Associates the distribution and effects of disasters 3. Associates the distribution and effects of disasters in Turkey. 4. Explain the methods of protection from disasters.
	Geography	1. Explains the relationship between living and non-living components of the ecosystem, 2. Explains the forms of nutrition in living things with examples. 3. Analyzes the flow of matter and energy in the ecosystem. 4. Establishes a relationship between material cycles and sustainability of life. 5. Evaluate the causes and possible consequences of current environmental problems. 6. As an individual, questions his/her role in the emergence of environmental problems. 7. Suggests solutions to prevent environmental pollution in local and global contexts. 8. Explain the importance of sustainability of natural resources. 9. Questions the importance of biological diversity for life, 10. Suggest solutions for the protection of biological diversity.
11	Elective Geography	1. Classifies environmental problems according to their causes. 2. Analyzes the use of non-renewable resources in terms of exhaustibility and alternative resources, 3. Evaluate the use of natural resources in countries with different levels of development in terms of their environmental impacts. 4. Analyzes the formation and diffusion processes of environmental problems in terms of their global effects. 5. Evaluate the sustainable use of natural resources in terms of recycling strategies.
12	Elective Geography	1. Compares the policies and practices of countries with different levels of development toward the prevention of environmental problems, 2. Explains the effects of environmental organizations and agreements on environmental management and protection.
	Biology	1. Explain the effect of environmental conditions on the persistence of genetic changes, 2. Gives examples of artificial selection practices in agriculture and animal husbandry

In general, the total number of student learning outcomes related to "Nature and Environment" education among the 552 learning outcomes given in the courses in 12-year compulsory education programs is 88 learning outcomes and constitutes 15.9% in total. Outcomes related to nature and environment education are presented to students in different units in courses such as science, social studies, life science, geography, and biology. It is seen that there are only 9 achievements in total in agriculture. In 12-year compulsory education programs, when nature and environmental education courses are examined in terms of sustainability, it is seen that a significant portion of the outcomes in the programs are aimed at developing knowledge and attitudes, while they are insufficient in terms of developing values, understanding, and skills. The main objectives set in these programs focus on topics such as knowing the environment, understanding the environment, understanding the relationship between humans and the environment, keeping the environment clean, and being responsible for the environment.

According to Tanrıverdi (2009), it was stated that 8-year compulsory education and training programs were prepared for the understanding of protecting the existing environment rather than sustainable environmental education and that there were no compulsory or elective courses under the name of sustainable environment or environmental education in primary education programs. In their study, Uzun & Sağlam (2007) found a significant difference between the mean knowledge and attitudes towards the environment of the students who took and did not take the elective course "Environment and Human" in the secondary education program in favor of the students who took the course.

According to Chu et al. (2007), an environmental literacy questionnaire consisting of 69 items and 13 demographic variables was administered to 969 third-grade primary school students. Accordingly, 62% of the students answered the questions in the knowledge dimension of environmental literacy correctly. However, it was observed that students had deficiencies in terms of the relationship between plants and animals and the energy and food chain of plants, humans, and animals. It was determined that female students had a higher level of environmental literacy than male students.

In the study conducted by Akçay & Şengül (2023), 1248 students studying in public and private schools in Isparta were surveyed using the "Environmental Literacy Scale". It was found that the environmental literacy levels of female students were better than male students, there was a significant difference between public and private school students in favor of public schools, and those who followed environmental magazines and social media or television were significantly higher than those who did not, and the environmental literacy of those who thought that the environmental education they received was sufficient was significantly higher than those who did not.

According to İmam (2018), as a result of the correlation analysis between environmental literacy components knowledge, attitude, and behavior scores, a negative correlation was found between environmental attitude and environmental knowledge test average, and a positive correlation was found between environmental behavior and environmental attitude. Therefore, it was revealed that students should be given more information about environmental education.

According to Nordahl (2009), change and development in food and agricultural culture should start in primary and secondary schools. This is because safe and healthy food and nutrition choices taught early in life will lead to healthy living habits. Therefore, in many countries, urban agriculture education is included as part of the curriculum in schools.

Increasingly unhealthy eating habits and obesity in children today reveal the importance of education at a young age.

The Martin Luther King Jr. School in Berkeley, Berkeley, USA, has an "Edible School Garden" consisting entirely of organic produce and encouraging children, teachers, and families to learn more about food, nature, and healthy eating. The program aimed to create an organic garden and landscape that is fully integrated into the school's curriculum, culture, and food program. The Edible School Garden is part of the curriculum for all students at the school. In the fall, as part of the curriculum, sixth graders start learning in the garden and seventh graders in the kitchen. Eighth graders use the garden for science lessons. Come spring, the classrooms return to the trading floor. The Edible School Garden program is visited by more than a thousand people each year from all over the world. Inspired by this program, hundreds of kitchen and garden programs have been established in schools across the United States (Nordahl, 2009).

Agricultural literacy or ecological literacy in schools cannot be realized only through the information provided in the curriculum. School gardens are important open landscape spaces (gardens) where children can integrate with ecological factors and where the knowledge they acquire can be transformed into action. These spaces should be of appropriate size and functionality according to the activities to be carried out.

Many scientific studies have identified the positive effects of school gardens on children, such as improving academic performance, providing opportunities for science-based education, increasing nutrition and environmental awareness, connecting children to nature, and social and cognitive development (Heerwagen, 2011; Gray et al., 2017).

Since the building and landscape spaces in schools in Türkiye are not designed for functional and aesthetic purposes, the landscape spaces are generally small and covered with hard ground and do not allow for the desired agricultural or ecological activities. School gardens are used only as sports and playgrounds and partly as ceremonial areas.

4. Conclusion and Suggestions

Ecologically-oriented education and ecological awareness raising are among the top priorities in solving current problems such as population growth and environmental problems, negative consequences of climate change, pandemic, cost of living, carbon economy effects, and unemployment in the world and Türkiye.

Today, food supply, safety, production, processing, transportation, distribution, consumption, loss, and waste have become unprecedentedly important for everyone. In particular, climate and environmental changes, the COVID-19 pandemic, and related lockdowns have further increased the importance of the food system. Rapid urbanization brings local policies and approaches to the urban food system to the fore, given the links with the built environment, consumption, and nature. Cities offer an opportunity to rethink the management of food systems (Gül, 2022).

In this context, agricultural literacy and a well-educated society are needed for the development and sustainability of the agricultural sector, which has become a vital sector in the global economy, and for the creation of a safe, healthy, and affordable food system and policies.

The main purpose of today's modern education and training system is to raise responsible, ethical, and conscious individuals with knowledge, skills, and competencies integrated with our human and national values. As a result of the acquisition of knowledge, skills, and competencies through curricula, the individual's attitudes, and behaviors are reflected in their attitudes and behaviors, gaining habits, assuming responsibility, and reaching conscious awareness through the processes of transforming them into action.

It is well known that the earlier the education is given, the earlier the gains will be acquired (İmam, 2018). Therefore, starting environmental education at an early age will be the right decision for the future. Because the knowledge and interest formed in preschool ages will also affect the child's future preferences, attitudes, and behaviors. Children and young generations form the basis of the social structure that the society will eventually change and evolve.

Ecological literacy should be one of the important components of primary and secondary education programs. Considering the potential of our country as an agricultural country, there is a need to start agricultural literacy with course outcomes in the primary education program and integrate it with applied agricultural activities in secondary education.

The main objectives in the process of agricultural literacy education can be summarized as follows;

- Raising awareness about agriculture and agricultural products and developing sensitivity in this regard,
- Collecting information on agricultural problems,
- Developing the right attitudes and behaviors about agricultural production and consumption,
- Promote a conservation and sustainable philosophy for agricultural activities,
- To develop the ability to identify, understand, and solve problems and needs in agricultural issues,
- Ensuring active participation in action for agricultural activities.

In the context of creating and developing agricultural literacy and ecological literacy in schools, recommendations can be summarized as follows;

- Urban agriculture needs to be recognized and supported by public institutions and organizations and included in their management policies. To this end, the Ministry of National Education in particular should envisage administrative policies and strategic actions to incorporate urban agriculture into the curriculum and school spaces.
- ○ Agricultural literacy in schools requires an experiential and cyclical learning process. It should involve an initial focus on acquiring knowledge and learning, interacting and reflecting on the topic, making generalizations, and then translating these generalizations into action to test them.
- Environmental education should not be taught under the title of life science, biology, and geography courses, but as a separate course called sustainable environment. It should be made a compulsory course in all schools. Or the number of environmental units should be increased.
- Specially prepared documentaries and videos about ecology, agricultural activities, and nature should be shown in the lessons. Barbas et al. (2009) stated that environmental documentaries positively affect students' environmental sensitivity and improve their environmental knowledge.
- To provide "Agricultural Literacy" in 12-year compulsory education and training programs in our country, the main topics can be suggested as; Agriculture - ecology (environment) - relations with nature, agricultural and animal products, plant production techniques, plant-

water relationship, plant-soil relationship, vegetable and fruit types, water production and use, evaluation of organic residues, compost fertilizer making, agricultural product processing and marketing, clean and healthy food safety and standards, climate change and agriculture relationship, etc.

- School management and administrator vision a very important factors in the development of ecological literacy. Because in schools where there is working peace with teachers, the vision, attitude, and behavior of the administrator, the interests and wishes of teachers emerge as an important factor in bringing nature and environmental education to students. Tokgöz & Önen (2019) stated in their study that the degree of relationship and interaction between the vision, purpose, attitude, and behavior of the manager in the school environment and the wishes, working goals, attitudes, and behaviors of all employees is the most important factor in the emergence of stress.
- The success of agricultural literacy and ecological literacy education is directly related to the quality and quantity of trainers. May (2000) stated that teaching conditions, teacher competencies, and teaching practices are effective in environmental education. Therefore, teachers should be well-informed and well-equipped.
- Since the use of project-based learning in agricultural literacy education and training practices will be very beneficial, the production of projects to be supported by various funds should be prioritized.
- Agricultural literacy should be trained not only for students but also for their parents simultaneously and in a coordinated manner. Because in the research conducted, it has been determined that students whose

parents are educated are more conscious and sensitive to the environment.

- Joint activities such as panels, symposiums, interviews, competitions, etc. should be organized by experts, universities, cooperatives, and NGOs on different topics related to agricultural literacy. Establishing agricultural cooperatives in urban areas and encouraging cooperation with educational institutions will be of great benefit.
- Environmental education should not only be taught in the classroom, but students' sensitivity to their environment should be increased by organizing environmental trips, nature walks, camps, and various activities. Activities in open spaces should be prioritized. This will positively affect social attitudes/behaviors and social relations.
- Environmental/nature protection clubs should be established in schools and supported by the school administration.
- Agricultural plots for vegetable and fruit production should be created in school gardens and actively used by students. Greenhouses for vegetable production can be established in the school garden according to the existing conditions.
- Vertical planting works can be carried out on roof and terrace gardens and wall facades in school buildings.
- Seeds, saplings, and plant materials for agricultural activities should be provided by relevant institutions.

Today, when the damage caused by human beings to nature and the environment is felt more and more every day, rational and sustainable nature-based solutions are needed more and more. Because the environment, which has been degraded by human hands, will only be possible with the efforts of human beings and their ecological consciousness on this issue. This ecological consciousness should be within the integrity of ecological ethical discourse and action of an organized society that accepts life and consumption habits in a way that does not harm nature, is in harmony with nature and enjoys it, knows the limits of ecological balance, is aware of the environmental problems where it lives and can take responsibility for solving these problems.

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All authors contributed equally to the article. There is a conflict of interest with the Person(s) named.

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Cultivating Resilience with Rooftop Gardens in Urban Areas

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1. Introduction

Global urban population increased tremendously with the onset of industrialization. Due to the housing needs of the population in cities, a dense structural urban fabric has been formed by destroying open and green areas. Open and green areas are the extensions of the natural environment within the city where the city is settled, and these areas have positive effects on the city from an aesthetic point of view, besides contributing to human psychology, urban climate and food security (Köylü, 1997; Kınalı, 2013). The land allocated to open and green spaces is extremely limited in many settlements of the world. At the same time, as new buildings are constantly constructed, the proportion of areas allocated to open and green areas decreases day by day (Mathieu et al., 2007). The problems caused by the decrease in green texture in urban areas have led to an increase in the interest in rooftop gardens. The balance between the green texture and the city can be restored by rooftop gardens (Ercan, 1992).

The rooftop garden denotes a cultural landscape realized above the natural soil level with the simplest explanation (Tunbiş, 1987; Güneş, 1996). There are conceptual differences in the world regarding the definition of rooftop gardens. Ekşi's study (2014) that the planted roof, planted building shell, ecological roof, roof and terrace garden, environmentally friendly roofs and green roof concepts are used instead of the term rooftop garden in Turkey. While green roof refers to systems with low irrigation and maintenance needs and low depth of the growing environment, rooftop garden refers to the formation of a garden on the roof that could also be replicated at ground level. The most commonly used term in our language is the term “rooftop garden”, which is also included in the legislation (Ekşi, 2014). The first rooftop garden was built by Kaiser Industries Company in Oakland California in 1959. Since the 1960s, rooftop gardens have been realized in many settlements around the world (Ercan, 1992).

It is possible to evaluate rooftop gardens both on the scale of buildings and in the class of green spaces in urban areas. On a building scale; the roof system is more durable in a building with a rooftop garden and heat loss is lower due to its special design (Aksoy & İçmek, 2010; Barış et al., 2012). On the urban scale, the creation of green areas on roofs supports controlling rainwater flow and quality, reduces the urban heat island effect, and contributes to food supply by agricultural activities carried out in rooftop gardens. Rooftop gardens are systems that improve air quality, reduce urban heating, produce innovative solutions to the problems created by rainwater, and offer recreational activities and/or living space alternatives (Aras, 2019).

The inclusion of building sections such as roofs, terraces, closed garage top, etc. in urban green areas can contribute to creating resilient cities besides providing aesthetic benefits in rapidly developing cities. When urban systems are not resilient, the result is the fragility of this human-made environment in the face of adverse conditions such as disasters. The resilient city is mainly defined in relation to issues such as sustainability, climate change, water management, food security, and disaster risks (Kavanoz, 2020). Urban resilience is not related to structural resilience alone, it also includes taking measures to ensure sustainability in the urban fabric in the face of global events such as climate change. This chapter of the book attracts attention to the potential of rooftop gardens in fostering urban resilience in the face of economic, environmental, and social difficulties faced today.

2. The Effects of Rooftop Gardens in Urban Areas

In addition to the aesthetic value that rooftop gardens bring to the urban landscape, they provide many potential benefits for people living in an urban area (Figure 1). These benefits can be grouped under three headings: economic, environmental and social (Tolderlund, 2010; Özyavuz et al., 2015).

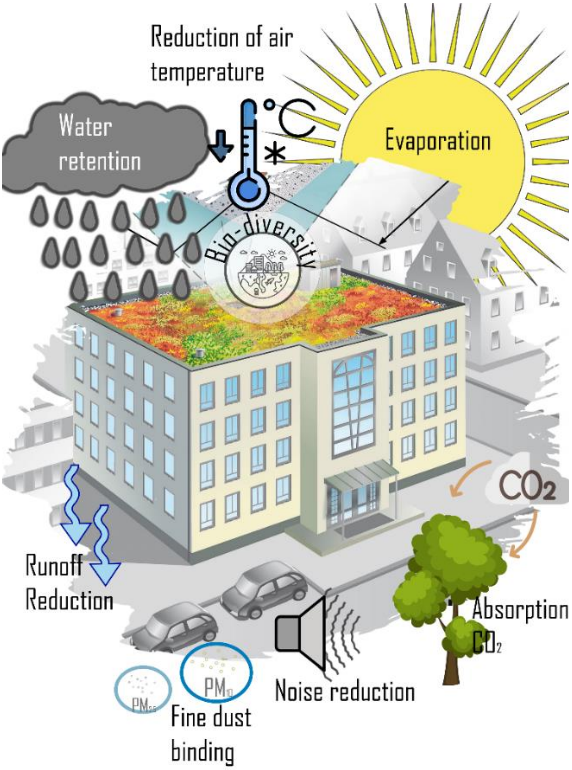


Figure 1. The benefits of rooftop gardens (Adapted from URL-1).

***Economic Benefits**

- •Reduces heating and cooling costs for buildings by providing energy efficiency,
- •Prevents fire or its rapid spread,
- •Creates business opportunities for the regional and national markets,
- •Rainwater stored in the rooftop garden can be used in areas of need (cleaning, car washing, irrigation, etc.).

***Environmental Benefits**

- •Enhances biodiversity and conservation by creating living spaces for habitat,
- •The plants used in the rooftop garden support urban heat island control with their cooling effect,
- •Improves air quality by capturing air pollutants via plants,
- •Ensures rainwater management.

***Social Benefits**

- •Provides recreational opportunities by creating resting and social meeting places,
- •Contributes to the aesthetics of the urban environment by creating an additional "green" area,
- •Prevents electromagnetic radiation,
- •Reduces noise,
- •Offers potential space for food production to cities.

Due to the environmental problems caused by climate change and ecological degradation, we can predict that the positive contributions of rooftop gardens to urban ecology and food security will become increasingly important compared to their contributions to urban aesthetics. The creation of rooftop gardens constitutes a fundamental way of providing food security, increasing biodiversity, reducing the negative effects of climate change and increasing human comfort.

3. The Effects of Rooftop Gardens on The Urban Climate

The change in land cover, manifested by the increase in built-up areas in urban areas disrupts the heat balance of the urban atmosphere. Concrete and asphalt-covered grounds prevent water from penetrating the soil. Heat differences are observed between open areas and urban areas as a result of the building masses that hold the energy from the sun in cities, reflecting the energy they accumulate at night. As a potential solution to this problem, rooftop gardens prevent the increase of surface and air temperature by replacing the vegetation that disappears with the construction in urban areas. The studies conducted detected that rooftop gardens provide an important cooling effect to cities (Takakura et al., 2000; Wong et al., 2003; Rosenzweig et al., 2006; Sun et al., 2012; Coutts et al., 2013; Santamouris, 2014).

3.1. Impact on the Formation of Urban Heat Island

As a result of the reduced vegetation, heat accumulates in structured areas, the urban environment has higher atmospheric and surface temperatures compared to rural areas (Figure 2). The urban heat island effect is structures absorbing solar heat during the day and releasing it back into the environment at night. The heat island effect prevails throughout the urban area due to the decrease of open and green areas with increasing construction, the use of heat-trapping materials in buildings (albedo value), changes in soil structure, etc. (Oke, 1981). As a result of the urban heat island effect, along with irregular precipitation, and disasters such as inundation and floods, water availability decreases, and increased heat waves threaten the health of the urban population, and a food crisis is looming (Uncu, 2019). The uncontrolled increase in population together with urbanization and the increasing use of fossil fuels by this population destroys the green texture of the structural areas resulting in the replacement of the structural areas with dark colored surfaces that have the characteristics of retaining more heat, which also results in wind and air currents not reaching urban surfaces due to irregular structural texture exacerbate the urban heat island effect and cause cities to heat up more than rural areas (Tokaç, 2009). For this reason, rooftop gardens are used to create green space in cities which are among the effective methods for reducing the urban heat island effect (Aras, 2019).

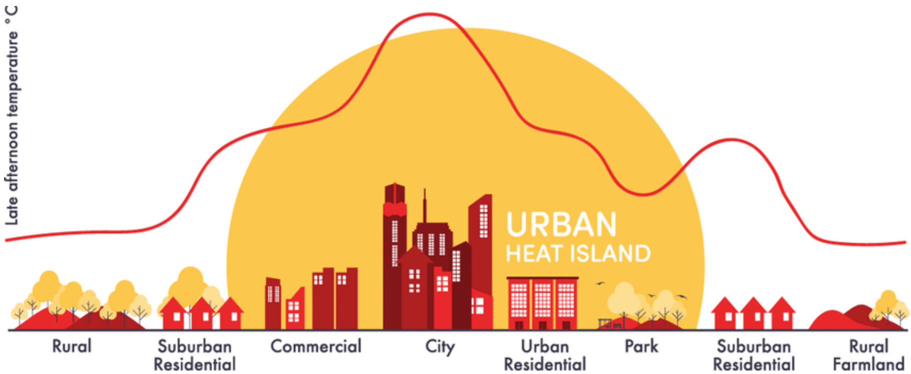
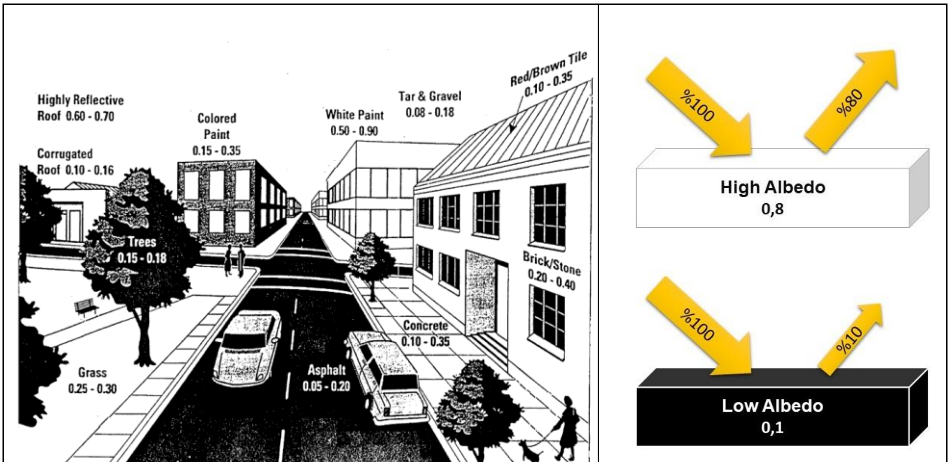


Figure 2. Urban heat island effect (URL-2).

Rooftop gardens have a cooling effect on the air and surface temperature in cities, as they remove heat from the air and provide shading. Therefore, rooftop gardens are considered one of the most effective and practical tools in controlling the urban heat island effect (Jamei et al., 2021). Temperature increase is balanced thanks to the evapotranspiration, shading and heat storage properties of the plants placed in the rooftop gardens. Evapotranspiration means that the plant releases water vapor into the atmosphere through evaporation and transpiration. The amount of heat required for the evaporation of the water contained in the plant is provided by infrared rays coming directly or indirectly from the sun to the surfaces (Yüksel & Yılmaz, 2008; Kınalı, 2013). The urban heat island effect decreases in cities by preventing these rays from increasing the surface temperature. In winter months, the soil layer provides additional insulation and saves energy by reducing the heating requirement of buildings, and in summer months, it directly affects both the internal and external environment of the building by preventing high roof temperatures (Kariptas, 2010). Santamouris (2014) found that if rooftop gardens are placed on an urban scale, the air temperature can be reduced by 0.4 °C in his study. In a study conducted in Toronto, urban area was compared to rural areas and a 2-3 ^{o}C higher temperature was found, and if the rooftop garden system is applied to buildings by 50%, the average air temperature would decrease by 1-2 ^{o}C (Bass et al., 2002). In their study, (Jamei et al., 2021) found that rooftop garden applications in regions with arid climates have a cooling effect of 3^{o}C, while rooftop garden applications in cities with hot-humid climates have a cooling effect of 1 ^{o}C. In a study conducted in Ottawa, measurements of green roof and conventional roof systems over the course of a year showed that green roof heat losses were reduced by

26% compared to conventional terrace roof systems (Kınalı, 2013). Thus, the consumption of electrical energy for heating and cooling purposes, therefore, CO_2 release decreases. Another study showed that agricultural roofs with plants reduced the temperature from 1.2% to 4.3% compared to conventional roofs (Begum et al., 2021).

The main recommendations for roofs to improve urban comfort are to increase the albedo value of roofs, known as cool or reflective roofs, or to fully or partially cover rooftop gardens with vegetation (Sfakianaki et al., 2009; Zinzi, 2010; Susca et al., 2011). The roofs' heat flux decreases and the surface temperature drops in both methods. Albedo is the capacity of a surface to reflect light falling on it (Figure 3). The surface albedo value affects the absorption and reflection of solar radiation.



Source: Huang & Taha, 1990; Bencsik & Háber, 2018 | Source: Adapted from URL-3

Figure 3. Albedo values of surfaces in urban areas.

The albedo value of a surface (a non-unit indicator between 0 and 1) has an impact on energy use, local air quality and greenhouse gas concentration during the hot season (Taha, 2008). The transformation of dark roofs into rooftop gardens throughout the urban space provides benefits both on a micro scale and on the urban scale. Replacing a one-square-meter dark-colored roof with a green roof reduces about thirty-eight kilograms of CO_2 release. At the same time, the construction phase of the rooftop garden emits less carbon than a traditional roof. A green roof requires less replacement of building materials over time and; as a result, has less negative effect on climate change than a traditional roof (Susca et al., 2011).

A light-colored roof with a high albedo value absorbs less sunlight than a traditional dark-colored roof. Less absorbed sunlight means a lower surface temperature (Akbari et al., 2009). Tsang & Jim (2011) found that traditional roofs with an albedo of 0.15 can store 75% more heat than rooftop gardens with a high albedo of 0.7 in their study. The albedo value varies between 0.7 and 0.85 in rooftop gardens, while this value is between 0.1-0.2 in conventional roofs (Berardi et al., 2014). Increasing the albedo value of urban surfaces such as roofs and sidewalks improves urban air quality and reduces the temperature in summer (Pomerantz et al., 1999). Increasing the surface albedo value is an effective way to reduce both energy use and the impact of climate change. The use of green roofs to increase the albedo value of cities offers the potential of reducing urban heat islands (Santamouris, 2014). It shows that rooftop gardens can significantly improve the thermal environment at the roof level, increase the albedo value of the city, and reduce the urban heat island effect (Knaus & Haase, 2020).

3.2. Impacts on Storm Water Run-Off

As a result of urbanization, impermeable surfaces such as roofs and roads increase, soil becomes compacted, vegetation decreases and changes in general (Ercolani et al., 2018). These changes can prevent stormwater infiltration into the ground, increase stormwater runoff, and increase pressure on existing stormwater infrastructure. Reducing hard surfaces and increasing permeable surfaces in urban environments can contribute to the healthy functioning of the hydrological cycle by preventing or delaying the transition of rainfall to surface runoff (Kural, 2010). Rooftop gardens slow down stormwater runoff compared to conventional roofs (Figure 4). This is because a certain amount of water is retained in the rooftop gardens. Some of the retained water is discharged and the rest is used by plants or evaporated. Factors affecting the flow and water holding capacity in rooftop gardens are given below (Berndtsson, 2010):

•Characteristics of a vegetated roof: Material type, soil type, vegetation cover, soil thickness, vegetation type, roof geometry (slope ratio) and roof position

•Climate conditions: Air temperature, humidity, wind, length of the ongoing dry period, rainfall intensity and rainfall duration.

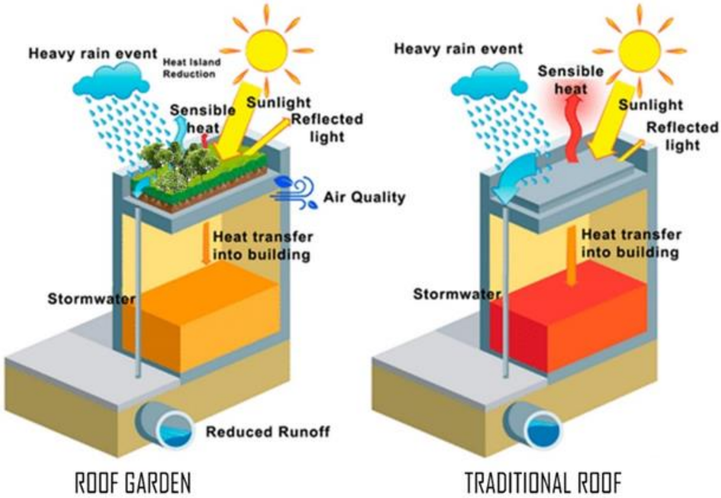


Figure 4. Comparison of the rooftop garden and the traditional roof (adapted from Fraga et al., 2021).

The plants used in the rooftop gardens slow down the excess rainwater so that the rainwater coming down from the roof of the building contributes to the groundwater instead of entering the city's drainage system. Chen & Chen (2021) proved in their study that when food is produced in rooftop gardens, it contributes to increasing water retention capacity, reducing the runoff volume and peak runoff duration of surface rainfall. The study found that the water retention capacity varied between 28.2% and 41.0% depending on the rainfall intensity.

4. The Effects of Rooftop Gardens on Food Security

A significant portion of agricultural land in and around the city is being lost to other uses, and these changes raise concerns about food security (Carey et al., 2011; Mok et al., 2014). Spatial limitations in urban areas create obstacles for agricultural activities. The roofs of buildings occupy a significant part of the urban fabric as unfunctional spaces (Whittinghill &

Starry, 2016). For example, there are 15,482 hectares of roof surface in New York City, 445 times the area covered by existing community gardens (Ackerman et al., 2013). Including agricultural activities even in a very small part of these idle areas offers important opportunities for the development of urban agriculture and thus food security (Bakkaloğlu & Şahin, 2022). Urban agriculture is a movement towards various goals, including food security, stormwater management, urban sustainability, urban heat island mitigation, and waste management (Harada & Whitlow, 2020). Food produced around houses represents the smallest scale of urban agriculture, including on rooftops and terraces. Agricultural activities can take many forms in cities (Grewal & Grewal, 2012). Urban agriculture activities are analyzed under three headings in terms of scale of implementation (Table 1).

Table 1. Urban agricultural activities, application scale (Pearson et al., 2010).

Micro scale	**Meso scale**	**Macro scale**
Rooftop gardens	Community gardens	Commercial farms
Balcony/ walls	Individual collective gardens (allotments)	Nursery
Courtyards	Urban parks	Greenhouses
The garden	School gardens	
Street verges		

Rooftop gardens contribute to food security (Pulighe et al., 2016). A study found that 650,000 m^2 of rooftop gardens growing vegetable crops in Canada could yield 4.7 million kg of produce per year (Peck, 2003). Urban flat roof surfaces in Bologna were found to cover 82 hectares, covering 77% of the urban vegetable demand. Based on estimates of potential carbon storage, rooftop gardens in Bologna sequester about 624 tons of CO_2 per year (Orsini et al., 2014). Rooftop gardens create opportunities for food supply in dense urban areas and, thanks to their contribution to nature and the environment, they are systems that can produce solutions to the problems caused by climate change. In addition, rooftop gardens can contribute to preventing climate change by reducing the level of carbon emitted during the supply chain through reduced food transportation distances. In this context, agricultural activities in rooftop gardens in urban areas are recognized as green technology in cities with socio-economic and environmental benefits.

Green spaces, such as urban roof agriculture, help improve the economic conditions and environmental quality of urban dwellers and offer the potential to provide fresh fruit and vegetables as a potentially healthy food source for them. Rooftop gardens contribute to the creation of resilient urban spaces and can facilitate a city's access to food in the face of a crisis (e.g., natural disasters, food security, pandemic, etc.).

5. Conclusion

Globally, urban built-up areas are growing faster than the population, leading to large-scale changes in land cover/land use patterns. As a result, various ecological and environmental problems have arisen and resulted in economic, social and environmental issues globally (Esringü & Toy, 2021; Naikoo et al., 2022). The different functions, service areas, types of use and sizes of green areas in the city reveal their impact on the quality of urban life. The protection and development of open and green areas also serve to regulate climatic conditions by contributing to the food supply in cities, lowering surface and ambient temperatures and reducing the heat island effect (Gedikli, 2020). There is an effort to meet the public's need for green spaces with planned rooftop gardens in the urban environment where open and green areas are gradually decreasing in many cities of the world (Aksoy & İçmek, 2010). Rooftop gardens may make an important contribution to building resilience in cities with their positive economic, social and environmental impacts. Since there is unused space in dense urban areas that can be converted into green spaces, constructing buildings suitable for the development of rooftop gardens, rather than constructing buildings with traditional roof systems, is essential for creating resilient cities. Creating low-carbon resilient cities and resilient infrastructure is emphasized in many of the United Nations' 17 Sustainable Development Goals. Within this scope, urban rooftop gardens and urban roof agriculture have the potential to play an active role in building resilience in cities thanks to their contribution to food security and urban climate in line with Goals 2 (zero hunger), 3 (good health and wellbeing), 11 (sustainable cities and communities) and 12 (responsible consumption and production) of the Sustainable Development Goals. The functions of the existence of rooftop gardens in the urban areas, described in more detail on the previous pages, can be summarized as follows;

- Allocating space for rooftop gardens throughout the city increases the albedo value of the urban environment and balances the thermal budget of cities by expanding green spaces.
- Urban agriculture in rooftop gardens reduces the storage time and transportation requirements between harvest and consumption, contributing to lower operational carbon emissions and thus reducing the heat island effect. It also improves air quality by reducing emissions released into the atmosphere.
- Has a positive effect on biological diversity.
- Contributes to urban aesthetics and reduces noise.
- Reduces energy usage in buildings in summer and winter months.
- The plants in the rooftop garden provide shade commensurate with their physiological activities, air cooling and dust retention, and structural features.
- They offer an environment for the storage and reuse of rainwater, thus also serving to reduce urban stormwater surface runoff.

The first step in achieving the benefits described above should be to plan the prioritized areas for the development of rooftop gardens in urban areas, and then manage them according to the success criteria and evaluation techniques to be determined. The ecological and socio-cultural characteristics of each city and its urban landscape character will provide the baseline information for the first step. In general terms, rooftop garden planning and management phases are proposed below. Detailed scientific studies are needed for each stage of landscape-based urbanization.

1. Determination of Priority Development Areas for Rooftop Gardens

Priority areas for rooftop gardens should be planned by considering the building density, building volume, temperature, and wind generation of the city in line with the benefits that can be provided by rooftop gardens in combating climate change. For this purpose, plant density analyses based on remote sensing data and associated urban climate zone maps should be utilized (Ng et al., 2012; Yıldız, 2022), which can be realized with the help of Geographic Information Systems. It is also recommended to conduct a landscape character analysis and assessment (Şahin et al., 2014) in urban areas to guide the identification of priority rooftop garden areas.

2. Rooftop Garden Performance Criteria

The following are the main achievement criteria proposed for the ecological, social, and economic benefits of rooftop gardens, including but not limited to;

- Integrity in the Urban Landscape
- Climate improvement potential
- Food supply potential
- Habitat provision and biodiversity
- Recreational opportunity
- Visual value

3. Performance Criteria Evaluation Technique and Integrated Urban Resistance Value

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The Role of Urban Agriculture in Cultivating the Adaptation to Climate Change and Sustainability in the Cities

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1. Introduction

The rate of urbanization is rapidly increasing both in the world and in Türkiye. In 2022, it was globally %57 (STATISTA, 2022) and %68 in Türkiye (TUIK, 2023). Urbanization results in the lack of open public places and the poor quality of urban residents' social and public lives (Aminoleslami Oskouei, 2019). Urban ecosystems are also harmed as a result of rapid urbanization, which also increases the need of urban residents for food and green lands. In addition to the detrimental effects of urbanization, climate change experienced in recent years has also caused significant damage to the urban ecosystem. One of the key strategies for minimizing harm to the urban ecosystem and its inhabitants is urban agriculture.

Urban agriculture is advantageous as a practice in both post-industrial and developing cities because it refers to the three aspects of sustainability including economics, society, and the environment (Ackerman et al., 2014). It helps cities, where the majority of the population lives, become more sustainable, and self-sufficient, and have more employment opportunities. Also, urban agriculture on top of buildings is one of the best ways to utilize unused space in cities (Andrade, 2022; Türker & Akten, 2023). Due to these fairly significant roles of urban agriculture, numerous national and municipal authorities are developing and putting into practice new urban agricultural initiatives (Anaafo & Akolgo, 2018). To make cities more sustainable and resilient, government policy should establish the ideal conditions for the best growth of the social, economic, and ecological benefits of urban agriculture (Ara, 2018).

Urban agriculture is a valuable driver of innovation. While urban agriculture cannot feed all cities (potential yields are very low and limited to certain types of food), it is recognized as a strategy that can help create resilient urban food systems that enable organic connectivity between cities and agriculture. In addition, urban agriculture plays a vital role in climate change mitigation and adaptation, disaster risk management, and increasing the climate resilience of vulnerable residents (Gül, 2022).

This chapter explains urban agriculture, climate change and its effects on the cities, and sustainability in the cities, and also elaborates on the role of urban agriculture in adapting the climate change and sustainability in the cities based on detailed literature.

2. Urban Agriculture

Urban agriculture has a longstanding history dating back to the inception of cities. However, its prevalence has diminished in modern urban landscapes characterized by high population density and towering structures. In today's context, the significance of urban agriculture has resurged due to environmental apprehensions linked to extended food transportation, which often compromises freshness. Moreover, the aftermath of events like the COVID-19 pandemic has underscored the importance of convenient access to locally cultivated produce as a viable food source within urban areas (Bhattarai & Adhikari, 2023). This has transformed urban agriculture into both a movement and a distinct land-use category (Bohn & Viljoen, 2016).

Urban agriculture, sometimes referred to as urban farming, involves the cultivation of food within urban areas, serving either personal consumption or small-scale commercial objectives (Bhattarai & Adhikari, 2023). The broader definition of urban agriculture encompasses the growth of crops and the raising of limited livestock within city confines, intended for household use or to be sold to urban consumers (Hodgson et al., 2011; Poulsen et al., 2015). Although the term "Urban Agriculture" is relatively recent in policy discussions, the underlying concept revolves around reshaping the utilization of natural resources in urban settings. This aims for a more health-conscious approach, fostering enhanced comprehension and education regarding food production origins and methods (Vejre & Simon-Rojo, 2016).

Urban agriculture is classified as part of the informal sector due to its shared characteristics with it. These characteristics include easy accessibility, reliance on local resources, labor intensity, absence of formal training, and the presence of irregular markets. In the midst of urban landscapes dominated by concrete structures, urban agriculture is viewed as a beacon of hope, representing the ability to thrive (Ara, 2018). A comprehensive systems definition recognizes the interrelation of urban agriculture with the broader food system, alongside its impact and reliance on diverse economic, environmental, and social factors. Notably, urban agriculture encompasses a scope that extends beyond just private and community gardens (Hodgson et al., 2011). Drawing from a study that examined 62 peer-reviewed articles spanning from 1993 to 2022, it is evident that a more comprehensive grasp of urban agriculture is necessary to support strategies that effectively integrate this practice within urban environments (Kanosvamhira, 2023).

Urban agriculture stands apart from traditional rural agriculture primarily due to its distinctive spatial and functional aspects (Vejre & Simon-Rojo, 2016). The social, economic, and environmental roles of urban agriculture yield both positive and negative outcomes. Notably, the advantages of urban agriculture, particularly in ecological and social dimensions, have been vastly underestimated (Azunre et al., 2019). Urban agriculture assumes a crucial role in supplementing the dietary needs of residents (Bhattarai & Adhikari, 2023).

There are four potential advantages associated with promoting urban agriculture: enhancing food security and nutrition (Delbridge & Ngoga, 2021), generating income (Battersby & Watson, 2019), fostering improved environmental preservation (Camargo Nino et al., 2020), and cultivating social inclusivity (Parece & Campbell, 2017; Ghosh, 2021; Nowysz et al., 2022). Urban agriculture can serve as a productive facet of cities, rendering vital environmental and social services that contribute to and uphold urban communities. These advantages encompass substantial biodiversity provision and ecosystem services that enrich urban nature and environmental processes. Additionally, they encompass diverse social benefits such as sustenance, cultural resources, and recreational advantages (Lin et al., 2017). Therefore, urban agriculture possesses the potential to alleviate the strain resulting from the perpetual necessity to expand farmland to accommodate the burgeoning population. Furthermore, it aids in mitigating the prevalence of diseases frequently linked to industrially processed and long-distance transported food (Bhattarai & Adhikari, 2023). Community gardens bear numerous responsibilities including caregiving, infrastructure management, financial enhancement, event coordination, and educational opportunities creation (Temizel, 2022) (Figure 1).

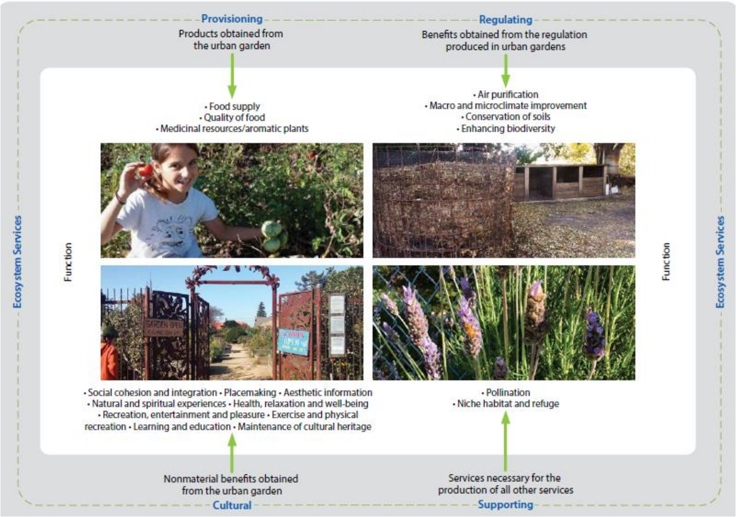

Figure 1. Ecosystem services provided by urban agriculture (Gómez-Villarino & Briz, 2022)

Urban agriculture has the potential to enhance the resilience of cities in the global North against various pressures and sudden shocks by bolstering food security and public health, fostering social cohesion, and advocating for circular economies (Gulyas & Edmondson, 2021). The implementation of urban agriculture is still relatively nascent and has yielded a broad spectrum of outcomes in terms of yields, water usage, energy requirements, and climate change effects, contingent upon diverse physical configurations, crops, and socio-economic contexts (Dorr et al., 2021).

Significant diversity exists in the objectives, sites, dimensions, production methods, and final outputs of various urban agriculture forms (Hodgson et al., 2011). Urban agriculture encompasses the establishment of food production hubs within urban domains. This includes practices like building-integrated agriculture, featuring concepts such as aquaponics, indoor farming, vertical cultivation, rooftop cultivation, and edible walls, alongside urban farms, food-producing landscapes, school gardens, and community gardens (Hodgson et al., 2011; Skar et al., 2020). Numerous cities already endorse urban agriculture by utilizing floodplains, introducing rooftop gardens in densely populated urban areas, integrating urban forestry into new housing projects, and safeguarding peri-urban greenbelts for local food generation (Dubbeling, 2019). Urban agriculture frequently occurs in community gardens, on building balconies and rooftops, within residential plots, and at times, within vertical structures. The methods of production encompass conventional planting, container planting, hydroponics, aeroponics, and vertical farms (Bhattarai & Adhikari, 2023).

A study (Dorr et al., 2023) conducted across France, Germany, Poland, the United Kingdom, and the United States, examining 72 urban agriculture sites, revealed that these sites utilized a variety of inputs, with a majority being organic (such as manure for fertilizers). On average, these sites required 71.6 liters of irrigation water, 5.5 liters of compost, and 0.53 square meters of land per kilogram of harvested food. Irrigation needs were lower in individual gardens and higher in sites employing drip irrigation. While outcomes varied widely, well-managed urban farms demonstrated the potential to surpass the yields of conventional counterparts. Notably, farm type did not necessarily predict yield; however, leisure gardens managed individually exhibited lower yields compared to other types. The study also highlighted the substantial contribution of these farms to local biodiversity, cultivating an average of 20 different crops per farm, excluding ornamental plants.

Nonetheless, urban agriculture presents both health and environmental risks. Factors such as previous land uses of these sites and their proximity to industrial areas, vehicular traffic, and pollutants require careful consideration. Potential land-use conflicts can also arise from urban agriculture practices. Mismanaged compost facilities, use of chemical fertilizers and pesticides, and subpar cultivation, harvesting, and animal-keeping practices can result in noise and odor disturbances (Hodgson et al., 2011).

Urban agriculture's effectiveness hinges on various factors such as climate, weather, light, insect and pest dynamics, available land or growing space, secure land tenure, uncontaminated soil or growing medium, water availability, labor availability, financial resources, agricultural knowledge and skills, processing and transportation infrastructure, distribution channels, consumer demand, and viable markets (Hodgson et al., 2011). The benefits derived from urban agriculture are context-dependent, influenced by geographical location, farmer characteristics, and regulatory frameworks (Delbridge & Ngoga, 2021).

The enhanced success of bottom-up urban farming initiatives could be achieved through a more informed adoption of place-based approaches (Cruz, 2020). Another study (Erişen, 2022), examining four community gardens in Ankara, underscored the significance of inclusive design, effective management and utilization, community interactions, voluntary participation, and spatial accessibility in nurturing social bonds within sustainable communities. The potential for home gardens to contribute to food production is contingent upon factors like plot sizes, land cover patterns, morphological urban/suburban forms, and socio-economic influences. Strategic policy support encompassing long-term planning, incentives, training, and skill development can significantly facilitate the integration of urban agriculture into residential land use (Ghosh, 2021). When managed through agroecological principles, urban gardens offer numerous environmental benefits to local communities (Gómez-Villarino & Briz, 2022).

Cities with substantial vacant lands can effectively sustain urban agriculture by thoughtfully integrating it into urban planning and zoning procedures (Azunre et al., 2019). Revitalizing vacant urban areas through urban agriculture not only ushers in new economic prospects but also fosters public spaces for recreation, ultimately fortifying the structural integrity of buildings and curbing vandalism (Andrade, 2022).

A systemic examination of urban agriculture patterns and functions can aid policymakers and urban planners in designing resilient cities (Dupuy et al., 2020). Sound urban planning policies should account for the diverse conditions and dynamics inherent in urban agriculture. This includes recognizing agriculture's role in urban sustainability, accommodating its impact on waste reuse and agro-industrial interactions, understanding its evolving dynamics and actors, and addressing social and political elements in policy implementation (de Zeeuw et al., 2011; Robineau & Dugue, 2018). Tailoring urban agriculture to a city's distinct characteristics is crucial, as it plays a vital role in the discourse of sustainable cities (Azunre et al., 2019).

In comparison to projects in developing countries that primarily target food security, urban agriculture in the Global North encompasses a more multifunctional perspective, leading to diverse combinations of farming goals and business models pursued (Orsini et al., 2020). In recent years, the urgency to understand the economic, environmental, and social functions of urban agriculture has grown, underscoring the need to manage it effectively to contribute to the well-being of cities. Additionally, the themes of urban agriculture-related sustainability and the water-energy-food nexus have emerged as significant research areas in alignment with international trends (Yan et al., 2022).

3. Climate Change and Its Effects on the Cities

Human activities, particularly the emission of greenhouse gases, have undeniably led to global warming, causing temperatures to rise by 1.1°C above pre-industrial levels. This has brought about significant alterations across the planet, affecting various aspects such as the atmosphere, oceans, and ecosystems. The consequences of climate change manifest in extreme weather events and disproportionately impact vulnerable communities. Despite ongoing efforts towards adaptation, there are still gaps and limitations, especially in less developed regions. Urgent and substantial reductions in greenhouse gas emissions are paramount to avert irreversible consequences (IPCC, 2023).

Cities, being central to human activities, play a pivotal role in addressing climate challenges. By adopting sustainable practices in urban planning, transportation, and infrastructure, cities can contribute significantly to mitigating climate change (IPCC, 2023). The rapid growth of urbanization, while presenting challenges like air and water quality concerns, can also be harnessed to create sustainable and thriving urban centers (OECD, 2014). However, urbanization contributes to the urban heat island effect, leading to heightened temperatures and increased risks like heatwaves, flooding, and air pollution (Rosenzweig et al., 2015).

The complexity of urban systems makes cities particularly susceptible to climate change impacts. Effective adaptation necessitates collaboration between stakeholders and the integration of climate indicators and monitoring systems (Rosenzweig et al., 2015). The capacity of local governments is crucial in driving adaptation efforts, which require an iterative process of learning, decision-making, and strategy revision in collaboration with various actors (UN-Habitat, 2011; Revi et al., 2014). Metropolitan areas must confront the tripartite tasks of diminishing their resident's susceptibility to climate change, curbing their greenhouse gas emissions, and ensuring an ample supply of nourishing sustenance for their inhabitants (Dubbeling, 2019).

Failing to implement adequate adaptation strategies will exacerbate health and other challenges in cities, where the majority of the global population resides (Barata et al., 2011). The implications of climate change reach beyond local contexts; they encompass global security concerns, affecting biodiversity, food security, sea levels, and water availability (de Zeeuw, 2011; Yönten Balaban & Akman, 2022). The interaction of climate change, urban heat islands, and air pollution threatens public health in cities, warranting immediate attention (Harlan & Ruddell, 2011; Kumar, 2021).

Human-induced climate change demands urgent action on various fronts. Cities are both vulnerable to its effects and vital in its mitigation and adaptation. Sustainable urban practices, effective governance, and international cooperation are essential to creating livable, resilient urban environments in the face of a changing climate. By recognizing the interconnectedness of these factors and implementing comprehensive strategies, cities can thrive while contributing to the broader global effort to address climate change.

4. Sustainability in the Cities

Lately, the notion of a sustainable city has gained significant prominence. This increased prominence of the concept is driven by the swift global urbanization and its consequential impacts on the environment's overall quality (Azunre et al., 2019). Cities are now expected to play significant roles in countering the adversities of climate change by shifting to low-carbon practices, and renewable energy sources and thus strive towards climate-resilient growth and development (Sen, 2023).

The concept of a sustainable city aims to minimize environmental impact while maintaining essential natural systems for human well-being. This involves integrating social values, legal structures, organizational capacity, financial resources, and comprehensive infrastructure to foster eco-conscious communities. Sustainable cities promote eco-friendly behaviors, manage waste, adopt renewable energy, and establish efficient transit systems, confronting challenges through investment, planning, and persistence. The fusion of these elements drives environmentally friendly urban development. As technology advances, sustainable cities become essential to balance human needs with ecological preservation, addressing resource consumption and social disparities through innovation and governance. By connecting people, places, and nature, these cities offer thriving urban centers while safeguarding the environment (Cohen, 2018). In addition to ecological considerations such as water and energy conservation, recycling of waste, and transportation, social considerations like enhancing the quality of life, fostering community bonds, and empowering residents are fundamental to the concept of urban sustainability. Food plays a vital role in urban sustainability initiatives (Cosgrove & Sati, 2019).

Characterized by compact, efficient urban structures, sustainable cities prioritize productivity, reduced costs, and minimal environmental impact. They provide secure, healthy environments with affordable housing, vibrant streets, and accessible essential services, often within walking distance or integrated transit systems (The World Bank, 2018). Sustainable and inclusive city industrialization fosters synergies by decoupling economic growth from environmental degradation, creating jobs, and driving clean energy innovation. Industries play a role in efficiency, clean energy solutions, and sustainability initiatives, contributing to a city's overall progress (UNIDO, 2016). Public involvement is crucial for proper sustainable city development, ensuring current needs are met without compromising the future (Ojo-Fafore et al., 2018). While emphasizing environmental dimensions and municipal context, the efficient collection of environmental data is essential for effective decision-making (Kongboon et al., 2021).

5. Urban Agriculture for the Adaptation to Climate Change and Sustainability in the Cities

Across the globe, the utilization of urban gardening as a means to bolster cities' ability to withstand the effects of climate change is progressively gaining traction (Burchard-Dziubińska, 2021; Andrade, 2022). Cities can reinforce this role by integrating it into climate adaptation strategies that actively involve public health, prioritize nature-oriented solutions, and place a greater emphasis on food security and dietary well-being (Sheehan, 2023). An inventive approach to fortifying cities' resilience against climate change threats and enhancing their adaptability involves the adoption of urban agriculture (de Zeeuw & Dubbeling, 2009; Dubbeling & de Zeeuw, 2011; Vásquez-Moreno & Córdova, 2013; Karienye et al. 2015; Anaafo & Akolgo 2018; Dubbeling et al., 2019; Dushkova & Haase, 2020; Belay, 2022; Gianfrancesco, 2022; Orsini & D'Ostuni 2022; Ebissa et al., 2023). Investments in agricultural practices and green infrastructure have proven to be more economically efficient compared to traditional approaches for mitigating the impacts of climate change (Dubbeling, 2019). The favorable outcomes of urban agriculture encompass decreased vulnerability among the urban underprivileged population, heightened ability to cope with challenges, diminished repercussions of heightened rainfall, and lowered urban energy consumption and greenhouse gas emissions (de Zeeuw, 2011; Dubbeling, 2015).

Urban farms and community food gardens serve as components of green infrastructure, playing a role in diminishing the urban heat island effect, alleviating the impacts of urban stormwater, and decreasing the energy expended on food transportation (Ackerman et al., 2014; Andres, 2017; Kanbak, 2022). The presence of abundant trees and plantings within the urban space, particularly in central zones like four-way intersections, constitutes a facet of urban agriculture that effectively mitigates the consequences of climatic shifts, storms, and particulate matter. This results in a notable reduction in air temperatures, particularly during the summertime. Furthermore, urban agriculture demonstrates the ability to absorb carbon dioxide and pollutants, contributing to environmental quality (Al-Sayed & Alanizi, 2023). By its capacity, urban agriculture holds promise in curbing the impacts of flooding, enhancing water permeation, and advancing overall environmental cleanliness (Anaafo & Akolgo, 2018; Guenther, 2019; Mishra, 2023) (Figure 2).

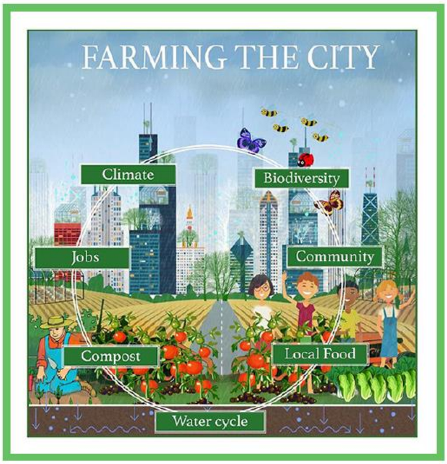

Figure 2. Numerous advantages of urban agriculture for the local ecosystem, city dwellers, and the climate (Orsini & D'Ostuni, 2022)

A noteworthy advantage of urban agriculture is its potential to curtail the necessity for long-distance food transportation, thereby diminishing air pollution and lessening reliance on fossil fuels. This concerted effort contributes to reducing the ecological footprint of urban areas (Belay, 2020; Andrade, 2022). Additionally, urban agriculture has the potential to play a role in ameliorating the net release of CO_2, a key greenhouse gas responsible for global warming, originating from urban activities (Deelstra & Girardet, 2000). From the perspective of carbon sequestration, a region encompassing 10,650 hectares in Goiania, Brazil, has the potential to capture 5.536.764.60 tons of CO_2 from the atmosphere over 20 years through the implementation of urban and peri-urban agricultural practices (Marçal et al., 2021).

Urban agriculture plays a pivotal role in reducing the reliance on pesticides and irrigation for cultivating edible crops (Belay, 2020; Andrade, 2022). Urban farmers can adopt techniques like crop rotation and companion planting to decrease the need for pesticides and herbicides. Employing cutting-edge technology such as sensor-based monitoring, automated irrigation systems, and data analysis, urban crop cultivation strives to optimize crop yield. In the context of the contemporary circular economy, urban crop farming holds significance as it not only enhances urban dwellers' income but also curbs agricultural waste (Bhattarai & Adhikari, 2023).

The intersection between urban agriculture and waste management becomes particularly evident in the utilization of organic waste (Deelstra & Girardet, 2000; Dubbeling, 2015). The decentralized management of urban waste can be facilitated through the reuse and recycling of organic waste, which, in turn, benefits urban food production (Agarwal et al., 2021). Urban agriculture can also offer solutions for waste disposal by acting as a receptor for organic waste or mildly contaminated water (Vejre & Simon-Rojo, 2016). Specifically, urban agriculture can aid in redirecting linear material, energy, and water pathways (Figure 3; Nehls et al., 2016).

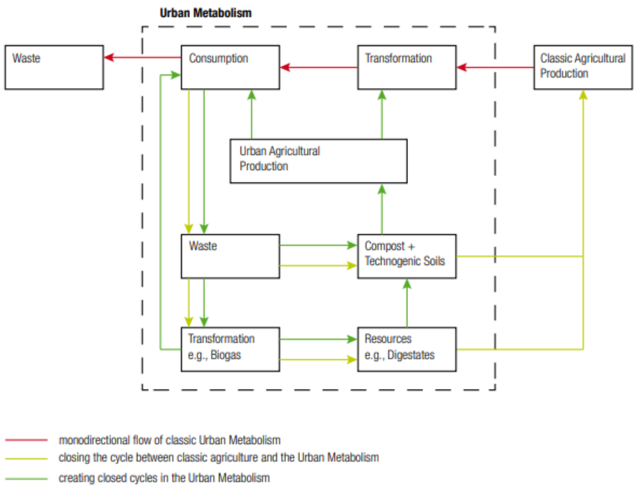

Figure 3. Urban agriculture's function in the ideal resource-circulation system (Nehls et al., 2016)

Urban agriculture holds significant potential to address a spectrum of challenges confronting developing nations, fostering the creation of resilient and food-secure urban areas (de Zeeuw, 2011; Dubbeling et al., 2019). The example of urban agriculture in a developing country like Albania underscores the prospect of establishing sustainable human settlements despite limited resources (Deelstra & Girardet, 2000). Empirical research (Ara, 2018) highlights the contribution of urban agriculture in meeting the basic needs of low-income urban populations in Bangladesh. Respondents demonstrate enthusiasm for expanding potted plant cultivation in their neighborhoods, thereby enhancing self-reliance.

Urban agriculture also exerts a positive influence on boosting biodiversity (Deelstra & Girardet, 2000). Notably, urban farms in the developing city of Makassar exhibit higher biodiversity compared to other types. These urban farms exhibit potential as ecological spaces due to their considerable plant diversity, the prevalence of trees, and limited built-up areas, offering room for further enhancement (Iswoyo et al., 2018). Moreover, the benefits of urban agriculture extend to the protection and sustainability of natural resources (Türker et al., 2021).

Elevated atop buildings, urban agriculture presents an impactful solution to utilize otherwise unused urban spaces (Andrade, 2022). Green roofs, for instance, substantially reduce stormwater runoff and electromagnetic radiation penetration (Le et al., 2020). Vertical farming techniques and container gardens prove valuable in densely populated cities where land scarcity is prominent. Developed countries with robust land use regulations can safeguard ecologically sensitive regions through zoning and simultaneously promote urban farming practices to reinforce ecological functions. Conversely, developing countries with weaker enforcement of land use regulations, like Ghana, can benefit from urban agriculture in conserving such ecologically sensitive areas (Azunre et al., 2019).

Community gardens contribute to cooling urban environments, providing ecosystem services, and enhancing stormwater retention. These gardens foster trust, engagement, disaster response, and food security - all vital components of effective climate change adaptation and resilience (Clarke et al., 2019). While allotment gardens in Baeza, Spain support sustainable city development, broader community connections, rejuvenation of local markets, and environmental initiatives dissemination remain areas for improvement (Maćkiewicz et al., 2019). Community and allotment gardens can regulate microclimates, mitigate urban heat islands, combat floods, sequester carbon, and foster social networks, thereby offering numerous socio-environmental advantages for urban climate planning (Tomatis et al., 2023). Additionally, urban floriculture can reduce the carbon footprint associated with flower transportation and provide higher-quality seasonal products (Manikas et al., 2020).

Effective policy support is pivotal for the success of urban agriculture and competent urban land use management (Ebissa et al., 2023). Neglecting urban agriculture in city planning, both in current designs and future adaptations, would be insufficient (Vejre & Simon-Rojo, 2016). Policymakers are urged to prioritize urban agriculture to address local economic and climate challenges (Mensah, 2023). Integrating agriculture into urban development through policy responses offers substantial social, economic, and environmental benefits, particularly in developing countries (Dubbeling et al., 2019; Bakkaloğlu & Şahin, 2022). A case in point is Venice, Italy, where certain city areas possess the potential, despite urban density, to be transformed into agricultural zones, thus fostering climate change mitigation, adaptation, and vegetable production (Lucertini & Di Giustino, 2021).

Adapting urban planning from traditional prescriptive models to adaptive approaches is pivotal. Central to adaptive planning is the engagement of all relevant stakeholders, necessitating citizen involvement in decisions affecting them (Mancebo, 2018). Enhanced policy participation across the food chain, from producers to consumers, is crucial for more relevant, equitable, and sustainable strategies (Dubbeling, 2019; Dubbeling et al., 2019). Contemporary urban planning strategies increasingly emphasize sustainable and urban agriculture, turning the challenge of climate change into an opportunity to reduce greenhouse gas emissions and ensure food security (Al-Sayed & Alanizi, 2023).

6. Conclusion and Recommendations

Urban agriculture has surpassed its sentimental appeal and has evolved into an essential response to the urgent climate challenges confronting mankind. Its capability to assimilate emerging sustainable technologies positions it as a forefront contender in strategies for adapting to climate shifts. Urban agriculture possesses the potential to convert urban residents from passive consumers into active co-producers. This fundamental transformation not only enhances food security but also constructs a pivotal instrument in our arsenal for countering climate change and attendant uncertainties. To comprehensively harness the potential of urban agriculture, a collaborative endeavor involving local governing bodies and institutions is imperative. Urban farmers can be nurtured using incorporating technology, implementing strategic marketing campaigns, providing comprehensive training, and formulating well-structured policies. Collaborative involvement with practitioners within urban environments is crucial for elucidating the intricate dynamics that underpin the environmental efficacy of urban agriculture. Encouraging and safeguarding spaces like urban community gardens fosters a sense of community-driven unity, thereby bolstering both social cohesion and environmental stewardship. Urban agriculture has the potential to serve as the foundational element of resilient cities, revitalizing neglected urban spaces and previously unused land. It emerges as a symbol of optimism, illuminating the path toward a more ecologically conscious and sustainable urban tomorrow. Although the potential of urban agriculture is unquestionable, conducting additional multidiscipline research is essential to unveil its impacts and successful practices. Urban agriculture must be included in the discourse and action dimension of urban management and investment policies. In particular, urban zoning plans should be reflected in decision-making processes. First of all, necessary arrangements and organizations should be made for plant production in the idle public open and green areas of the city or on the roofs and gardens of idle public buildings. For this purpose, local governments or local agricultural cooperatives should be allocated and encouraged.

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Legal and Administrative Situation of Urban Agriculture in Türkiye

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1. Introduction

One of the key strategies to encourage urban sustainability is agricultural activities in urban areas. The term, urban agriculture, is used to describe the production, processing, and distribution of food and other goods through plant and animal husbandry in urban areas (Butler & Maronek, 2002). According to Viljoen (2005), urban agriculture refers to a variety of agricultural activities carried out in cities, whether they be on the ground, on walls, fences, borders, or rooftop gardens. Mougeot (2000) offers a precise definition *"Urban agriculture is an industry located within or on the edge (peri-urban) of a town, a city or a metropolis, growing, processing and distributing a variety of food and non-food products. This industry largely reuses human and material resources, products, and services in and around the urban area in which it is located, and largely provides human and material resources, products, and services to that urban area"*.

Rapid urbanization brings local policies and approaches towards the urban food system to the fore, given the links with the built environment, consumption, and nature. Cities provide an opportunity to rethink the management of food systems (Gül, 2022). Agriculture has traditionally been connected to the idealized rural setting, and the activities that go along with it are frequently restricted to this setting. Because of this, it was long believed that feeding the urban population only through rural agricultural production was sufficient. However, this turned out to be untrue for many cities in developing nations around the world, primarily due to a lack of infrastructure (transit, roads, marketplaces, etc.) and the low purchasing power of the underprivileged people (Drescher, 2001). The growth of various agricultural and food systems in and around cities has been influenced by several factors over time, including the rise in poverty, high unemployment rates, and possibilities provided by the city on the one hand, and the need for food and accessibility to markets on the other, especially on the production of fresh produce, dairy products, eggs, and poultry. The practice of producing crops and keeping animals in cities for both domestic consumption and revenue generation has been referred to as urban agriculture.

However, urban agriculture's most important features, according to Mougeot (2000), are not just its location within city limits but also its expanding socioeconomic and ecological impacts on the urban fabric. By feeding city dwellers, urban agriculture makes use of municipal resources like land, labor, organic waste, and water. Contextual factors including laws, competition in land usage, market presence, price trends, and quality standards also have a big impact on it. Urban agriculture is essential to the socioeconomic situations of city dwellers in terms of food security, poverty, health, and the environment (Figure 1).

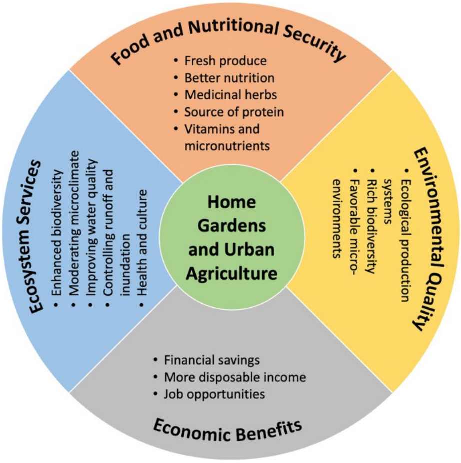

Figure 1. Food, environmental, economic, and ecosystem service benefits of urban agriculture (Lal, 2020)

There have been international, national, and local laws, regulations, policies, guidelines, and other initiatives to promote urban agriculture over the past 25 years (Cissé et al., 2005). Governments in many nations are promoting the growth of urban agricultural output. In this study by using the previous studies in the literature, research has been conducted on the legal and administrative situation of urban agriculture in the world and Türkiye.

2. A Review of Urban Agriculture Legislation in the World

Urban and suburban agriculture has become more and more popular recently. Therefore, urban agriculture policies are frequently viewed by governments as a component of the regional food system, and they can encourage related actions to promote agricultural processing, distribution, and marketing. Coordination between various stakeholder groups on matters about the local food system is promoted by the establishment of state-wide food policy councils, task forces, and other organizations. By allocating funds and creating grant programs, state legislators support urban agriculture initiatives. By authorizing the use of public lands and unoccupied parcels, another policy strategy encourages land access.

To encourage urban agriculture, national policies and initiatives have been developed in Argentina, Brazil, and Cuba (van Veenhuizen, 2006). A strong institutional foundation has been created in the Democratic Republic of the Congo to support the expansion of national urban agricultural programs across Africa. Municipal committees working under the leadership of the city mayors organize land titles for horticulture with urban planning in mind. The nation's national urban agriculture support service provides farmers with technical advice through a network of related offices (FAO, 2010). A program to promote urban self-sufficiency in grain production allows Shanghai (China) to produce 2 million tons of wheat annually (Yi-Zhang & Zhangen, 2000). In partnership with Xavier University, the local government of Cagayan de Oro City, Philippines, has taken action to help the poorest households cultivate community gardens (Holmer & Drescher, 2005). In its mission statement, the Ministry of Food and Agriculture in Accra, Ghana, promised to support urban agriculture. It also conducted studies on safer irrigation water in different areas of the city (Obuobie et al., 2006). The national government directed the municipality of Bamako, Mali, to investigate the possibility of leasing up to 600 hectares to farmers in areas adjacent to Bamako's international airport (Velez-Guerra, 2004). The city-wide urban development plan for Niamey, Niger, calls for increasing irrigation and rainfed agriculture, notably along the Niger

River. Additionally, according to the United Nations, encouraging urban agriculture is a key approach to reaching the Millennium Development Goals (Mougeot, 2005).

The International Development Research Center (IDRC) of Canada, for instance, has led initiatives to support urban agriculture projects all around the world. The innovative system-wide program "Urban Harvest" enabled the Consultative Group on International Agricultural Research (CGIAR) to include urban agriculture as one of its research focuses in 2000. Since that time, research on urban agriculture has been prioritized in numerous national research institutions, such as those in Argentina, Kenya, Senegal, and Niger (van Veenhuizen, 2006). Even though the IDRC and CGIAR's efforts concluded around the same time in 2010 and despite having a lot of experience and lessons learned, it appears that urban agriculture has not taken off since it is not politically acceptable to promote it (Prain et al., 2010).

The United States has also various food-related programs. In 2009, First Lady Michelle Obama constructed the White House's first vegetable garden since Eleanor Roosevelt's Victory Garden (Figure 2), providing the urban agriculture movement with more impetus and respectability. Besides, The Know Your Farmer, Know Your Food project, which was implemented at the system level in 2009, provided infrastructure and clarified regulatory ambiguities to assist regional food producers in gaining access to national markets (USDA, 2012). The project aims to assist local and regional food groups while establishing connections between farmers and consumers. The Farm Bill, a comprehensive piece of agricultural legislation in the US, deals with a variety of agricultural and food-related concerns, including global commerce, rural development, conservation, research, food safety, nutrition initiatives, and subsidy programs. Congress typically passes this legislation every five years (American Farmland Trust, 2012).

Figure 2. Michelle Obama, the First Lady of the United States, serves as an inspiration by establishing a vegetable garden on the grounds of the White House in Washington, DC. (Hoi-Fei Mok et al. 2014).

In 2013, a law was established in California to establish Urban Agricultural Incentive Zones (UAIZ). According to this statute, towns and counties are free to enter into agreements with landowners that limit the use of their property for small-scale agricultural production. In return, landowners receive a lower assessment of the worth of their property based on the price per acre of farmland in California.

A Food Systems Advisory Council was established in Colorado (2010) to make suggestions for bolstering regional food economies. These suggestions can focus on local and regional initiatives to establish local food economies, identify regulatory and policy obstacles, improve local infrastructure, and encourage entrepreneurial endeavors. It can also involve determining how local food economies might affect Colorado's economic growth or other issues with food access and the economy.

Political subdivisions are permitted to create "Urban Agricultural Incentive Zones (UAIZ)", which enables them to contract with landowners for the agricultural use of abandoned, undeveloped, or deteriorating land. The contract must last for at least three years. Area restrictions on UAIZ homes must fall between 3,000 square meters and three acres. A residence ban applies to UAIZ properties. Property owners may be charged fees for the execution and administration of the contracts.

3. A Review of Urban Agriculture Legislation in Türkiye

There are currently no legal articles and legislation on the concept of urban agriculture in the Constitution of the Republic of Türkiye. However, in the Agricultural Production Legislation in our Constitution; Constitutional Laws such as "Agricultural Law", "Organic Law", "Soil Conservation and Land Use Law", "Law on Agricultural Producer Associations", "Environmental Impact Assessment Directive" and "Hobby Gardens Regulations" have articles on the concept of urban agriculture. Likewise, in the "Urbanization Legislation", there are many articles and directives that consider it a principle to protect agricultural areas and water basins, to support animal husbandry, to keep these areas under the supervision of municipalities and to support the necessary practices and projects for agriculture and especially sustainable agriculture. The laws and regulations in the Turkish Constitution that are directly or indirectly related to urban agriculture are listed below through a literature review. Then, in the discussion section, these articles and directives are analyzed by comparing them with examples from abroad.

Table 1. Urbanization and agricultural production legislation analysis in the context of urban agriculture (Modified from Kayasü & Durmaz, 2021)

Law on the Constitution of the Republic of Turkey/1982 dated, legislation numbered 2709
Article 45: Protection of agriculture, animal husbandry, and workers in these branches of production to increase the efficiency of agricultural production
Agriculture Law/2006, legislation no. 5488
Article 2: Determining the objectives, scope, and subjects of agricultural policies; defining the necessary programs and R&D arrangements
Article 4: The objectives of agricultural policies are the development of agricultural production, conservation of resources, increasing productivity, food security, development of producer organizations, strengthening agricultural markets, rural development
Article 6: Priorities of agricultural policies (productivity, product diversity, quality, safe food, use of technology and information systems, producer organizations, rational use of soil and water resources
Article 8: Adaptation of agricultural information technologies, conducting R&D activities and ensuring institutional cooperation on these issues
Article 15: Improving employment in rural areas by raising the level of education, developing rural development programs and projects (with participation and bottom-up approach)
Article 19 Agricultural support instruments: e) Rural development supports: State support for rural development and investment projects, employment-enhancing initiatives and basic principles of stakeholder participation, bottom-up approach, sustainability, use of modern management systems
Organic Agriculture Law/2004, numbered 5262
Article 3(b): Characteristics of organic farming production activities (using natural resources in natural areas and basic operations in the supply chain)

Law on Soil Conservation and Land Use/2005, numbered 5403
Article 3: Definitions of agricultural land, absolute agricultural land, special cropland, planted agricultural land, marginal agricultural land, agricultural land parcel of sufficient size, non-agricultural areas, irrigated agricultural land
Article 8: Classification of agricultural land and determination of land parcel sizes. The smallest area size that can be divided
Article 9: Conservation of soils and prevention of soil loss due to natural and artificial events
Article 10: Making land use plans, its authority, content, and emphasis on the principle of sustainable development
Article 11: The preparation and purpose of land use plans and projects for agricultural purposes and the consultation of farmers and landowners in this process are guaranteed by law
Soil Conservation and Land Use Law/ 2020 dated 7225 numbered
Article c: Those who cause the deterioration of the integrity of the land and its misuse by means of transferring the possession of agricultural lands by establishing unregisterable actual shares, by establishing a membership or partnership relationship with this legal entity within the scope of the activity of a private law legal entity, or by mediating these works. It has been regulated that imprisonment from one year to three years and a judicial fine from one hundred to one thousand days will be imposed, and an administrative fine from fifty thousand Turkish liras to two hundred and fifty thousand Turkish liras will be imposed on this legal person
Law on Agricultural Producer Associations/2004, numbered 5200
Article 1: General framework of agricultural production and establishment of agricultural producer associations
Regulation on Environmental Impact Assessment/2014 dated 28186 Official Gazette Number
Annex 5 (3b): Protection of agricultural areas
Sample Provincial Regulations on Hobby Gardens
Antalya Metropolitan Municipality: Article 1- The purpose of the Regulation is to enable urban dwellers to spend time in nature, grow crops, and satisfy their hobbies.

Balıkesir Municipality Article 1- To determine the principles of allocation, utilization, and operation of hobby gardens built and put into service by Balıkesir Municipality	
Afyonkarahisar Municipality: Article 1- Determining the scope to evaluate the leisure time of the people living in the city, contributing to their family budgets, hobby satisfaction, relieving the tension and stress caused by apartment life and crowded city life, offering the pleasure of production, and acquiring a green space culture	
Sivas Municipality: l) Instilling environmental awareness in citizens. m) Establishment of botanical gardens and hobby gardens.	
Zoning Law/1985, numbered 3194	
Article 8 (c): Agricultural lands cannot be used for other than agricultural purposes and their protection	
Metropolitan Municipality in Fourteen Provinces/2012 dated, numbered 6360	
Article 1: In the new situation, the legal personality of villages and town municipalities located within the territorial borders of the districts of the provinces with metropolitan status has been abolished, villages have been incorporated as neighborhoods and municipalities have been incorporated into the municipality of the district to which they are affiliated as a single neighborhood with the name of the town	
Metropolitan Municipality Law/2004 numbered 5216	
Article 7 (i): Sustainable development, protection of the environment, agricultural areas and water basins as a duty of the Metropolitan Municipality	
Article 7 (additional paragraph): Authority of metropolitan and district municipalities to support agriculture and animal husbandry	
Municipal Law/2005, numbered 5393	
Article 69: The municipality must produce zoned land except agricultural land	
Unplanned Areas Zoning Regulation/1985 dated, 18916 Official Gazette Number	
Article 4 (paragraphs 30 and 33): Permit status and rules for building agricultural structures on agricultural land and description of the structure	

Regulation on the Establishment, Duties, Authorities, Responsibilities, Working Procedures and Principles of the Mayor's Directorate of Parks and Gardens
Article 11 (1) - C: Duties of the Urban Agricultural Services Bureau: - Cooperation with national and international organizations for the socio-economic development of rural areas and urban agricultural activities - Provision of necessary tools, equipment, and materials for urban agriculture works, - Training and promotion of modern methods for crop production - To organize urban agricultural activities (urban gardens, rainwater harvesting, urban beekeeping, conscious nutrition, organic products, production, etc.), to plan and implement activities to provide necessary training and support.

4. Conclusion

Agricultural cultivation, which until yesterday was undesirable in the city and directed to the countryside, has started to be practiced in the city again with the realization of the seriousness of humanity's food production, and there has been a significant increase in research on the concept of urban agriculture in recent years. There are important studies in the literature that urban agriculture can be used as an effective weapon against food problems caused by increasing population and urbanizing cities. Even if the socio-economic, physical, and psychological benefits of urban agriculture to the city and its inhabitants other than food cultivation activities are not fully understood, the number of important implementation steps and research in this direction is also increasing.

There are important articles in the Constitution of the Republic of Turkey to protect agricultural areas and support agricultural activities. Kayasü & Durmaz (2021) created the current picture by examining the relevant documents in agricultural and urbanization legislation. In this context, it would be correct to analyze the relevant legislation under two headings. Since there is no urban agriculture concept and legislation in the legislation, the keywords to be created by intersecting the articles related to agriculture in the legislation on the protection of agricultural areas and urbanization legislation will make it easier for us to analyze the legislation on urban agriculture. First, there are legislations for the protection of agricultural areas, including general principles in agricultural production, the importance of rural development, and the protection of agricultural lands and lands where agricultural production is carried out. Then, the articles in the legislation on agriculture, participation, formation of producer associations, organic agriculture, hobby gardens, food security, and the use of information technology services can be defined as articles aimed at protecting and legalizing agriculture in the city, although not directly under the concept of urban agriculture. These articles have the potential to form the structural framework of the concept of urban agriculture.

Within the scope of urbanization legislation, general laws, and directives in the constitution, there is no article directly related to urban agriculture as in the legislation and laws for the protection of agricultural lands. However, as mentioned above, there are important articles in urbanization legislation such as protecting agricultural lands and encouraging agricultural activities. The urbanization legislation focuses on the relationship between urban development and agriculture.

As a result, although there is no legislation on the concept of urban agriculture in the Turkish Constitution, articles are encouraging the public to protect agricultural areas and increase agricultural activities. However, these legislations are insufficient to protect urban agricultural areas, and day by day, agricultural lands (including open-green areas) in cities are being destroyed and misused because of urbanization. So much so that the prefabricated housing-style structures built on state lands for hobby gardens by taking advantage of the loopholes in the law could not be prevented and hobby gardens were banned, and demolition of the structures was decided. Today, there is still no clear conclusion on hobby gardens. The policies implemented by the USA and Canada after

World War I and World War II and the permanence of these policies are seen as evidence that agricultural production in these countries has reached high levels. In addition to the laws and regulations of the state in these areas, the budgets allocated to encourage the public have played an important role in achieving positive results.

Beyond agricultural production activities in the city, urban agriculture plays an important role in helping individuals in poor communities to have jobs and in helping communities fight poverty. There is significant research in the literature that they reduce crime rates in the city. In addition, it supports the meeting of new generations with the land and the development of cultural ties between the new generation and the old generation. It is known that dealing with soil has important effects on mental and physical health.

In this context, it would not be wrong to say that our country has a great potential for urban agriculture considering its climate, geopolitical location, and microclimatic features. The concept of urban agriculture, which has become popular especially in recent years, has been studied as a research topic in many theses and articles. The greatest freedom of countries is their ability to be self-sufficient. For this reason, it is obvious that there are important steps to be taken and a system to be created in Turkey, especially in the food sector, agricultural land laws, and urban agriculture. The food, energy, water, agriculture, and urbanization-related policies indirectly targeting urban agriculture imply the potential for better integrating urban agriculture in the future.

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Allotment Gardens: Empowering Communities, Enriching Urban Green Multifunctionality and Ensuring Food Security in Urban Settings

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1. Introduction

The rapidly increasing population worldwide has led to an increase in the rate of urbanization in parallel with developing technology. While 30% of the world's population lived in cities in 1950, this rate increased to 55% in 2018 and is expected to reach 68% in 2050 (United Nations, 2019). In this process, cities spreading rapidly to the periphery have brought along many environmental problems (Akseki, 2011).

In addition to air, water and soil pollution; urban sprawl has started to put great pressure on surrounding forest areas, water resources, natural landscapes and agricultural areas. Agricultural areas have been affected the most by this pressure (Akseki, 2011). In this context, the need for food increases on the one hand, and on the other hand, problems related to food security and safety grow in the process of rapid agricultural production (Wiskerke, 2015).

The design of open and green spaces is one of the important outputs of urban landscape planning. Urban open and green spaces are indispensable elements of urban planning as an important response to climate change-related problems with their socio-cultural functions as well as their ecological benefits.

The demand for agricultural uses is increasing within the open and green space system in rapidly expanding areas with planned or unplanned urbanization. Allotment gardens and other urban agricultural areas constitute one of the system elements of open and green spaces. The increase in urban areas causes people to move away from agricultural production spatially and cognitively; and increases food security concerns due to the increasing reduction of agricultural areas, in addition to damaging natural areas. The most effective way to reduce the distance to food is to support food production in urban areas and areas around the city, it is in other words urban agriculture (Bakkaloğlu & Şahin, 2022).

Urban agriculture has played an important role in the improvement and sustainable development of cities throughout history. Establishing the relationship between urban and rural areas is of critical importance to improve the quality of life in urban areas.

Since the Industrial Revolution, irregular migration movements in the West have led to unplanned growth from rural to urban areas, which has put pressure on fertile agricultural lands on flat and near-flat slopes that are well suited for construction. In contrast, new urbanization models have emerged in different parts of the world. One of the most popular of these is the "Garden City" model, developed by Ebenezer Howard in 1892 by combining the advantages of the city and the countryside. The most important aspect of the Garden City approach is that the planned residential area is surrounded by a green belt. While this green belt forms a spatial boundary to the settlement area, it also provides an opportunity for residents to engage in agriculture-based production activities in their leisure time (Najafidashtapeh, 2018). Following this first attempt to encourage agriculture within the city itself, Le Corbusier introduced the idea of the "Functional City" in the 20th century and suggested that the areas around the city should be used as agricultural production units (Kanbak, 2018).

In the early 20th century, urban agriculture emerged as a solution to food supply problems in countries caused by the world wars. On the other hand, agricultural areas have continued to be under pressure from rapid and irregular urbanization in the aftermath of the world wars, which has become a serious problem for food security. In response, urban agriculture has the potential to address this threat by meeting the food needs of urban dwellers partially or fully. Urban agriculture gains importance today as one of the effective tools against social, economic, and ecological problems (Kayasü & Durmaz, 2021; Tandoğan & Özdamar, 2022).

Akyol (2011) has based the history of urban agricultural areas back to the 1500s in the world. However, according to Birky (2009), the first purpose of the establishment of allotment gardens was to enable poor people in cities to provide food for themselves which developed with the Industrial Revolution (Kef, 2015). It is stated that the shaping of open and green spaces within the framework of standards started in England in the 1800s and is the leading country (Gül et al., 2020). There are references in the literature to the development of allotment gardens in England during the 19th century especially (Birky, 2009; Burchardt, 2002).

Allotment gardens are becoming more and more practiced around the world, which has positive effects in terms of socio-cultural, ecological, and public health. One of the best practices in this context was realized in Turkey at the beginning of the 20^{th} century. Atatürk Forest Farm was established after Ankara became the capital of Turkey, and it is one of the exemplary models of urban agriculture practices in the world. It was established in 1925 in the center of the capital city of Ankara spreading over 55,000 acres, following the instructions of Mustafa Kemal Atatürk, the founder of the Republic of Türkiye (Kimyon & Serter, 2015).

Due to the increasing rate of urbanization and metropolitan structures, international strategies and policies besides local and national practices on urban agriculture have gained importance. In 1991, an Advisory Board on Urban Agriculture was established within the United Nations Development Program (FAO, 2007). World Health Organization (WHO), World Food Program (WFP), Food and Agriculture Organization of the United Nations (FAO), and International Fund for Agricultural Development (IFAD) produce, and study various policies related to food security and global nutrition.

Allotment gardens are defined as an urban green space element that gains more and more importance on a global scale. Allotment gardens contribute to the economies of the city administration and garden owners. In addition to bringing aesthetic value to the urban appearance, it also has positive contributions to urban ecology (Önder & Polat, 2008). It is an important instrument in food supply. They also function as therapy gardens for disadvantaged groups.

In addition to that, allotment gardens play an important role in protecting agricultural lands in the urban area and urban fringe. According to the Kayıkçı (2005), "Agricultural soil is the most important part of the soil, which is a natural resource, providing nutrition to the living. Because agricultural soils have been able to feed living creatures for thousands of years thanks to their reusability. There is no doubt about the importance of agricultural soils for living things, which are a source of food and a natural resource that cannot be replaced by any other. The importance of that further increases because agricultural lands have become a strategic resource that can be used as a 'weapon of hunger' and the necessity of food for present and future generations" (Sezgin, 2010).

The need has risen for tools that will allow the increasingly isolated urban dwellers to mingle with the increase in urban areas. At the same time, people have started to look for ways to return to nature, breathe in fresh air, and access organic and reliable food products; because interaction with nature has been interrupted as a result of intense urbanization (Çelik, 2018). Allotment gardens emerged in or near the city in the 1980s in Türkiye, where urban dwellers got involved in agriculture as a leisure activity (Aliağaoğlu & Alevkayalı, 2017).

Today, the importance of allotment gardens is addressed in the context of environmental, social, and economic issues such as sustainable food production, food safety and security, urbanization problems, climate change, social resilience, and socio-economic development (Çelik, 2018). In this context, allotment gardens gain more and more importance on a global scale as an element of urban open and green spaces. Allotment gardens provide economic contributions to the city administration and garden owners, in addition to positive contributions to the aesthetics and ecological characteristics of cities (Önder & Polat, 2008).

In this study, allotment gardens; It is evaluated in terms of aspects that empower communities, enrich urban green multifunctionality, and help ensure food security in urban settings. As a result, in general terms, the phases of planning and managing the allotment garden are proposed.

2. Ensuring Food Security

The right to access food was first mentioned in the United Nations Universal Declaration of Human Rights in 1948 in the international arena. Despite the conceptual similarity, we see that the concept of food security emerged during the global food crisis in 1970.

Food security was recognized as an international problem for the first time at the World Food Conference in 1974 (Dağdur, 2017). World Food Conference organized in 1974 in response to the crisis defined food security as "having access to the basic food resources on earth at all times and an adequate level to ensure the regular distribution of food consumption and to compensate for fluctuations in production and prices". FAO defined food security as "the ability of all people to have physical, social and economic access at all times to sufficient, safe and nutritious food to meet their dietary needs and preferences for a healthy and active life" in its publication titled "The State of Food Insecurity in the World" (FAO, 2015; Bakkaloğlu & Şahin, 2022).

Food security has four dimensions indicated in Table 1 and it is emphasized that all these dimensions should be evaluated together to ensure food security (Kıymaz & Şahinöz, 2010; Keskin & Demirbaş, 2012; Niyaz & İnan, 2016; Dağdur, 2017; Bakkaloğlu & Şahin, 2022).

Table 1. Four dimensions of food security (Kıymaz & Şahinöz, 2010; Keskin & Demirbaş, 2012; Niyaz & İnan, 2016; Dağdur, 2017; Bakkaloğlu & Şahin, 2022).

1. Availability of food: One of the most important factors in ensuring food security is the availability of sufficient food. This means that food is available at a sufficient level to meet people's nutritional needs.	2. Access to food: The fact that it is sufficient in terms of quantity does not mean that food security is provided. People need to have economic and physical access to food.
3. Utilization of food (Usefulness): Food can only be consumed after people have reached the food. The utilization of food means that safe food is used in sufficient quantities per person and in accordance with basic nutritional requirements (healthy and balanced).	4. Stability (Resoluteness): This means that the first three parameters are maintained stably. Even in extraordinary situations (such as climate events, wars, economic crises, and natural disasters), people's food needs must always be met without interruption.

Food security poses a threat to consumers living in urban areas that are quite far from the production process and increasingly losing control over food (Demirbaş, 2023). The concept of food security, having been a strategic issue throughout history, comes to the fore today, when food poverty increases gradually (Niyaz & İnan, 2016; Sertyeşilışık, 2022). There are many factors that threaten food security and cause insecurity. These are;

- Land cover/land use change,
- Low harvest due to low rainfall caused by climate change,
- Decline of people's incomes and increasing food inflation as a result of income distribution injustice,
- Fragmented and small agricultural areas,

- Failure to implement agricultural policies,
- Insufficiency of legal sanctions on food security,
- Events such as floods, pandemics, and earthquakes increase the fragility and inadequacy of the food system. The COVID-19 pandemic has led to severe and widespread global food insecurity, affecting especially vulnerable households all over the world (World Bank, 2022).

Among these factors, the reduction in the amount of arable land as a result of changes in land cover/land use is one of the most important factors affecting food security. Allotment gardens have become increasingly important as an agricultural production activity to create arable land in and on the fringes of urban areas. Allotment gardens are areas that facilitate urban access to food, reduce supply chain distances, support the elimination of the negative impacts of climate change, support local production and provide ecological, economic, and social benefits to the city.

3. The Role of Allotment Gardens in Enriching Urban Green Multifunctionality

Cities are defined as spaces that have been in constant change since the first day they emerged, depending on time, geography, and especially the urban dwellers they host (İlgar, 2008; Güneş, 2017). Urbanization has led to an increase in building density, environmental pollution, disconnection from nature, reduction in open and green areas in public space and agricultural lands, and deterioration in ecosystems in many settlements around the world (Wolch et al., 2014; Düzenli et al., 2018; Yılmaz Çildam, 2022).

Urban green spaces provide the link between the city and nature. Mostly, green areas are the continuation of landscapes around the city (Şahin et al., 2018). Open and green areas have many ecological, social, physical, and aesthetic functions as urban landscapes (Şahin, 2008) that are partially or completely open to human use (Bilgili, 2009). According to Öztan (1968), Akdoğan (1987), and Özbilen (1991) the concept of open space is one of the important and basic elements of the urban fabric and is defined as plains or empty spaces outside architectural structures and transportation areas (Şahin, 2008). Green areas are also defined by Saatçioğlu (1978) and Akdoğan (1987) as the surface areas of existing open spaces covered or combined with vegetative elements (woody and herbaceous plants). According to these definitions; we can say that every green area is an open area. However, not every open spaces are green spaces (Gül & Küçük, 2001; Şahin, 2008).

Open and green urban spaces have become indispensable elements of urban planning, especially with their ecological benefits as an important response to the problems caused by nature degradation and climate change. The increase in urban areas results in damaging natural areas, while simultaneously causing people to move away from agricultural production and increasing food security concerns due to the decrease in agricultural areas. The most effective way to reduce the distance to food is to support food production in urban areas and areas around the city, it is in other words urban agriculture (Bakkaloğlu & Şahin, 2022). In this context, like other urban agricultural areas allotment gardens offer an alternative solution to the problem of food security by forming one of the system elements of open and green spaces. In addition, allotment gardens are urban agricultural activity areas contributing to the aesthetic values of cities which can be used as a recreation area (Demiralay, 2023).

It is necessary to make an effort to reach green areas, which are a part of nature, due to many reasons such as inactivity, stress, and high work tempo brought by urban life. Nowadays, as a result of the built-up spaces and traffic density in cities, people are in search of recreational activities where they can spend more time with nature (Yasak et al., 2020). One of these recreational activity areas is allotment gardens. Allotment gardens have become a need for cities with a high density of buildings and a lack of open and green spaces. Therefore, allotment gardens should be established in cities, support recreational activities, increase the amount of green space, and support food security (Yılmaz Çildam, 2022). Agricultural activities integrated with recreation in allotment gardens, considered a part of the urban green fabric, also contribute to the psychological health of individuals.

4. The Role of Allotment Gardens in Empowering Communities

The physical, psychological, and social needs of people and the physical and mental health of society are negatively affected in the structural gray landscapes since natural areas are not protected in rapidly growing and crowded cities (Yılmaz Çildam, 2022). There is a need for tools and environments that will allow individuals to mingle who became lonely with the increase in urban areas. Simultaneously, people who have lost contact with nature have started to look for ways to return to nature, to breathe in fresh air, and to access organic and reliable food products (Çelik, 2018). It is known that spending time in nature accelerates social communication, provides mental and physical relaxation, and improves quality of life (Cooper & Barnes, 1999; Elings, 2006; Kingsley & Townsend, 2006; Cheng et al., 2010). In this context, it is clear that including elements of the natural landscape as well as the green cover created by agricultural activities is important in the design of allotment gardens. In one study evaluating the survey data applied to individuals interested in allotment gardens, Yılmaz (2021) concluded that people prefer allotment gardens because of longing for green space, spending time in nature, healthy nutrition, rest, getting away from the tiring urban life and staying away from the pandemic in recent times.

Allotment gardens have the capacity to improve health, quality of life and well-being (Clatworthy et al., 2013; Kingsley et al., 2021). It offers alternative experiences that do not alienate people from each other and the natural environment, but also provide the opportunity to integrate different cultural structures (urban and rural dwellers) (Bailey & Kingsley, 2022). Allotment gardens are effective landscape structures to distance people from the stressful environment of the city, satisfy people's longing for plants and soil, and create a fondness for nature in future generations.

It is stated that engaging in activities in allotment gardens creates a drug-free treatment effect on retired individuals with health problems at the age of 65 and over (Aktu, 2016; Marsh et al., 2017). Activities in allotment gardens keep the body in shape and neutralize stress as they require a certain amount of effort which also has an impact on the reduction of obesity (Telesetsky, 2014).

Allotment gardens help build social justice with their economic, social, and environmental contributions (Rasouli, 2012; Yenigül, 2016; Yılmaz Çildam, 2022, Sapin et al., 2023).

5. Conclusion

Failure to ensure food security, defined as a right of society to access sufficient and quality food has become one of the most fundamental problems today (Erbaş & Aslan, 2012; Doğan & Özaltın, 2022). This is because particularly productive landscapes; and agricultural areas are being destroyed by urbanization activities that are far from sustainable development in urban areas. Urban agriculture practices should be considered within sustainable urbanization policies as they support local production and facilitate access to food. As one of the urban agriculture activities, allotment gardens provide economic, socio-cultural, and ecological contributions to nature-based sustainable urban development and solve food supply problems (Aytin, 2022). Allotment gardens, offering the opportunity to get away from the stress of the city filled with concrete piles, support people to fulfill their longing for the countryside by combining urban life with agricultural activity (Yılmaz, 2021). This study; contributes to literature in terms of emphasizing the ecological, economic, and social benefits provided by allotment gardens.

The first step in achieving the benefits described above should be to plan the prioritized areas for the development of allotment gardens in urban areas, and then manage them according to the success criteria and evaluation techniques to be determined. Urban landscape character will provide the basic information for the first step specified.

In general terms, the phases of planning and managing the allotment garden are proposed below. Detailed scientific studies are needed for each stage of landscape-based urbanization.

1. *Determination of Priority Development Areas for Allotment Gardens*

The identification of priority development areas for allotment gardens in urban areas should be based on Landscape Character Analysis and Assessment (Şahin et al., 2014) for guidance. In this context, landscape functions such as agro-ecological suitability, urban climatic comfort, cultural agricultural landscape identity, etc. may play a dominant role in the evaluation. The location of allotment gardens can be assigned as unique areas within the structural urban fabric, or they can be developed within urban parks. Figure 1 shows the map of Landscape Conservation Strategies produced on the basis of Landscape Character Assessment for the design of an urban park in Sivas, Turkey, and Figure 2 shows the Landscape Development Plan produced on the basis of this map. Development areas 4 and 7 in Figure 2 are urban agricultural areas including allotment gardens. Preliminary Landscape Design for these agricultural areas (allotments) is shown in Figure 3 (Şahin et al., 2017).

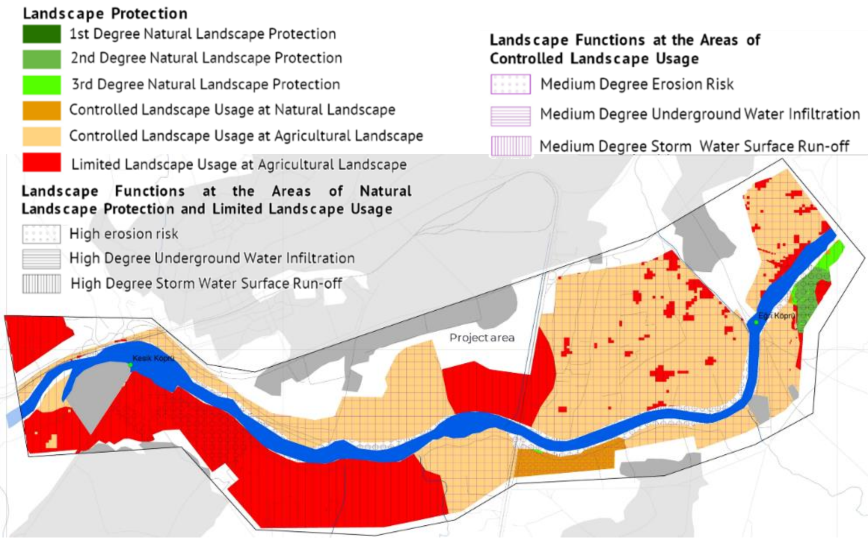

Figure 1. Landscape protection plan for urban park based on landscape character assessment (Doğan et al., 2017)

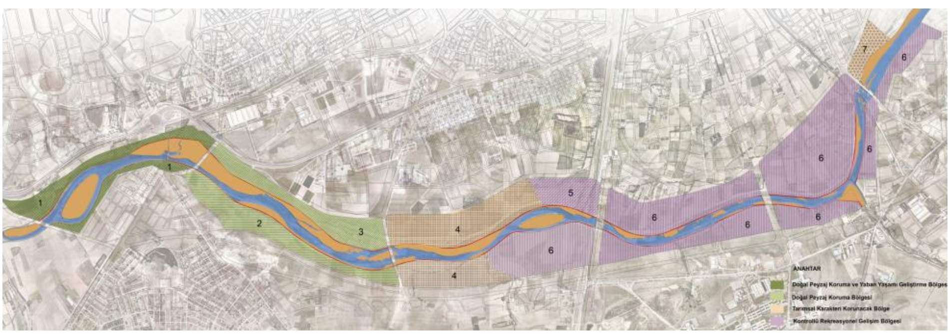

Figure 2. Landscape Development Plan for Urban Park. The areas with the numbers 4 and 7 (with the color of light brown) are dedicated to urban agriculture including allotment gardens (Çakçı Kaymaz et al., 2017).

Figure 3. Landscape design for allotment gardens (Memlük et al., 2017)

2. Allotment Garden Performance Criteria

Suggested measures of ecological, social, and economic impacts of allotment gardens include, but are not limited to the following:

- Integrity in the Urban Landscape
- Creating equal opportunities for different income groups
- Secure food production
- Agroecological compliance
- Improvement of climate
- Economic benefit-cost
- Habitat provision and biodiversity
- Recreational opportunity

- User satisfaction
- Visual value

3. Holistic Evaluation of Performance Criteria

Standard documents should be created for the measurement technique and weight calculation of each criterion in order to measure the ecological, social and economic achievements of existing allotment gardens or newly designed projects. The weighting of each criterion may vary depending on the urban landscape character and the pressures and/or environmental issues that affect/may affect this character.

Allotment gardens have positive effects in terms of socio-cultural, economic, ecological, and public health as urban open and green space elements, increasingly take more and more place in practice in the world. On the other hand, there may be problems such as mainly wealthy people or middle-income groups participating; the poor group being the riskiest group within the scope of food security not being able to benefit, the loss of agricultural land as a result of the transformation of allotment gardens into a profit-making tool due to populist approaches, inadequate rural-urban cohesion, etc. due to the implementation of allotment gardens by city administrators. There are detailed installation and usage guides and legislation on allotment gardens in the successful practices in the world. These negative aspects can be avoided with the help of these documents. Detailed installation and utilization guidelines and relevant legislation on allotment gardens include definitions and standards, purposes, modes of operation (private enterprise, state-owned enterprises, NGOs, and/or different combinations thereof), principles of use, and environmental impacts (ability to create equal opportunities for different income groups, safe food production, agroecological suitability, ecological benefits, feasibility, etc.) in guiding allotment gardens.

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Types of Hobby Gardening

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1. Introduction

Depending on their busy work lives and fast-paced lifestyles, people today need to leave their environment for either a short period or an extended to relax and have fun. Therefore, they travel to rural areas that are close or uncontaminated places in nature. However, this desire is often not possible in today's increasingly urbanized are crowded world. Thus, urban outdoor areas with a wide range of possibilities are preferred to meet the need for relaxation and pleasure. Urban outdoor spaces are created within residential areas. These spaces are available for public use and provide a variety of individuals and social in various ways. In certain locations, the garden is prepared ready for human processing by having water brought to the garden's following which it is hoed, and drainage put in. These lands are divided into parcels that are utilized by people for recreational activities. The aim is to enjoy small-scale gardening while providing entertainment and relaxation. In addition to landscaping, agricultural activities can also be performed in hobby gardens. These activities can be supported by training to be given beforehand. Plant cultivation is more than just a pastime. Regardless of your age, it can be good for your physical and mental health. Growing plants that bear vegetables, fruits, or flowers is another way to enjoy the products of your effort. The type of garden is determined by factors including the amount of area available, the soil type at the location, and the desired vegetables and fruits. In this review, the types of hobby gardening (vegetable and orchard, ornamental, bulbous plant, succulent, and rock gardening) are discussed and details about their construction and functions are provided.

2. Vegetable-Orchard Gardening

People have started to lay out vegetable and fruit gardens with an enthusiasm for organic farming in hobby gardens (Gülgün & Pirli, 2018). People are becoming more interested in hobby gardening in the fresh air away from the city center. As a result, institutions and organizations have begun to rent and sell hobby gardens that they have created. There isn't much of a difference between a commercial fruit and vegetable garden and a hobby garden. Fruit trees can live for many years depending on the soil type and variety in the area where they are planted. Because problems in constructing a garden will become apparent after many years, the product that is lost is important for both the grower and the national economy. Vegetable cultivation is common in hobby gardens. Vegetables grow and produce in a very short time. Planning begins after selecting where and how large the garden will be. It will be very beneficial if the planning process is continued throughout the production period. It will be advantageous if the planning process is carried out throughout the process of production.

2.1.Vegetable garden establishment

In the ornamental vegetable garden, medicinal plants are used together with vegetables and ornamental plants of different colors and shapes. The first characteristics to consider are the taste, smell, and appearance of the plants to be used. The garden should be designed for all seasons. This includes the winter months when vegetables are not harvested. Design becomes more important when the garden we are designing is close to the house and can be seen from the window. A garden designed with seating is the ornamental vegetable garden. Therefore, the texture and color characteristics of such materials used in the garden should be compatible with the garden (Bowe, 1996; Segall, 2002; Bartley, 2006). Color is the most important element to consider in the design of the garden. Attention is paid to the arrangement of each parcel of the garden in different colors. The color of the plant is determined according to the design. A list of plants is prepared according to the color we have designed. It is known that red is the opposite of green, orange is the opposite of blue, and yellow is the opposite of purple. Decorative vegetable garden designs often use complementary or contrasting colors. Thus, the garden will be more attractive and aesthetic. Red cabbage, kale, and some varieties of mustard retain their color in winter, adding color to the garden in winter. In regions with cold winters, it is a good idea to have these plants as part of an ornamental vegetable garden (Bowe, 1996; Segall, 2002; Bartley, 2006).

a) Plant combination

The leaves of vegetables like kale, lettuce, and cabbage used in ornamental gardens are large and rough. Such plants are considered to be the main element of the garden and they are the last to be planted in the garden and they serve as a background for the smaller plants. Plants such as onions, garlic, and leeks add a vertical dimension to the garden. Other plant species used in the garden typically grow horizontally, adding a horizontal dimension to the garden. These horizontally growing plants cause the garden to gain an informal structure. When planting horizontally growing or spreading plants in the garden, 15x45 cm between rows and above should be considered (Bowe, 1996; Segall, 2002; Bartley, 2006). When choosing soil for vegetable plots, it is important to consider the relatively flat or gently sloping terrain, its ability to hold water, high moisture content, texture, and good drainage. Proximity to the road increases ease of transportation for the establishment of the garden, as well as proximity to the city center and the likelihood of the product finding a market. This is in addition to the availability of fertilizers, chemicals, tools, machinery, spare parts, and repair services, all of which contribute to an optimal vegetable garden. If we classify the methods of propagating certain vegetables, such as carrots, radishes, beets, okra, and broad beans, which are consumed as roots, they are sown from seeds. Vegetables such as onions, potatoes, and garlic are grown directly from shallots or seeds. Vegetables such as melon, cucumber, watermelon, and zucchini can be planted from seed, but it is better to first grow these seeds in the nursery and take them to the garden while they are seedlings. Vegetables such as tomato, eggplant, pepper, lettuce, celery, and cauliflower are planted directly as seedlings.

b) Planning rules for the vegetable garden

After the perimeter of the vegetable garden is fenced, there should be a gardener's house in the garden area. This house, built at the entrance, should be able to see all sides of the garden if possible.

-Storage, packing houses, and storage: It should be placed close to the gardener's house, on the side of the main road of the garden, where all kinds of vehicles can easily enter, and on the north side.

-Stables and manure storage: The wind needs to blow in the opposite direction to stop the foul odor from wafting into the living quarters. It should be placed as far away from living quarters as possible. The floor of the manure pit should have a layer of concrete. It needs to be enclosed by a wall that is 80-100 cm high and has entrances on both sides for a tractor with a trailer.

-Water well and irrigation pool: The irrigation pool should be placed at the highest point of the garden and the water should flow to all sides without the help of a pump. It should be ensured that the water is heated by continuous sun exposure and aeration should be provided with high flow.

-Seedling containers: It is located in a secluded area near the gardener's residence, sloping towards the south, shielded from the north, receiving sunshine throughout the day, and experiencing moderate winds.

Roads: Depending on the size of the business land, one or two main roads are made. In our country, one main road is sufficient since the enterprises have 10-50 decares of land.

Main and side plots: The main plots are large parts of the garden divided by the main and side roads.

2.2. Orchard Garden Establishment

The ideal and most fertile soil for fruit or vegetable production is loose, humus-rich, sandy-clay mixed soils. Otherwise, it will be an unproductive garden. An appropriate fruit sapling includes the following characteristics; it is true to its name, grafted on the proper rootstock, one year old, the size and thickness required by the variety and rootstock, the stem is smooth and firm, the buds are well-formed, the grafting place is closed, it has plenty of fringe roots and disperses in all directions, and it is disease and pest-free. Square, quadrangular, chess, and triangular plantings are generally applied on flat lands. Contour planting is applied parallel to the curves of the terraces on sloping lands. In general, seedlings can be planted from

December to the end of March. Autumn planting is done in places where the winters are not too harsh or where the soil is not frozen deep because the soil is covered with snow. Planting in the spring is very dangerous, especially if it is delayed, and the rate of saplings decreases. Before planting, the places where the seedlings will come are marked with planting stakes. For this purpose, a rope is first taken. The upper end of this rope is indicated by colored cloths or ropes based on the distance between the trees. Then, the rope is pulled tautly to the top of the garden. When the line is drawn, it is entered from the garden border, at a distance that is halfway between the rows. A stake is driven at the places where the marks on the rope fall on the ground. Afterward, the rope is raised and drawn to the side of the pitch until it is at a right angle to the rope that was previously pulled. This part is marked in the same way. Saplings are pruned before planting. This is called planting pruning. With this pruning, the roots of the saplings that are crushed, broken, and injured during removal are cut. Roots that overlap each other are removed. When planting the sapling, the planting board is placed on the side stakes that have been driven before. Thus, the hollow in the middle of the board becomes the seat of the sapling. The part of the sapling that comes up to 10 cm from the graft place is overlapped into the cavity and the soil is started to fill. First, the topsoil and then the bottom soil is filled into the pit. The calculation of the number of seedlings to be planted in a certain area is made with the following formula:

$$\text{The number of saplings} = \frac{\text{Area size of planting place}}{\text{Over-row Distance x In-row Distance}}$$

3. Ornamental Bulbous Plant Gardening

Plants that spend most of the year underground in the form of bulbs, tubers, or rhizomes, but bloom in spring and autumn, are classified as bulbous plants. These plants can be used for ornamental, medicinal, and aromatic purposes. Flower bulbs find wide usage areas, especially in parks and gardens. It is divided into two groups those that bloom in spring and summer or autumn. Plants that flower during spring are typically planted in autumn, whilst those that bloom during summer or autumn are typically planted in spring after the winter frost has passed. Please note that technical term abbreviations will be explained upon first use. In recent years, the use of many bulb species as cut flowers has increased considerably. If bulbs are to be grown in the garden, the planting area must be cleared of weeds beforehand. Then, employing suitable cultivation methods, the coarse layers of soil should be broken up and aerated. After bringing the pan, the hard soil needs to be moistened and processed. Flower bulbs like permeable, loose soils rich in organic matter. For this reason, if the soil to be planted does not have these characteristics, it must be made more suitable with materials such as farmyard manure, sand, and peat. A soil pH of around 6-7 is suitable for bulbous plants. After choosing the bulbous plant to be grown, it is necessary to decide in which order they will be planted. To start, devise a garden plan and meticulously plot the layout for our intended hobby garden. It should be determined how much of which plant bulbs will be planted and where. Bulbous plants should be planted in clusters, just like in their natural habitat. This brings out their aesthetic and colors much better. In such a planting, it will be easier to fulfill the plant's requirements such as light and water. Never plant a bulb in a single row or a circle around the tree. Onions will be much better visually when planted in clusters. Bulbous plants are found in irregular clusters in their natural habitat. When making a cluster, care should be taken to make an arrangement close to nature. For this, 4-5 onions are taken at once, randomly thrown into the grass, and planted where they fall, even if some are far away. Among the best species for this type of planting are autumn crocus, dwarf tulip, daffodil, and hyacinth. With natural planting, onions should not be taken from where they are but should be left in the same place for years. A group should be made with at least 12 tall bulbs. The larger this number, the greater the visual impact of the group. When forming groups of small bulbs, at least 50 bulbs should be planted if a good visual effect is desired. Generally, tall bulbs should be planted in the back and short bulbs should be planted in front. Tall bulbs, like inverted tulips, that are easily visible from a distance, should be planted in the corners of gardens. Flower bulbs should be used as a single color in small areas. Mixed-color designs make a small space look even smaller. It is more effective to use two or three-color bulbs in large areas. These plants should not be planted randomly but with a uniform color distribution.

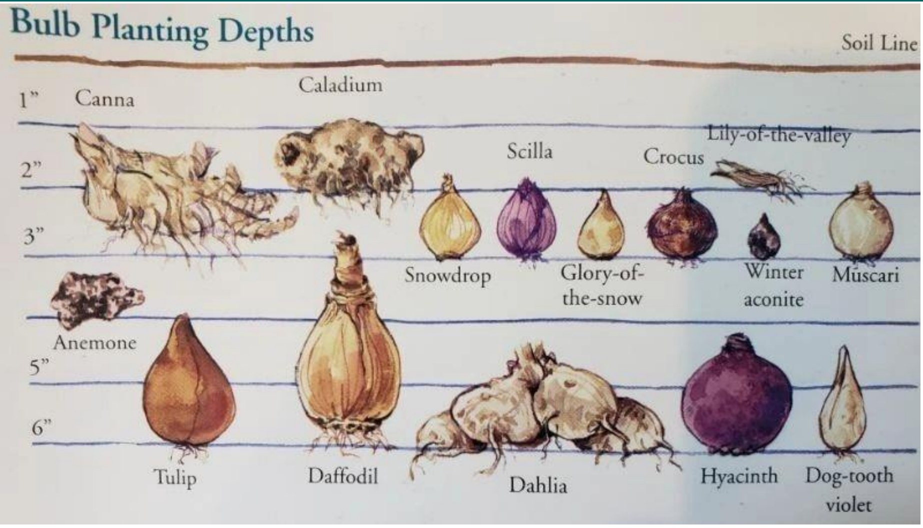

Figure 1. Planting depth guide (https://rissakhani.com/f/bulb-planting-depth-and-more-on-forcing-bulbs/full/url) (01.06.2023)

Planting Rules of Bulbous Plants

1. The soil should be well prepared before planting. It should be cut and straight. The soil mix can be obtained from a mixture of sterile peat, vermiculite, and animal manure.
2. The ideal planting time is when the soil temperature drops below 15 °C. In coastal areas, this time is between November and December.
3. Since the bulbs are difficult to store, planting should be done as soon as the soil is prepared.
4. The general rule in planting bulbous plants is that they should be planted twice as deep as the bulb to be planted. For example, if the diameter of the onion is 15 cm, it is recommended to plant the onion at a depth of about 30 cm, and if the diameter is 5 cm, at a depth of about 10 cm.

5. The tip of the onions should never be left on the soil. Onions should be planted at least as deep as their size.
6. Planting depths can vary according to the onion species, as well as depending on the climatic conditions of the region where planting will be made. For example, while onions are planted closer to the surface in Antalya, where the hot climate prevails, they are planted deeper in regions with cold climates such as Ankara-Erzurum.
7. Planting depth should be determined considering the season in which the onions will be planted. While the depth of spring-summer planting is low, the planting depth can be increased a little more in autumn plantings.
8. Onions are usually planted in the fall. Thus, the flowering of plants will coincide with spring-summer. The most suitable planting season for plant physiology is autumn. However, if the planting is done according to the rules in other seasons, results can be obtained.
9. Small bulbs with stem structures can be planted very close to each other, approximately 10 cm apart, and larger bulbs approximately 10-20 cm apart. In other words, the distance between the bulbs and the distance between the rows vary according to the plant species. However, if it is desired to create a very distinctive color riot, the row spacing of the onions can be reduced.

4. Succulent Plant Gardening

Succulents are fleshy leaf plants. In other words, they have a thick and meaty appearance as they contain water in their stems. Succulents are plants that adapt to extreme environmental conditions such as lack of water and high temperature, with their general morphological characteristics and lifestyles. In addition to these features, the structure of flowers and seeds, and the shape, texture, and color characteristics of their leaves make these plants aesthetically interesting. Succulents are plants that can be used indoors and outdoors. It is very easy to grow and maintain compared to many plants. In addition to its use as an indoor plant, especially in the last few years, municipalities in the hot climate region, which are trying to reduce water consumption due to global warming and climate change, are growing succulents among alternative green field plant species. There are many genera and species of succulent plants, which are considered as an alternative to grass species due to their low plant water consumption in green field arrangements. The number of genera in the world is more than 500 and the number of species is about 10,000. Sedum and Sempervivum species belonging to the Crassulaceae family constitute the highest number of species in our country.

Terrarium; (Latin terra (earth) atrium, derived from analogy with the word aquarium) is an area usually prepared from succulent plants, which resembles a dry habitat in an enclosed space such as a jar or aquarium. Although it is perceived as an ornament today, it is possible to see the terrarium as an ecosystem. It will be enjoyable to create such an environment to grow our succulent plants (https://www.tarimbilgisi.com/haber/sus-bitkileri/teraryum-nedir).

Figure 2. Succulent plant gardening (https://homebnc.com/best-succulent-garden-ideas/full/url) (01.06.2023)

In general, succulent plant species are divided into two groups leaf and stem type. Both of these types can take their place in succulent gardens.

- **Leaf Type Succulents:** Leaves can take many forms. They can be tufts attached to the branch, long branches at the ends of tufts, or spirally arranged leaves, as in shrubs. Succulent leaves are very different from normal leaves. In certain species, like lithops, the entire vegetative portion of the plant can consist of two leaves fused, resembling a pair of pebbles. In some Aeonium and Sempervivum species, the leaves are somewhat fleshy and resemble typical foliage.
- **Body Type Succulents:** The exact boundary between stem and leaf type may not always be drawn. Some Sedum species can fall into both groups. Most of the cacti are stem-type succulents. Succulent stem structures may be spiny, swollen, tuberous, knotty, or segmented. These stems are spherical or cylindrical.

The essential characteristics of succulents are;

- They absorb water the fastest. Because it is not clear when and how much water will come.
- Stores water, sometimes 95% of the plant is water.
- In succulents, leaves are usually shrunken, cylindrical, or spherical.
- Water is retained in the stem, leaves, and roots.

There are numerous genera and species of succulent plants, which are deemed a viable substitution for traditional grass species because of their minimal water consumption in green field setups. We can prepare the succulent herb garden on a certain land, parks and gardens, private hobby gardens, terraces, and botanical gardens. When we create a garden, the materials we use can differ. The materials we will use in the garden are sand, gravel, and rock. It consists of peat, perlite, pumice, bark, and plant species to be planted. Since the purpose of succulent herb gardens is exhibition, hobby, or landscaping, it is not possible to fix the material amounts. Succulent herb gardens are usually created in the rock gardens section of botanical gardens. It is one of the indispensable plant species of rock gardens. Succulents are planted in the prepared sand material. Slightly larger stones are placed in between to avoid impeding their growth. Cacti, which are among succulents, are very tolerant plants in terms of growing conditions. Like all plants, succulents are like well-drained soils. Before creating our succulent garden, it is important to plan according to the dimensions of our garden. Then we have to adjust the ambient conditions and start planting. Generally, it is more correct to create a succulent garden by creating a greenhouse. We can grow any succulent plant we want in the greenhouse.

5. Rock Gardening

A rock garden, in short, is a composition of rocks and plants. While Japanese rock gardens typically feature artistic combinations of stone, rock, and sand, the term "Rock Garden" most commonly refers to English-style rock gardens. Alpine gardens became popular in England during the 1800s as a means of creating habitats for alpine plants. Over time, they evolved to incorporate more natural views, and with growing aesthetic considerations, rock gardens gained popularity. Plants have a very important function in natural rocky areas. The rough and solid appearance of rocky areas is made smoother by plants, revealing beautiful and pleasing landscape features. Thus, such rocky areas become more natural and closer to people. Garden flowers are also an important part of rock garden planting as colorful, short, and showy species. If it is aimed that the most beautiful mountain plants in the world can grow in the garden and present all their beauty, a rock garden can be created. The most important elements of rock gardens are mountain plants or, in other words, Alpine plants. A rock garden, also called a rockery or alpine garden, is a type of garden made with rocks and stones, featuring plants that grow in rocky areas or the cool climate found in alpine regions. A rockery is a display of plant species adapted to rocky environments, growing on rocks or between stones. The ecological demands of the plant species grown here are quite different. There are rock plants that thrive in hot and arid climates, as well as those that require a very humid and wet environment.

Rock gardens are typically compact, so the flora featured in rock gardens tends to be of smaller stature, and the rocks are not fully concealed. People can set up a hobby rock garden plant in a garden of their own. It is also possible to come across rock gardens in botanical gardens. When establishing a rock garden facility, it is important to begin by determining the area where it will be located and creating a sketch of the space. A normal rock garden has a pile of rocks, large and small, arranged aesthetically with small gaps between them. Plants will take root on these rocks. When deciding which plants to grow in rock gardens, it is necessary to consider the climatic conditions of the region we are in. When selecting plants for these gardens, those that thrive in well-drained soils with low water requirements are typically preferred.

Figure 3. Rock Gardening (https://cembotanic.com.tr/kaya-bahcesi-bitkileri/full/url) (01.06.2023)

5.1. Rock Garden Materials

There is no space restriction in the rock garden. A large garden or a small place on the balcony can be arranged in this way. It is important to start the application by choosing the right materials. Even very small areas can be applied if smaller rocks, fewer trees, and bushes are used and sand replaces the gravel. Soilless and sunless areas can be evaluated with artificial greening. The shape and location of rock gardens vary. Accordingly, the application materials also change. In general terms, the main materials of the application are sand, gravel, stones, rocks, logs, sometimes grass, bright stones, rakes, and Japanese plants, all of which have different meanings. Stone, gravel, gravel, sand, peat, and soil are generally inanimate materials used.

Wooden flooring, bridges, or Japanese stone garden lanterns can be added to the garden optionally. Most of the plant species used in the design can be used for a long time without spoiling and should be low-maintenance plants. Grass planting can also be done upon request. However, if the grass is not preferred, the maintenance of the garden will be easier. According to the lifespan of rock garden plants, they are classified as annual, biennial, or mostly perennial. According to their root structure, they can have fringed roots, bulbs, rhizomes, or tubers. These plants are also classified according to the degree of lignification. In particular, some annual and biennial plants that can grow better in different environments are of great importance in rock gardens. Plant groups appropriate for growing in rock gardens are conifers, broadleaf trees, shrubs, herbaceous plants, bulbous and tuberous plants, meadow plants, and ferns. Some plant options suitable for rock gardens include mountain herbs such as meadow chamomile, mouse ear, and mountain thyme, as well as floral options like Persian cyclamen, primrose, and immortal flower. Trees like dwarf spruce, blue pine, and juniper can also thrive in rock gardens. Additionally, roof groves, rosemary, and miniature roses are viable options.

The essential characteristics of rock garden plants:

a. Rock gardens should look natural and should be designed without detracting from naturalness.

b. The arrangement features and sizes of rock gardens should be in harmony with the environment.

c. A single type of rock should be used in a garden or similar origins should be preferred.

d. The plant species to be used in the design should be selected by considering the climatic and soil conditions of the region.

e. For plants of rock garden arrangement, the soil should be prepared by mixing especially calcareous, calcareous soils with a pH value of 7.5 with alluvial soil and peat.

f. Dwarf coniferous plant species should be preferred for background planting.

g. Materials should be selected taking into account the dimensions of the garden.

h. There should be parts between the rocks where we can place plants.

ı. Ground cover plants should not be preferred in any way as they can obscure the view of the rocks. The places of the plants that will expand and grow quite a lot should be separated accordingly.

j. The sun should be taken into account when establishing a rock garden, and the plants to be used should be chosen accordingly.

k. The final state of the plants should be known and placed accordingly.

5.2 Rock Garden Types

a. Natural Looking Rock Gardens: These are gardens formed by the informal arrangement of rocks of different sizes on an artificially created elevation on a flat area along a slope. Natural-looking rock gardens are well suited for sloping areas such as slopes and slopes. It should be created with artificial slopes or hills on flat lands. For hillocks, elevations of 0.50 - 1 m are visually sufficient. Slopes or hills should be in a position that is open to the sun (southeast, south, southwest), protected from shadow effects and strong drying winds. In rock gardens, integrating moving and still water features with plastic rocks and aesthetically pleasing plants enhances the overall arrangement. This enriches the environment and provides a balanced landscape. With a general approach, it is appropriate to design rock gardens according to areas ranging from 15 to 60 m2 (the most suitable is 50 m2).

b. Formal Rock Gardens: Stone stairs are installed in areas designed as geometric terraces. It differs from natural stone gardens in terms of the way the stones are arranged and processed. As the construction is based on stepped dwellings or terrace formations, it requires slopes or terraces with sufficient incline. On flat lands, stone gardens in architectural style can be arranged with sloping areas formed in the form of wide hillocks.

c. Other Rock or Stone Garden Forms: Stone cushions are stone gardens arranged in the form of wall cushions or living walls and stone troughs. Stonewall cushions should be installed near the terrace due to their strict geometric form. They are arranged in the form extending in the north-south or north-west-south-east direction at a height of 80 cm. Stone troughs, on the other hand, are suitable for miniature arrangements based on rock vegetation with a natural or artificial groove, on the edges of seating areas and terraces.

6. Conclusion and Proposals

The growing number of people residing in cities around the world is resulting in the reduction of green spaces and the decline of connections between individuals and the environment. Urbanization practices that are not in line with sustainable development within urban and agricultural areas are decreasing. Climate change is adversely impacting the urban ecosystem. Hobby gardens, one of the urban agricultural activities, are also very important for sustainable urban development. These places encourage individuals to escape their stressful surroundings and to state their desire for plants and soil. They are also important in inspiring future generations to value nature (Yılmaz Çildam, 2022). Cities use eco-friendly strategies as part of their sustainable urban plans to address environmental concerns.

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Biological Control Approach to Plant Pathogen Management

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1. Introduction

Agricultural production is not only the livelihood of people worldwide but also serves as a primary source of food for humans and animals and as a raw material for various industries (Bulut & Dinler, 2021). Agriculture is essential not only for meeting people's basic needs but also for contributing to the country's economy and providing employment opportunities. As the world population rapidly increases, countries are facing hunger issues due to the decreasing available agricultural land. To meet the food needs of approximately 9.8 billion people worldwide by 2050, agricultural productivity needs to be increased by about 70% due to various factors such as global climate change, emerging diseases, harmful species, and other constraints on agricultural production (FAO, 2017; Abdelrahman et al., 2017; Valeria et al., 2022).

The reduction in agricultural land leads to an intensification of agricultural activities in different parts of the world, increasing the use of various agricultural practices like pesticides and fertilizers to enhance productivity by increasing the yield per unit area. However, various biotic factors such as plant pathogens (bacteria, fungi, viruses, insects, nematodes, weeds) cause yield losses ranging from 31% to 42%. Additionally, abiotic factors like extreme weather conditions, salinity, alkalinity, acidity, soil pollutants, drought, and flooding also deteriorate soil health (Sood et al., 2020). The losses caused by plant diseases and pests have been a continuous challenge for humanity, resulting in quality and quantity losses of up to 100% in some regions and years. Overall, crop losses, including post-harvest losses, due to diseases and pests are known to exceed 40%

(Baloğlu, 2022). It has been reported that the financial value of these losses amounts to approximately 550 billion US dollars per year. To control these losses, approximately 3.5 million tons of pesticides are used worldwide, with an estimated value of 45 billion US dollars (Baloğlu, 2022). Herbicides, insecticides, and fungicides are the most widely used pesticide groups (Sharma et al., 2019). It is projected that the global usage of pesticides will increase to 4.5 million tons by 2030 (Zhang, 2018).

One of the main ways to improve and increase agricultural production is to reduce losses caused by biotic and abiotic stresses. Several techniques, methods, and approaches are employed to manage plant diseases. These include the development of resistant varieties through plant breeding; genetic modification of crops; the use of pesticides and physical treatments such as heat, UV light, atmospheric changes, cold storage, and inducers to enhance resistance; the use of biological control agents; and the use of appropriate agricultural and cultural practices (Gupta & Sharma, 2014; Singh, 2014; O'Brien, 2017).

Modern agriculture is constantly evolving and changing. Biotechnologies and new breeding techniques have emerged since the widespread use of chemical fertilizers and pesticides, which contributed significantly to yield increases in the twentieth century (Van Montagu, 2019). Production increases are often linked to improvements in cultivation techniques, particularly the use of resistant and more efficient varieties, especially against major diseases (Ngoune Liliane & Shelton Charles, 2020).

Chemical control has been widely preferred in the control of plant diseases in agricultural production for many years. Plant pathogens develop resistance to the chemical pesticides used, making it difficult to control and manage plant diseases (Koike & Gordon, 2015). Therefore, while pesticides are effective in increasing agricultural production efficiency, their improper and excessive use causes significant pollution in water, air, and soil, harming the environment and nature. Due to the inappropriate use of chemical pesticides, increased production costs, and reduced income, farmers are now seeking economically viable, environmentally friendly, biotic and abiotic stress-managing, sustainable, and effective integrated pest management methods, considering the significant effects of biocidal agents (Pandey et al., 2021). The intense and uncontrolled use of pesticides has led to disruptions in natural balance, negative effects on the environment and human health, and the banning of most chemical fungicides by the European Union, resulting in the search for sustainable, alternative new methods for plant disease management (Koike & Gordon, 2015). Therefore, due to all these negative effects, in recent years, the need to reduce the use of chemicals in disease management has searched for new alternative methods. It has been reported that when chemicals applied to the soil before planting are used together with appropriate application methods, the amount of inoculum in the soil can be significantly reduced (Koike & Gordon, 2015).

For this purpose, one of the first methods that come to mind for sustainable, environmentally friendly, and long-lasting effective control of plant diseases is biological control. Biological control is seen as an alternative control method that meets these requirements and is widely used in agriculture (Gouvea et al., 2009; Noling, 2016; Abd-Elgawad, 2020); Tronsmo et al., 2020).

In recent years, there has been an increase in research on biological agents that aim to reduce the need for pesticides or minimize their use (Howell, 2003; Benitez et al., 2004). Currently, biological control agents from genera such as *Aspergillus*, *Gliocladium*, *Trichoderma*, *Ampelomyces*, *Candida*, *Coniothyrium*, *Bacillus*, *Pseudomonas*, and *Agrobacterium* are commonly used in biological control of plant diseases (Cawoy et al., 2011; Naher et al., 2014).

In recent years, there has been a search for effective, economical, and commercially producible biocidal products, particularly for controlling soil-borne pathogens. Some biological control agents are currently being formulated into commercial products to be used in field conditions for the control of plant diseases (Spadaro & Gullino, 2005). These antagonists exhibit different mechanisms of action, for example, mycoparasitism, competition for space and nutrients, antibiotic and secondary metabolite production, and stimulation of plant defense (Yedidia et al., 1999; Howell, 2003; Kredics et al., 2003; Benitez et al., 2004), all of which contribute to enhancing plant growth and increasing crop yield (Harman, 2006).

This study focuses on the significance of biological control, biological control agents, and the mechanisms through which bioagents are used for biological control.

2. Abiotic and Biotic Stress Factors in Plants

Plants are affected by various unfavorable conditions that limit their development in the areas where they are found. According to research, the negative impact of environmental stress factors on crop production will increase in many regions of the world due to the continuation of climate change and the increase in adverse weather conditions (Denby & Gehring, 2005). These factors can be classified into two groups based on their origins: abiotic and biotic stress factors. Biotic stress is caused by organisms/microorganisms, while abiotic stress factors such as soil structure and pH, soil moisture, nutrient deficiencies, air humidity, air and soil pollutants, drought, salinity, high and low temperatures, light, heavy metals, radiation, oxidative stress, and wind negatively affect plant growth, quality, and productivity. Deviations of these factors from normal conditions can cause stress in plants, resulting in significant crop losses if left unaddressed (Ekinci et al., 2018).

Abiotic stress factors have been reported as the main limiting factors for plant production worldwide, causing a decrease of over 50% in the yield of most crops (Mahajan & Tuteja, 2005). In recent years, numerous studies have gained momentum in the effort to reduce the impact of stress factors on crops. These include the use of different irrigation techniques, soil improvement, and the appropriate use of fertilizers.

Biotic stress is caused by living organisms, especially viruses, bacteria, fungi, nematodes, insects, spiders, and weeds. Agents that cause biotic stress can disrupt the host plants metabolism or deprive it of nutrients, resulting in plant death. In recent years, the number of diseases resulting from fungal, bacterial, and viral infections that affect plants at various vegetation stages has increased in agricultural production. Plants are exposed to the negative effects of these biotic stress agents and various environmental conditions. Biotic stress can result in significant losses both pre-harvest and post-harvest (Kumar & Nautiyal, 2022).

Crop losses due to a variety of biotic and abiotic stresses are a serious problem worldwide, with disease and pest losses in various crops estimated at 20-40% worldwide (CABI, 2023). Depending on environmental conditions and whether the plants are healthy or not, disease prevalence can reach 70-80% of the total plant population. In some cases, yield losses can be as high as 80-98% (Nazarov et al., 2020).

In conclusion, plants worldwide are affected by approximately 80,000 diseases, most of which are known as soil-borne diseases. These diseases lead to crop loss, and considering that according to the statistics of the World Food Programme (WFP) in 2015, 815 million people suffer from hunger worldwide, and on average, one in every nine people is hungry, they are seen as a major cause of hunger in the world (Ghosh et al., 2019).

3. Biological Control and History

Among the objectives of agricultural production is to achieve high yields per unit area while ensuring both economic and environmentally friendly production, taking into consideration the environment and human health. To achieve this goal, various methods of control against diseases, pests, and weeds are applied in agricultural fields, in a harmonious and balanced manner, within the framework of Integrated Pest Management (IPM) principles. These methods include Cultural Measures, Physical-Mechanical Control, Chemical Control, Biological Control, and Biotechnical Control. Chemical control is often preferred due to its ease of application and quick results. However, the long-term irreversible negative effects of chemical control on the environment and human health have led to an increase in research on alternative control methods.

The threat posed to the environment and human health as a result of intensive and indiscriminate use of pesticides, along with issues like residue problems and high pesticide prices, have led people towards alternative and environmentally friendly control methods. "Biological Control" is considered one of the most environmentally friendly, cost-effective, and sustainable methods among these alternatives. Biological control emerges as a safer, more sustainable, and economically viable method in the long term, both for the environment and human health.

Biological control of plant diseases is generally defined as the direct or indirect prevention of a disease or its pathogen by another organism (antagonist) or group of organisms (Cook & Baker, 1983). Biological control with antagonistic microorganisms has been continuously researched since the 1980s (Guédez et al., 2009). The use of biological control agents in integrated pest and disease management (IPDM) has been recognized as an important sustainable alternative for the reduction of negative impacts on the quality and productivity of agricultural products (Villarreal Delgado et al., 2018). Thus, biological control is the control of harmful organisms / microorganisms by beneficial organisms / microorganisms. Biological control has been found to offer several advantages for better disease control, particularly in situations where traditional methods are inadequate or limited (Villarreal Delgado et al., 2018). The use of biological control, together with the use of disease-resistant varieties, plays an important role in integrated pest and disease management programs aimed at reducing the use of chemical pesticides (Collinge et al., 2022). A biological control agent is not a chemical itself but an organism or a group of organisms. It is preferred over most agricultural chemicals available in the market due to its more specific effect and lower likelihood of leaving potentially harmful residues in the environment. A living organism can enter a diseased plant or control the target pathogen more effectively than a chemical. Additionally, in some cases, the risk of developing resistance to the used chemical pesticide by pathogens can be significantly reduced by applying a biological control agent. Biological control is also perceived as less harmful to the environment compared to chemical control in public opinion; in many cases, this is true because no new chemicals are introduced into the environment. Due to these advantages, many forms of biological control are also accepted in organic farming (Collinge et al., 2022).

Since 1932, Weindling has published several articles demonstrating that a Trichoderma isolate can reduce the damage caused by *Rhizoctonia solani* in citrus seedlings and identify some potential mechanisms of action (Weindling, 1932; 1934; 1941).

Currently, *Trichoderma* spp. are probably the most commonly used organisms worldwide as biocontrol agents for plant diseases (Lorito et al., 2010). In research conducted, the inoculation of freshly cut pine tree branches with commercially available *Phlebiopsis gigantea* has been used as a biocontrol against *Heterobasidion annosum* in pine plantations in some regions of Europe since the 1960s, following Rishbeth's (1963) study (Pratt, 1999). In the 1970s and 1980s, other significant projects demonstrated effective measures to prevent yield loss in wheat (Cook, 2007). Since the 1970s, biological control of crown gall caused by *Agrobacterium tumefaciens* in stone fruit trees with the biocontrol agent *Agrobacterium radiobacter* K84 (syn. *Rhizobium rhizogenes*) led the way for extensive research showing that beneficial microorganisms can be used to control plant pathogens (Kerr, 2016). In the 1980s, biological control emerged not only as a strategy but also as an approach to reducing yield losses caused by plant diseases. In 1981, Papavizas pointed out that the foundation of biological control could be found in previous agricultural practices that allowed time and opportunity for the biological elimination of pathogens, such as crop rotation, burying diseased plant residues, and fertilizing with organic manure. However, Baker & Cook (1974) introduced the term "pathogen-suppressive soils" to describe apparent examples of biological control in soil-borne plant pathogens where disease did not occur despite the presence of a suitable environment, a susceptible host, and virulent pathogens. The suppression of specific pathogens was explained as a result of the natural "microbiological structure" of the soil or management practices that encouraged antagonists capable of controlling the disease (Papavizas, 1981).

Over the past 30-40 years, much work has been done to understand the biology of disease or pathogen-suppressive soils. An additional crucial stage of turning research outcomes into products practical for producers centres on the formulation of new plant protection products based on micro-organisms. Jacques and Suoma Ricard founded the BinabR company in Sweden in 1972, producing the *Trichoderma*-based biocontrol agent product Binab-T™ and becoming among the first to commercialize Trichoderma-based biocontrol agents.

Nowadays, many products based on *Trichoderma* spp. are available in the market. Since then, many biocontrol agent products have been developed and commercialized worldwide. These products include bacteria (particularly *Bacillus*, *Pseudomonas*, and *A. radiobacter* strains) and fungi (particularly *Trichoderma* spp.), widely used globally (Collinge et al., 2022).

4. Importance of the Use of Biological Control

The use of biocontrol agents began in the early nineteenth century with the application of living organisms or their metabolites to reduce diseases in agricultural products (Villarreal Delgado et al., 2018). The use of a biocontrol agent serves as a method to prevent diseases applied either before or after planting. Furthermore, considering its characteristics, biocontrol can be used in conjunction with other control methods for integrated pest management purposes. Traditional methods used to control post-harvest losses include storage, chemical products, and more recently, integrated management or the use of biocontrol. The latter, applied after harvest, allows for the ongoing control of factors (for example humidity, temperature, etc.) using biocontrol agents, which offers a high probability and ease of use (Wisniewski et al., 2007; Pal & Gardener, 2006).

Post-harvest fungicides available for use are limited, and their application to fruits and vegetables raises concerns about potential oncogenic agents, leading to increased hygiene and health restrictions. This has led to the establishment of Maximum Residue Limits (MRLs) in food legislation. In contrast, biocontrol, unlike agricultural chemicals used in farming, does not leave residue effects on fruits and vegetables, making it a suitable and safe application for humans (Guédez et al., 2009).

Biological control methods that utilize microorganisms, like other alternatives, offer a possible way to minimize pollution and significantly reduce the environmental impact and challenges associated with the use of synthetic chemicals (Usta, 2013; Compant et al., 2005). The idea of biocontrol has initiated significant economic, technological, and political discussions focused on creating sustainable agriculture that has fewer ecological costs (O'Brien, 2017; Barratt et al., 2018). In line with this goal, various countries have implemented pest control programs that can potentially reduce pesticide use by around 50% (Macfadyen et al., 2014). The measures demonstrate an awareness of the accumulation of harmful residues in the environment and their presence in various links of the food chain. Moreover, they indicate the absence of alternatives to reduce the agriculture sector's reliance on pesticides. Therefore, it is essential to improve our understanding of biocontrols to enhance their usefulness and effectiveness (Barratt et al., 2018).

Over the past thirty years, many microorganisms have been studied for their antagonistic activities against various bacterial and fungal plant pathogens, leading to an increase in the use of microorganism-based biopesticides for the management of various plant pathogens (Jeyarajan & Nakkeran, 2000; Kong, 2018; Babbal & Khasa, 2017; Poveda et al., 2021; Bonaterra et al., 2022; Boro et al., 2022). Many bacteria, fungi, and actinomycetes play a vital role in the biological control of plant diseases.

Several microbial antagonists like bacteria, including *Bacillus*, *Pseudomonas*, *Burkholderia*, *Agrobacterium*, and *Enterobacter*, as well as fungi such as *Streptomyces*, *Trichoderma*, *Gliocladium*, and *Coniothyrium* show immense potential in the biocontrol of various leaf and root diseases on several crop plants. They have shown enormous potential for biocontrol against various leaf and root diseases on different crop plants. Many commercial bio-products have been developed using bacterial and fungal biocontrol agents. They have been evaluated against several plant diseases and are currently available for sale on the market (Krishnaraj et al. 2014; Kong, 2018; Babbal & Khasa, 2017; Chenniappan et al., 2019; Poveda et al., 2021; Bonaterra et al., 2022; Boro et al., 2022; Gusella et al., 2022).

5. Biological Control with Biological Control Agents

In modern agriculture, plant diseases pose a significant challenge since they reduce both the yield and quality of products. Therefore, it is essential to develop methods that protect against diseases and pests while ensuring high-quality food production and maintaining or increasing yields. Over the past 50 years, the use of conventional chemical pesticides in agriculture has been associated with environmental pollution, including soil and water contamination. These chemical pesticides can also leave residues in food and negatively impact beneficial non-target organisms. Consequently, researchers are seeking natural and environmentally friendly alternatives for crop protection that can address the issues associated with chemical pesticides (Hamdi & Alzawi, 2023).

Soil-borne plant pathogen control has been an area of research for more than 80 years, and microorganisms in the rhizosphere are ideal candidates for use as biocontrol agents. This is because they can provide the highest level of resistance to root pathogens' attacks, as they are close to the roots (Suprapta, 2012).

In recent years, natural compounds and beneficial microorganisms have attracted attention as biological control agents or plant biostimulants. These applications offer various advantages compared to conventional pesticides; for instance, they generally exhibit low toxicity, leave zero residues in food, and their mode of action often allows them to be used both preventively and curatively. These advantages make them suitable for sustainable agriculture, meeting new demands from the agricultural and food sectors in the European region, and aligning with the objectives of the European Green Deal for the benefit of society (Llorens & Agustí-Brisach, 2022).

Biological control methods of plant diseases have revealed biocontrol agents, which are organisms or microorganisms that either stimulate biological mechanisms to reduce the quantity or impact of pathogens or alter the microenvironment to support the activity of naturally occurring antagonists (Baker, 1987; Stirling & Stirling, 1997). These biocontrol agents are responsible for controlling plant pathogens.

Biocontrol agents, which are usually fungal or bacterial strains obtained from the phyllosphere, endosphere, or rhizosphere, play a major role in controlling pathogenic organisms that afflict plants. Microbial antagonists, also known as biocontrol agents, prevent pathogen infection in host plants or hinder pathogen development within the host plant. It is generally accepted that the main mechanisms of control are those that directly affect the pathogens.

Antagonists can demonstrate several direct or indirect mechanisms involved in the biological control of diseases. These mechanisms include antibiotic production (inhibitory metabolites or antibiotics produced by the antagonist), induced resistance (stimulating plant defense mechanisms against plant pathogens), mycoparasitism (the antagonist obtaining a portion or all of its nutrients from the fungal host) and promotion of plant growth and development (biocontrol agents reduce the effects of the disease while promoting plant growth through microbial hormones such as indole acetic acid and gibberellic acid). Other elements involved in biological disease control include the secretion of extracellular hydrolytic enzymes by antagonist organisms, competition among organisms for space and nutrients, and detoxification of virulence factors (Chandrashekara et al., 2012; Singh, 2014; Zhang et al., 2014; Deketelaere et al., 2017). Recent studies have also shown the importance of effects such as induced systemic resistance or localized resistance on plants through microbial biocontrol agents. These fungi or bacteria can colonize the root epidermis and outer cortical tissues, producing bioactive molecules that result in the closure of fungal tallus or bacterial colonies with the plant wall (Harman, 2006).

They play an important role in controlling disease agents and protecting plants from many diseases. They kill the disease agent population before the disease spreads. Biocontrol agents have wide-ranging applications since they do not cause any harm to the main product and naturally eliminate the disease population. Many bacteria (*Pseudomonas* sp., *Bacillus* sp., etc.) and fungi (*Candida* sp., *Trichoderma* sp., etc.) are used as biocontrol agents (Sarma, 2019).

Among them, Bacillus has properties such as high survival due to its endospore-forming ability and promotion of growth, which contribute to biological control (Moreno Velandia et al., 2018). On the other hand, Trichoderma is highly useful due to its stability in root colonization, endophytic nature, mycoparasitic activity, competition for nutrients, antibiotic production, and promotion of resistance in plants. Pseudomonas, with its diverse metabolism, can colonize roots endophytically, produce siderophores and substances that promote plant growth, and adapt to stressful conditions (Moreno Velandia et al., 2018). Both *Trichoderma* spp. and *Bacillus* spp., as well as *Pseudomonas* spp., are known as biocontrol agents for soil-borne pathogens, including *Pythium oligandrum, Sporidesmium sclerotivorum, Coniothyrium minitans* and *Fusarium oxysporum* (Moreno Velandia et al., 2018).

The characteristics of an effective biological control agent are as follows (Prajapati et al., 2020):

- It is necessary for biocontrol agents to inhibit the development of the pathogen to be effective.
- An effective biocontrol agent must be able to compete with the pathogen for nutrients and space.
- The production of antibiotic compounds is another important feature of effective biocontrol.
- Producing lytic enzymes which are effective against a pathogenic organism.
- The ability to be a parasite of the pathogen.
- The ability to interfere with the ability of the pathogen to reproduce.
- Induction of host defense mechanisms.

Advantages of Biocontrol Agents

Biocontrol agents have numerous advantages. They are environmentally friendly and prevent soil pollution, without any negative effects on humans, animals, and other beneficial organisms in the soil (Chandrashekara et al., 2012).

• Biological control is less costly and more economical compared to other methods. It is cheaper than chemical pesticides and insecticides.

• Biocontrol agents protect crops throughout the vegetation period. They can be used in every season, and they do not cause toxicity to plants.

• The use of biocontrol agents is safer for the environment and for the health of the applicator.

• They easily thrive in the soil and do not leave any residue issues.

• Biocontrol agents not only control disease. They also promote root and plant growth by stimulating beneficial soil microflora, thereby increasing crop yields.

• The use and application of biocontrol agents are straightforward.

• Biocontrol agents can be used in combined applications with bio-fertilisers.

• Their production is relatively easy.

• They are harmless to humans and animals (Environmentally safe).

Disadvantages of Biocontrol Agents

There are many advantages to biological control. However, there are also disadvantages (Chandrashekara et al., 2012).

• Biocontrol is a process that yields slow results compared to the quick outcomes of chemical methods, which are more commonly preferred.

• Biocontrol agents require a great deal of patience and waiting for them to be effective.

• Biocontrol agents may not completely eradicate the disease or pest.

5.1. Bacteria as Biological Control Agents

In recent years, many microbial biocontrol agents (BCA) have been developed for the control of fungal and bacterial diseases (Bonaterra et al., 2022). For decades, bacteria have been added to soil, seeds, roots, and other cultivation environments to promote plant growth and development. The purpose of these bacteria is to provide benefits in areas such as degradation of toxic compounds, nitrogen fixation, plant growth and development, and biological control of phytopathogenic microorganisms. According to various research results, many bacteria have significant potential in controlling various plant pathogens such as nematodes, fungal and bacterial diseases. Many bacterial genera such as *Acinetobacter*, *Agrobacterium*, *Alcaligenes*, *Arthrobacter*, *Azospirillum*, *Azotobacter*, *Bacillus*, *Bradyrhizobium*, *Frankia*, *Pantoea*, *Enterobacter*, *Erwinia*, *Pseudomonas*, *Rhizobium*, *Serratia*, *Stenotrophomonas*, *Streptomyces*, *Thiobacillus*, and *Xanthomonas* are known to be effective against fungal and bacterial plant pathogens (Bonaterra et al., 2022). Bacterial biocontrol agents utilize various mechanisms to protect plants from pathogen infections. These mechanisms include colonization of infection sites and competitive elimination of the pathogen, antagonist properties based on the secretion of highly active antimicrobials like antibiotics or cell wall lytic enzymes, and stimulation of plant defense mechanisms (Montesinos & Bonaterra, 2009; Lugtenberg & Kamilova, 2009; Berendsen et al., 2012).

The effectiveness of a bacterial biocontrol agent against plant diseases depends on the microbial agent itself (its mode of action, conditioning, dose, application methods), the targets of plant pathogens (sensitivity), the host (plant species, physical characteristics), and environmental conditions (chemical residues biotic and abiotic factors, presence of nutrients, temperature, humidity) (Montesinos & Bonaterra, 2009).

To prevent or reduce plant diseases, biocontrol agents use one or more mechanisms by directly or indirectly interacting with the pathogens (Köhl et al., 2019; Legein et al., 2020). The biocontrol agent can directly interact with the pathogen through the secretion of antimicrobial compounds, influence the pathogen's virulence, and compete for nutrients and space. Many biocontrol agents synthesize and secrete metabolites, such as bacteriocins, lipopeptides, antibiotics, biosurfactants, or microbial volatile compounds and cell wall degrading enzymes which have antimicrobial activity by reducing the development or metabolic activity of pathogens (Kalia et al., 2019; Bonaterra et al., 2022).

5.2. Fungi as Biological Control Agents

Developments in modern agriculture in the world are moving towards reducing the use of chemical pesticides and various biocontrol methods, strategies, and approaches are used in plant disease management. For this purpose, certain fungi are employed systematically and biologically to control the growth of other pathogenic fungi that adversely affect plant growth and development. These antagonists play a significant role in controlling plant diseases and are used worldwide as biocontrol agents (Thambugala et al., 2020).

Fungal biocontrol agents are target-specific and are considered a developing field in biocontrol studies due to their high reproductive capacity and short generation period. They have replaced chemical pesticides due to their complex mechanisms of action, which are utilized against pests, insects, weeds, and plant pathogens without inducing resistance or causing harm to the environment. Fungal biocontrol agents are used to control disease through a variety of mechanisms including antibiosis, mycoparasitism, induced resistance and competition. Extensive research is ongoing to explore biological disease control mechanisms and develop new and effective fungal biocontrol agents (Thambugala et al., 2020).

Trichoderma is one of the important biocontrol agents used to control other phytopathogenic fungi. It is an effective mycoparasite against numerous plant pathogens originating from both air and soil, and it can be utilized as a potential biopesticide in field or greenhouse treatments. *Trichoderma* is considered the genus with the highest potential, containing 25 biocontrol agents used against various plant fungal diseases. Other fungi such as *Penicillium* (Alam et al., 2010), *Gliocladium* (Agarwal et al., 2011), *Aspergillus* (Adebola & Amadi, 2010), and *Saccharomyces* (Nally et al., 2012) have been reported to exhibit antagonistic effects against many plant fungal pathogens, including *Pythium*, *Alternaria*, *Aspergillus*, *Rhizoctonia*, *Fusarium*, *Phytophthora*, *Pyricularia*, *Botrytis* and *Gaeumannomyces* (Pal & Gardener, 2006).

6. Mechanisms of Biological Control Agents

Biocontrol agents act by various mechanisms to control plant diseases, making them useful tools in disease management. Understanding the mechanisms responsible for the protective effects of biocontrol agents will facilitate the optimization of control strategies and allow the use of more efficient species in the right environment (Mishra et al., 2018; Ghorbanpour et al.,2018). These mechanisms can be employed by biocontrol agents alone or in combination to directly and indirectly control plant diseases (Lahlali et al., 2022). Many studies have shown that biocontrol agents exert antagonistic effects through one or more mechanisms such as competition for space and nutrients, production of hydrolytic enzymes, induction of systemic resistance in host plants, antibiosis, mycoparasitism, and hyperparasitism (Bora & Özaktan, 1998; Benli, 2003; Özaktan et al., 2010; Lahlali et al., 2022). In disease control, biocontrol agents function through activities such as antibiosis, parasitism, reducing pathogen virulence, and direct antagonistic effects on pathogens through competition (Dukare et al., 2019; Köhl et al., 2019).

Antibiosis: Antibiosis is the inhibition or destruction of one organism by the metabolites produced by another organism (Bora & Özaktan, 1998). Antibiosis is one of the most extensively studied biological warfare mechanisms. Biocontrol agents exert their effects through antibiosis, which involves the secretion of disseminable metabolites or allelochemicals that can be lipopeptides, antibiotics, biosurfactants, bacteriocins, or cell wall-degrading enzymes. These compounds interfere with the phytopathogen metabolism, thus inhibiting pathogen development as microbial volatile compounds. There are many studies demonstrating the suppression of plant diseases. A remarkable example of antibiotic production is the antagonistic effect of *Agrobacterium radiobacter* (Beijerinck & van Delden, 1902) Conn 1942, which produces antibiotics that suppress the root tumor-causing pathogen *Agrobacterium tumefaciens* (Smitt and Town) (New & Kerr, 1972; Kerr & Htay, 1974).

Various *Pseudomonas* species produce numerous antibiotics with antiviral, antibacterial, and antifungal properties, such as 2,4-

diacetylphloroglucinol (DAPG) (Raaijmakers & Mazzola, 2012), phenazine-1-carboxamide, pyoluteorin, phenazine-1-carboxylic acid, pyrrolnitrin and oomycin, Additionally, Bacillus species are known to produce antibiotic lipopeptides such as iturin, bacilysin, bacillomycin zwittermicin, surfactin and fengycin (Ongena & Jacques, 2008; Khabbaz et al., 2015).

The biocontrol agent *Gliocladium virens* is known to produce numerous antifungal antibiotics such as gliovirin, gliotoxin, viridiol, viridin, valinotrocin and heptelidic acid (Tariq et al., 2020). Singh et al., (2005) found that the antibiotic gliotoxin is effective against several fungal pathogens such as *Rhizoctonia bataticola*, *Pythium debaryanum*, *Pythium aphanidermatum*, *Sclerotium rolfsii*, *Macrophomina phaseolina* and *Rhizoctonia solani*. Antibiosis is the primary antibiotic interaction between *Trichoderma* spp. and plant pathogenic micro-organisms, which produce a large number of compounds and are used as biocontrol agents against plant pathogens. Vinale et al., (2009) reported the production of antibiotics T22azaphilone, 1-hydroxy-3-methylanthraquinone, 1,8-dihydroxy-3-methyl-anthraquinone, T39butenolide, harzianolide, and harzianopyridone by the T22 and T39 strains of *T. harzianum*. In their tests for antifungal activity, T22azaphilone and harzianopyridone were found to inhibit the growth of *Phytophthora cinnamo*mi, Leptosphaeria maculans, *Rhizoctonia solani*, *Botrytis cinerea* and *Pythium ultimum* at 1-10 μg/plug.

Place and Nutrient Competition: It refers to the suppression of the development of two or more microorganisms when they require the same resource, but only one of them can utilize it, and the other cannot benefit from it (Bora & Özaktan, 1998). In the natural environment, pathogens and antagonists coexist in the same ecological habitat. Due to their similarities in nutrient requirements and optimal environmental conditions, they compete in a limited nutrient environment within a restricted area (Benli, 2003).

Antagonists and pathogen microorganisms compete for resources such as space, nutrients, oxygen, and even light. An effective antagonist microorganism typically rapidly consumes the available nutrients and thrives, occupying the environment. As a result, the development of pathogens is hindered since they are unable to obtain the required nutrients (Stirling, 2017).

The limiting nutrients for growth vary depending on the microorganism, environment, and host plant. These nutrients can be iron, carbon, nitrogen, or any other micronutrient element. The best example of this is the competition for iron. Iron is present in the soil in an insoluble form (Fe^{3+}). Antagonists produce a substance called siderophore, which reduces the iron in the environment to its usable form, Fe^{2+}. The siderophores produced by soil-dwelling antagonists inhibit the development of certain soil-borne pathogens (Özaktan et al., 2010).

These important plant-microorganism interactions mostly occur in the rhizosphere, enhancing plant growth and helping the plant cope with biotic and abiotic stresses (Zamioudis & Pieterse, 2012).

Hyperparasitism: Hyperparasitism is the effect of a secondary parasite on a primary parasite. Antagonist and pathogen are in close proximity.

Once the antagonist recognizes its host, it directs its hyphae directly towards the host. It weakens the pathogen with the chemicals it produces. Upon reaching its host, the antagonist's hyphae wrap around the host's hyphae, creating hook-like structures to attach to the host. The antagonist's hyphae grow around the pathogen's hyphae. During this period, the antagonist dissolves the pathogen with the enzymes it produces (Bora & Özaktan, 1998). Subsequently, with its destructive ability, the antagonist inhibits the development of the pathogen. An excellent example of this mechanism is the relationship between the antagonist *Trichoderma hamatum* (Bonord.) Bain and *Trichoderma harzianum* Rifai with the pathogenic *Rhizoctonia solani* and *Sclerotium rolfsii* Sacc. This mechanism is considered one of the most effective and precise mechanisms among biological control mechanisms (Chet & Baker, 1981; Elad et al., 1983).

Hypovirulence: Hypovirulence is the reduction in the virulence of a pathogen as a result of hybridization between a virulent pathogen and a less virulent individual (Bora & Özaktan, 1998). One of the best examples of hypovirulence is the management of chestnut blight caused by *Cryphonectria parasitica* (Murrill) Barr (Milgroom & Cortesi, 2004). However, the interactions between viruses, fungi, trees, and the environment determine the success or failure of hypovirulence. Plant pathogens have a variety of fungal parasites, including those that attack sclerotia-forming pathogens (e.g. *Coniothyrium minitans*) and those that attack live hyphae (e.g. *Pythium oligandrum*). As another example, a single fungal pathogen may be attacked by multiple hyperparasites. Some examples of fungi with the ability to parasitize powdery mildew pathogens are *Acrodontium crateriforme*, *Acremonium alternatum*, *Ampelomyces quisqualis, Gliocladium virens,* and *Cladosporium oxysporum* (Kiss, 2003).

Indirect mechanisms of biocontrol agents stimulate resistance by triggering plant defense mechanisms and stimulating plant growth and feeding systems (Dukare et al., 2019; Olanrewaju et al., 2017). Biocontrol agents can initiate systemic resistance in plants, leading to the accumulation of structural barriers and the activation of various molecular and biochemical defense responses in the host plant. This process requires the activation of pathways such as phytoalexins, phytohormones, and defense enzymes such as chitinase, phenylalanine ammonia-lyase, PR-proteins, and phenolic compounds (Dukare et al., 2019; Shafi et al., 2017).

Induced Resistance: In recent times, researchers have begun to define the characteristics and principles of induced resistance stimulated by biocontrol agents and other non-pathogenic microorganisms. Plants actively respond to various environmental factors such as temperature, light, water, physical stress, and nutrient status. They also respond to various chemical inducers produced by soil and plant-associated microorganisms. The stimulation of host defense can be inherently local and/or systemic, depending on the mode, source, and quantity of the inducers (Pal & McSpadden Gardener, 2006).

When plants are attacked by pathogens or exposed to stress, they activate defense mechanisms (Arıcı & Yardımcı, 2001). The physiological state known as induced resistance is the term used to describe how plants defend themselves and enhance their resistance against pathogens. This induced resistance has been demonstrated by specific environmentally friendly inducers with antimicrobial activity against various plant diseases, including fungi.

Systemic Acquired Resistance (SAR) is a feature associated with salicylic acid (SA), a compound often produced after pathogen infection. It typically causes pathogenesis-related (PR) proteins to form. These PR proteins include various enzymes. They can directly lyse infected cells, strengthen cell walls to resist infection, or induce local cell death. The defense response is triggered due to the accumulation of PR proteins (such as chitinases, β-1,3 glucans), lignin, chalcone synthase, peroxidases, phenolics, phenylalanine ammonia-lyase, callose, and phytoalexins. Another feature is Induced Systemic Resistance (ISR), which occurs through the production of jasmonic acid (JA) and/or ethylene following the application of certain non-pathogenic rhizobacteria (Pal & McSpadden Gardener, 2006).

Exactly, plants activate their immune system by responding to various biotic (fungi, bacteria, viruses) and abiotic elicitors. These elicitors can be either pathogens with reduced or eliminated virulence or non-pathogenic agents. Additionally, various chemicals such as ethylene, UV rays, certain synthetic compounds, herbicides, fungicides, salicylic acid, jasmonic acid, and indole-3-acetic acid can also act as elicitors. These elicitors mimic the behavior of a real pathogen, making the host plant's defense system more sensitive and primed to respond to future pathogen attacks. As a result, the host plant becomes prepared to defend itself against potential pathogen invasions (Bora & Özaktan, 1998).

Exactly, plants activate their immune systems not only against one disease-causing agent but also against many different factors (Tuzun & Kuc, 1983). The interaction between these mechanisms can result in a more stable, long-lasting, and systemic effect. In some cases, this effect can persist throughout the production season even in annual plants. This shows that the complex defense mechanisms of plants have a versatile and long-term impact in providing effective protection against various pathogens and environmental stresses (Liu et al., 1995).

Cross-protection: Cross-protection, like induced resistance, is a biological control mechanism that occurs within the plant. Cross-protection involves the prevention of the second organism (virulent pathogen) within the host tissue by the first organism (antagonist) through one or a combination of mechanisms such as antibiosis, competition for space and nutrients, hyphal interference, or parasitism (Bora & Özaktan, 1998). The effect of induced resistance is indirect and is related to the activation of active defense mechanisms in plants against microorganisms as soon as they are induced by the first organism. The elicitor used in cross-protection is either closely related to the pathogen to be prevented (a weakly virulent isolate) or is the pathogen of similar tissues in other crops. These related isolates (or pathogens of similar tissues) can compete for edible materials in tissue, just like any two organisms that have adapted to the same "ecological niche" (Özaktan et al., 2010).

Understanding the difference between cross-protection and induced resistance can be quite challenging. Cross-protection occurs when one organism (antagonist) has a direct or indirect effect on another organism (virulent pathogen) within the host tissue. A non-symptomatic strain of mosaic virus can defend tomato against a virulent strain of the same virus. An example of cross-protection is inoculating young citrus trees with a moderately virulent strain of tristeza virus while they are in the nursery. The inoculated trees are then protected against infection by more virulent strains. The protection can last for years.

Induced resistance, a type of cross-protection, is achieved by inoculation of plants with pathogens, low virulence pathogens (for example, pathogens inactivated by heat treatment) selected non-pathogens, or by applying chemicals that stimulate the immune system. In summary, making a clear distinction between cross-protection and induced resistance can be challenging. However, both aim to activate the plant's immune system against diseases (Stirling & Stirling, 1997).

Plant growth promotion: Biocontrol agents also produce growth hormones like auxins, cytokinins, and gibberellins. These hormones not only suppress harmful pathogens but also promote plant growth and increase yields (Guzman-Guzman et al., 2019; Abdelaziz et al., 2023). Studies on growth promotion mechanisms showed that PGPR promotes plant growth directly by producing plant growth regulators or indirectly by stimulating nutrient uptake, and producing siderophores or antibiotics to protect plants from soil-borne pathogens or harmful rhizosphere organisms. *Pseudomonas* spp. can increase plant growth through the production of gibberellin-like substances and the mineralization of phosphates (Bonaterra et al., 2022).

7. Conclusion and Suggestions

In addition to the rapidly increasing world population, the reduction of available agricultural land poses a problem of hunger in countries worldwide. Agriculture is not only essential for meeting the basic needs of people but also plays a crucial role in contributing to the country's economy and providing employment opportunities. In a world where hunger is such a significant issue, preventing diseases, pests, and weeds from damaging agricultural products while also safeguarding the environment and human health is imperative.

Today, agriculture is an integral part of countries' socio-economic policies and a strategic field concerning food security. Agricultural activities should be able to meet the food needs, be productive, and be sustainable. Therefore, in the agricultural process, the natural resources that future generations will rely on for sufficient food (soil, water, wildlife, and energy) must be conserved. Because the most important legacy we can leave to future generations is our natural resources.

In developing countries, it is estimated that food demand will increase by 50-100% by the year 2025 due to the growing population. Therefore, it is essential to find the most suitable approach that preserves the environment and human health simultaneously. Effective methods should be employed in agricultural control programs to eliminate product losses and increase agricultural production.

In conclusion, the continuously increasing demand for food has led to the use of harmful chemicals in agriculture, which not only disrupt the ecological system but also cause ecotoxicity. To control serious environmental health issues and losses caused by pathogenic microorganisms, there is a widespread search for alternative methods to synthetic pesticides worldwide. Numerous studies have indicated the adverse effects of synthetic pesticides on the environment and non-target organisms. Due to the hazardous effects on non-target organisms and their negative impact on the environment, the indiscriminate use of chemicals must be prevented.

There is a need to develop non-chemical alternative strategies for protecting crops from plant diseases in agricultural production. Biological control, which involves the use of fungal and bacterial antagonists to prevent plant diseases, is a promising alternative strategy and has been effectively applied in controlling certain diseases in various plants and plant products. While eliminating synthetic pesticides in modern agriculture may not be feasible, reducing their usage is achievable.

Therefore, biocontrol holds critical importance due to its environmentally friendly and cost-effective nature. Additionally, biocontrol should be integrated with other management methods such as cultural and even chemical control to ensure sustainable yields and effective disease management in crop production.

Integrated Pest Management (IPM) should be used to control diseases and pests to achieve a sustainable agricultural system that reduces risks and environmental pollution. The application of IPM can provide safer and more cost-effective disease management in the control of bacterial and fungal diseases.

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Author Contribution and Conflict of Interest Disclosure Information

There is no conflict of interest.

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Drought Stress is a Global Problem in Sustainable Agriculture: Response of Plant, Role of Fungal Endophytes

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1. Introduction

Food will always be needed because of the expanding world population. By 2050, there may be more than 9.7 billion people in the world, which might result in a surge of up to 70% in the global food output (Castaneda et al., 2016; Abdelrahman et al., 2017). However the population is more than 65% relying completely on agriculture for their subsistence, this number can reach up to 90% in underdeveloped nations (Castaneda et al., 2016). Food security in all nations, but particularly in emerging nations, is seriously threatened by crop losses (Ghini et al., 2008; Chakraborty & Newton, 2011). Crop losses are primarily caused by pathogens and abiotic factors (Singla et al., 2016). Small land ownership and improper mechanization are both ongoing factors that affect agricultural productivity (Ahluwalia et al., 2021). Abiotic stress is one of the most significant constraints in agricultural production, principally in dry and semi-dry districts. It contains drought, temperature swings, excessive soil salinity, metal toxicity, and oxidative stresses (Fahad et al., 2017). These affect the sustainability of plants in natural and agricultural communities (McCartney & Lefsrud, 2018; Bhat et al., 2020). In recent decades never-before-seen climate change has made the consequences of these abiotic stresses worse (Fedoroff et al., 2010). The anthropogenic effects are deforestation, industrialization, agriculture, urbanization, and changes in the use of land caused the climate change (Suryanarayanan et al., 2018; Chandra et al., 2021). The rise of temperature and atmospheric carbon dioxide (CO_2) amount with variations in the timing of rain is the result of climate change (Chandra et al., 2021). In addition, the Intergovernmental

Panel on Climate Change (IPCC) has explained that if anthropogenic activity keeps at its current rate, global temperatures might climb by up to 1.5ºC by the year 2052 (IPCC, 2018). This will create often and severe drought occurrences in several regions (Okunlola et al., 2017). Drought is the most important abiotic stress that inhibits crop productivity worldwide (Zolin & Rodrigues, 2015) and causes a 50–70% drop in the productivity of agriculture (Verma & Deepti, 2016). Also, about 700 million people will face the risk of relocation in 2030 due to drought stress (Jamieson et al., 2021). Water minorities through a reduction in rainfall and a rising density of arid terms produce drought circumstances (Mirajkar et al., 2019; Ahluwalia et al., 2021). Numerous negative impacts of drought stress on plants include decreasing plant biomass and photosynthesis and changes in hormone metabolism and enzyme function. Moreover, severe drought can reduce the yield of plants and increase plant mortality (Challinor et al., 2004; Stovall et al., 2019). Drought stress decreased output in a variety of crops by almost 70% (Kaur et al., 2008; Akram et al., 2013). Recent studies have emphasized the significance of plant-associated microbial communities in supporting the resistance and recovery of their host plants from abiotic stresses (Lata et al., 2018; Sadeghi et al., 2020).

This study focused on the impacts of fungal endophytes and drought stress in plants.

2. Drought Stress and Its Effect on Plants

Every year, drought is a severe problem for farmers. It is a typical occurrence that is initiated and perpetuated over time by a lack of freshwater to meet ecological and human needs (Balint et al., 2013). Drought is challenging to observe, and recurrent in nature, so typically not restricted to a particular district or time frame (Lund et al., 2018). Because the effects of drought vary depending on the level of stress and the life stage of the plant. Kajla et al. (2015) found that abiotic pressures account for 50% of crop losses, of which 10% are due to drought, 20% are due to heat stress, and the remaining percentage is due to other abiotic stresses. There are four different categories of drought: i) a meteorological drought that takes place in regions with dry weather, ii) a hydrological drought that occurs when there is a limited and inadequate quantity of water, iii) reduced soil water content and subsequent crop failures are frequently linked to agricultural drought. iv) A socioeconomic drought is defined as a failure of supply and demand for a range of products as a result of the drought (Heim, 2002). Significant financial losses are also a result of the socioeconomic repercussions of drought. For instance, agricultural casualties in the protracted drought in California were estimated to be at 3.8 billion dollars, with crop income declines in the years 2014 to 2016 totaling 1.7 billion dollars (Howitt et al., 2015). Similar to this, the 2005 drought in Spain's Ebro River Basin had a negative economic effect of almost 0.57 billion dollars (Juana et al., 2014).

Plants require particular physiochemical and physiological circumstances for the best growth. Drought stress is an important urgent issue in abiotic stress (Vurukonda et al., 2016). This stress is a few of the detrimental effects that it may have on plants, as follows. It may affect seed germination in the first stage. When a seed absorbs water, germination begins and in the lack of water, seeds do not absorb enough water, which consequently reduces germination and lowers the total number of plants per unit area (Jajarmi, 2009). The expression of genes that are crucial for seedling survival is impacted by drought (Zhang et al., 2009). Inhibition of cell growth and division is another impact of drought (Nonami, 1998). As a result, in plants, overall biochemical and physiological processes, such as photosynthesis, ion absorption, respiration, nutrition metabolism, and translocation, are negatively impacted (Brenchley et al., 2012; Hidangmayum et al., 2019). Leaf growth is decreased in the absence of water, thus the photosynthetic area is decreased, and the photosynthetic pigments are adversely affected (Chandra et al., 2021). Additionally, the formation of Reactive Oxygen Species (ROS) in thylakoids causes oxidative damage (Roach & Krieger-Liszkay, 2014). Maintaining sufficient soil moisture is crucial for the vascular system of the plant to operate properly (Pandey et al., 2015; Choudhary et al., 2016). Pistil and pollen formation are affected by drought and heat stress at the same time as ovule functions, stomatal conductance, grain weight, and root growth (Engelbrecht et al., 2007; Prasadet al., 2011). The occurrence of low turgor pressure as a result of drought causes dwarfism in plants (Chandra et al., 2021). The ongoing drought during the vegetation period results in yield losses and plant death in agricultural production (Deeba et al., 2012; Zhang et al., 2018).

3. Plant Defense Mechanisms Against Drought Stress

Drought impacts physiological and biochemical processes and causes oxidative stress, lipid peroxidation, and a decrease in cell turgidity (Talaat et al., 2015). It circumstances can have a negative impact on a plant's overall development and productivity, increase the abscission of leaves and flowers, and lead to often occurring cell necrosis and senescence (Sahin et al., 2018). Furthermore, numerous plant biological processes, such as nitrogen absorption, cell membrane functioning, and protein synthesis, are hampered by protracted drought (Saneoka et al., 2004). Plants typically find a way with some mechanisms to survive during droughts. These mechanisms; i) drought tolerance, plants adapt to drought, ii) drought escape, plants control the somatic and reproductive processes to complete their life cycles, and molecular signals that regulate the intake and loss of water, iii) drought resistance, alteration of cell wall structure by osmotic pressure regulation (Hoque et al., 2008; Zheng et al., 2017). Plants respond at the cellular and organismal levels to the ongoing drought stress in a number of physiological and biochemical ways by the above-mentioned mechanisms. Reduced carbon uptake, stomatal closure, growth inhibition, osmotic adjustment, hydraulic alterations, signal transfer, and cell-drought signaling are a few examples of short-term reactions. Plants are often not significantly harmed by these reactions as long as normal circumstances resume (Kaur & Asthir, 2017). To prevent water loss, the plant closes its stomata earlier than necessary and lowers the heat of the leaves through transpiration which results in increased stomatal conductance (Rizhsky et al., 2004).

Repressed shoot development, metabolic adaptations, a reduced transpiration area, senescence, and kernel abortion, are examples of long-term responses (Kaur & Asthir, 2017). Reactive oxygen species (ROS) (O_2, H_2O_2, and OH) are one of the first reactions of plants to a water shortage (Kocsy et al., 2013). For example, hydrogen peroxide (H_2O_2) is a signal molecule in ROS under drought stress (Deeba et al., 2012; Koffler et al., 2014). Malondialdehyde is formed as a result of membrane lipid peroxidation and this is an indicator of drought and other abiotic stresses (Cheng et al., 2018). To counteract the negative effects of ROS, plants utilize an antioxidant system that includes both enzymatic and nonenzymatic antioxidants (such as total phenols, and flavonoids). Osmo-regulatory molecules like proline, soluble protein, and soluble sugar are frequently able to mediate these negative effects (Reddy et al., 2004). Proline is one of osmoprotectants in plants, and the accumulation of proline occurred during drought together with other stress conditions (Mittler, 2006; Cohen et al., 2020). Plants generate the enzyme of superoxide dismutase (SOD), catalase (CAT), peroxidase (POD) when adverse drought circumstances induce metabolic damage (Perl et al., 1993; Cheng et al., 2018). High amounts of glycine betaine are produced when the genes encoding the enzymes choline monooxygenase and beta aldehyde dehydrogenase are expressed in higher plants, which enables the plants to thrive even in drought-stressed environments (Giri, 2004). Abscisic acid (ABA) regulates stomatal closure, lowers transpiration, boosts antioxidant system activity, and enhances ROS scavenging effectiveness in plants (Hassan & Elnemr, 2013; Ban et al., 2017).

Gibberellin (GA) concentration is decreased while ABA concentration is elevated (in the roots) in order to help plants adapt to the drought (Kowitcharoen et al., 2015; Zhang et al., 2018). The photosynthetic pigments carotenoids and chlorophyll are impacted by drought (Simkin et al., 2008; Anjum et al., 2011). Plants under water stress have a drop in CO_2 absorption rates (Waraich & Ahmad, 2010). A plant elongates its roots in response to a severe drought in order to access deeper amounts of groundwater (Sahin et al., 2018). Drought decreases flower size and number, pollen and pollen viability, nectar quantity and quality, and total pollination (Waser & Price, 2016). The other responses plants to drought like inducing carbon absorption, leaf withering, and siderophore formation (Bernardo et al., 2019).

4. Fungal Endophytes and Their Effects on Drought

Fungi are heterogeneous, and they include saprobes, pathogens, endophytes, and epiphytes (Hyde et al., 2019). It is found in a wide variety of environments and has evolved to a range of ecological niches, including plant systems. Mycorrhizal, parasitic, and endophytic fungi have formed mutualistic associations with plants (Rodriguez et al., 2009; Patkar & Naqvi, 2017). The stems, roots, petioles, leaf segments, fruit, buds, and seeds in plant tissue include endophytes and they can develop either systemically or locally in the plant, as well as intercellularly or intracellularly (Schulz et al., 2015; Gouda et al., 2016). Endophytes are organisms that spend at least a portion of their life cycle asymptomatically inside plants. They don't harm their hosts and occasionally even help them. Since only around 150,000 fungal species have been described and categorized so far, we estimate that there are likely over 3 million different types of fungal endophytes. However, the current estimate of fungal endophytes is that there are approximately 1 million different species (Fouda et al., 2015; Bhunjun et al., 2023). Based on their evolutionary relationships, taxonomy, host plant range, and ecological roles, these endophytes are categorized (Rodriguez et al., 2009; Santangelo et al., 2015). Fungal endophytes may be generally divided into the Clavicipitaceous and Non-Clavicipitaceous groups. Clavicipitaceous endophytes involved Atkinsonella, Balansia, Balansiopsis, Echinodothis, Epichlos, Myriogenospora, and Paraepichlos and these have a mutualist cycle with the host (Rodriguez et al., 2009; Purahong & Hyde, 2011; de Silva et al., 2019). Non-clavicipitaceous endophytes including *Fusarium*, *Colletotrichum*, *Phomopsis*, *Xylaria* and might not spend their complete life cycle in the host plants (Delaye et al., 2013; Jayawardena et al., 2016). Either by vertical transmission between seed generations or through horizontal ingestion from the environment, fungal endophytes are spread. Only a few cool-season grasses are infected by vertically transmitted endophytes, which are members of the Clavicipitaceae family and have a limited host range. Endophytes that spread horizontally typically belong to the groups Pezizomycetes, Sordariomycetes, Dothideomycetes, and Eurotiomycetes. The leaves of many plant species are infected by the wind-dispersed spores of the fungus Pezizomycetes, Sordariomycetes, Dothideomycetes, and Eurotiomycetes (Paranetharan et al., 2022). It has been demonstrated that the horizontally transmitted fungus has an impact on a variety of plant fitness indices, including plant growth, tolerance to abiotic and biotic stressors, mineral nutrient absorption, and generation of secondary metabolites (Gouda et al., 2016). Additionally, it directly affects photorespiration and carbon photosynthesis in the leaves of the plant (Suryanarayanan et al., 2018). Sordariomycetes make up 36% of all known endophytic fungal species at the class level. And then follow Dothideomycetes (25%), Eurotiomycetes (9.6%), Agaricomycetes (6.4%) respectively. Another part of the host that is most researched for endophytes is the root, which is after the leaves (Rodriguez et al., 2009). Root fungal endophytes are the highly diverse majority of Ascomycota (52 orders), Basidiomycota (32 orders), Chytridiomycota (5 orders), Mucoromycota (3 orders), and Oomycota (2 orders). Hypocreales (Sordariomycetes), Pleosporales (Dothideomycetes), Helotiales (Leotiomycetes), Eurotiales (Eurotiomycetes), and Xylariales (Sordariomycetes) have been done many studies (Shirdam et al., 2009; Barberis et al., 2023).

A few more frequently found endophytic fungal genera are *Colletotrichum*, *Pestalotiopsis*, *Phoma*, *Phomopsis*, *Diaporthe*, *Trichoderma*, *Acremonium*, *Cladosporium*, *Chaetomium*, and *Curvularia*, in addition to the ones described above (Rashmi et al., 2019). The diversity of plant features involved in determining tolerance has made traditional crop development techniques to make plants robust to abiotic stressors and tolerant to climate change only partially successful. Endophytes can reduce the effects of both biotic and abiotic stresses, including predators, diseases, heavy metals, salinity, floods, and other environmental toxins (Waller et al., 2005). Among the different biological approaches, using endophytic fungi as biofertilizers has promise as a rapid, affordable, and ecologically acceptable way to reduce the damaging impacts of abiotic stressors on crops (Rodriguez et al., 2008; Andres-Barrao et al., 2017).

Utilizing endophytic fungus to change how plants react and adapt to abiotic stressors is a more recent development. Fungal endophytes affect their host plants abiotic stress tolerance with diverse mechanisms. These mechanisms are;

- regulation of osmotic (Rodriguez et al., 2008)
- plant protection (Grover et al., 2011),
- minimizing the uptake of water and raising efficiency (Rodriguez et al., 2008),
- enhance the root development and diameter (Malinowski & Belesky, 2000),
- rising in the concentration of photosynthetic pigments (Zarea et al., 2012),
- reduction of ROS production (Sadeghi et al., 2020),
- generating of the antioxidant enzymes (Sadeghi et al., 2020),
- proline holding (Jogawat et al., 2013),
- stating of homeostasis genes (Estrada et al., 2013)

This capability of fungal endophytes, especially in arid and semiarid fields, makes them indispensable. Additionally, it has been determined that when given to plants other than the host from which endophyte fungi are taken, it offers resistance to abiotic stress (Sangamesh et al., 2017;

Rho et al., 2018; Moghaddam et al., 2021). Increased root development is needed for plants to better access soil moisture and nutrients under low-water situations which is best achieved by endophytic fungi (Ali et al., 2018). Salinity and drought stress reduce the amount of chlorophyll in plants by limiting nutrient absorption and inhibiting the enzymes necessary for chlorophyll production. Under this stress, it appears that fungal symbiosis can boost the chlorophyll content in its host plants by enhancing their nutrient intake (Giri & Mukerji, 2004; Ghorbani et al., 2019). Antioxidant molecules help the plant tolerate stress. These compounds are phenolic acids, isobenzofuranones, isobenzofurans, mannitol and other carbohydrates. Endophyte fungi can secrete these compounds or stimulate the plant to produce them (Jogawat et al., 2013; González-Coloma et al., 2016). Besides, the encouragement of cell-wall synthesis by endophyte fungi serves as a defense combat pathogen penetration (de Silva et al., 2019).

In recent years, studies to determine the effect of Trichoderma species, one of the endophyte fungi, against abiotic stresses have increased. The results of some studies are given here. Trichoderma species can mitigate abiotic stresses in germinating plants and seeds, reducing reactive oxygen species (ROS) damage (Shukla et al., 2012). Trichoderma treatment in plants under water stress increases root biomass and water-holding capacity. Thus, it has been determined that it increases plant growth by facilitating the movement of nutrients (Harman, 2011; Bakhshandeh et al., 2020). As it is known, one of the plant responses to environmental stresses is the synthesis of jasmonic acid and salicylic acid.

In a study, an increase in the amount of jasmonic acid and salicylic acid in the plant was observed by stimulating the defense mechanisms in the plant during the interaction of *T. asperellum* with the plant. It has been shown that this application will contribute positively to the defense mechanism at the gene level that occurs in the plant under abiotic stresses (de Sousa et al., 2020).

5. Conclusion

Climate change in recent years has made the consequences of abiotic factors (such as drought, soil salinity, and heavy metal) much worse in plants (Fedoroff et al., 2010; Hyde et al., 2019). The total economic sustainability of agriculture is negatively impacted by drought, which has a significant impact on plant output. To combat drought, a variety of approaches have been created, and each has strengths and weaknesses. However, drought in agricultural plants can be mitigated by endophytes, as is clear from the research that has already been done. In contrast to traditional and molecular breeding procedures, this strategy is that it provides a non-genetic-invasive method to modify plant phenotype likewise it is quick and economical. Therefore, identifying such microbes linked to plants under stress and learning about their species, community makeup, and ecological influences are of considerable importance, particularly in drought locations. It is necessary to perform research to understand the chemical and molecular mechanisms behind the interaction between drought stress, plants, and endophytes.

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Important Plant Parasitic Nematodes in Urban Agricultural Areas

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1. Introduction

Urban agriculture is a variety of agricultural activities primarily carried out within the city limits. It is defined as 'plant and animal breeding in and around the city'. Urban agriculture can be at the household level or in the form of commercialized agriculture. Being self-sufficient is increasingly important in terms of food scarcity and safe food supply in the world. Therefore, epidemics, disasters, wars, etc. What such situations indicate is that the "agricultural sector" has an important place in the economic policies of countries (Akın et al., 2020). Urban agriculture's scope includes food production in mass housing, small-density urban farms, land sharing, beekeeping, roof gardening, restaurant gardens, school gardens, food production in public spaces, private gardens, and balcony and window vegetable cultivation. Especially edible vegetables, flowers, medicinal and aromatic plants, and various vegetables constitute the product pattern of this sector. In terms of environmental quality and ecosystem, urban agriculture contributes to the sustainability of the city by maintaining biodiversity, reducing heat islands and carbon emission formation in cities, increasing the air quality of the town, and evaluating urban wastes and wastewater (Tandoğan & Özdamar, 2022). Urban gardens, established with intense labor, expense, and enthusiasm, need protection against many diseases and pests. Plants and animals in production areas close to these areas are more susceptible to diseases and pests, mainly due to the polluted nature of cities and decreased species diversity. Just like humans and animals, plants also have many diseases and pests. For this reason, to protect the products produced, it is necessary to have information about agricultural pests that may occur in the grown plants. There is a possibility of contamination of the same plants with the same diseases and pests in urban agriculture, as in the cultivated plants grown in the field and greenhouse agricultural areas. Nematodes are essential among many pests that threaten crop plants in agricultural areas. Nematodes can live in any environment where plants are present. These creatures appear as a factor limiting plant production in urban areas as well as in rural areas. Knowing nematodes that harm plants is essential to maintain the quantity and quality of the products produced in urban agriculture.

Nematodes are known as the most abundant invertebrate branches in the world. They are in the Animalia realm. They are roundworms in the Pseudocoelemata (animals with a false body cavity) subset of the suborder Eumetazoa. The word nematode, which has its root in Latin, means like a rope. It means 'parasitic maggot with filamentous structure' in Turkish. These creatures are animal organisms that can live harmoniously in very different ecological conditions. They can interact differently (parasitic, mutualistic, etc.) with other living things in their environment. Nematodes are also grouped as parasites, predators, or free-living with different feeding behaviors. Thanks to these nutritional characteristics, they can adapt to very different habitats. They can live in or on salty or fresh waters, moist soils, peat, dead and living people, animals, or plants. They generally like wet environments. Most of them die in dry conditions. In addition, some can live even in extreme environments such as deserts or glaciers. Some tropical nematodes enter anhydrobiosis in anhydrous and arid conditions and can survive even at soil temperatures of up to 50 °C. About

50% of nematodes live in the seas. 15% of these creatures live in vertebrates or invertebrates (including humans), and 10% in plants. The remaining 25% live freely (Kepenekci, 2012). Free-living ones feed on protozoa, fungi, bacteria, or other nematodes.

Records of nematodes living parasitically in humans and animals date back to ancient times. The first zoological record of the human body belongs to the Guinea worm, whose scientific name is *Dranunculus medinensis* (L.) (Camallanida: Dracunculidae). Afterward, it is possible to find records of many nematodes that harm humans or animals. The first record of nematodes that are harmful to plants belongs to the wheat gal nematode, which was found in 1743 by a scientist named Needham and whose current name is *Anguina tritici* (Steinbuch) (Tylenchida: Anguinidae) (Thorne, 1961; Siddigi, 2000). Studies on plant parasitic nematodes have been with the invention of the microscope, and taxonomic studies have progressed rapidly with the development of microscopes over time.

Nematodes are generally non-segmented and bilaterally symmetrical creatures with two nested body layers (Decraemer & Hunt, 2006). The largest of these creatures, which vary in size, can reach up to 2 meters. Those that feed on plants are usually microscopic. Although their bodies often appear threadlike, the females and males of some species may have different body shapes (dimorphism) from each other. Females can be shaped like a bag, sphere, pear, or lemon in these species. They are generally 400 µm-5 mm long, covering their body surfaces with soft, flexible skin (cuticle). While it is possible to see the large ones with the naked eye, it is impossible to see the small ones. Nematodes are colorless but can appear green, brown, or black depending on the plants they feed on. They have no eyes and no legs. They move by crawling. Those that feed on plants have a stinging needle called a stylet inside their mouth. In this way, they can pierce plants and feed on plant tissues.

Respiratory and circulatory organs are absent in nematodes. The muscular, excretory, and nervous systems comprise elementary cell groups. Digestive and reproductive systems are better developed than other systems.

Reproduction in nematodes occurs sexually, parthenogenetically, or by hermaphrodism. Depending on the ecological conditions, both sexual and parthenogenetic reproduction can occur in some species. Their mobility is limited.

Nematodes that cause damage by feeding on plants are called plant parasitic nematodes. Plant parasitic nematodes can also live in all environments where plants are present. Plant parasitic nematodes can move up to 1 meter a year with their movements in the soil. However, they can be passively transported from one crop production area to another by irrigation water, infected plants or soil, animals, people, or agricultural tools. They can also spread to distant areas by soil transport with strong winds. They can move vertically depending on soil temperature and soil moisture. During the dry seasons, they move from the soil surface to the depths. If the moisture on the soil surface increases, they move upwards again. They are usually found between 10-30 cm from the soil surface. However, depending on the root depth of the host plants, they can go down to 6 meters.

Plant parasitic nematodes have different biological periods. These are the egg, larva, and adult stages. The first larval period is spent in the egg. The larvae hatching from the eggs in the second period pass into the soil. They find their hosts by root secretions of nearby plants. It usually enters the plants from a region close to the root tip or starts to feed near the root tip. Feeding continues until adulthood. Plant parasitic nematodes become adults after four larval stages. They molt as they pass from one larval stage to the next. The majority of these nematodes cause damage to the roots of plants. Very few of them cause damage to plant parts such as leaves, flowers, or stems (Hunt et al., 2005). It physically damages the plant cell wall primarily by means of stinging-sucking needles called stylets. Then, they disrupt the structure of the cell wall by means of their pectolytic and cellulitic enzymes (Jaubert et al., 2002). By means of these methods, plant parasitic nematodes feed effectively or can move between cells (Karssen & Moens, 2006). As a result of their feeding, they cause deformations in the stem cells, thus preventing the transmission of nutrients taken from the soil. Due to some toxic substances in their secretions in their styles, they can damage the host plant cells and even lead to the death of the cells (Prot, 1985; Abad et al., 2003; Karssen & Moens, 2006; Schomaker & Been, 2006). Plant parasitic nematodes cause significant damage to plants indirectly as well as directly. Due to the wounds, they cause on the roots, they cause some soil-borne disease agents (fungal, bacterial) to enter the host plants. Some nematodes, on the other hand, carry many plant virus diseases that do not have chemical treatment for plants during their feeding. Such nematodes are called virus vector nematodes. The damage (secondary) they cause in this way can sometimes be much more than the damage they cause through their direct feeding.

Injury caused by plant parasitic nematodes is often similar to symptoms caused by inanimate environmental conditions or other disease agents. For this reason, they are often confused with each other. Soil and plant samples should be taken when symptoms such as wilting, nutrient deficiency, or growth retardation occur in plants. The samples should be analyzed in the laboratory in terms of nematodes. The symptoms caused by nematodes in plants can be listed as follows.

- **Symptoms caused by nematodes in the underground parts of plants:**

  1-The formation of tumors in the roots

  2-Fringing and irregular root formation in the roots

  3-The formation of brown or black necrotic areas on the roots

  4-Wounds and rot on the roots (secondary infections)

- **Symptoms caused by nematodes on the above-ground parts of plants:**

  1-Shortening in plant height

  2-Shrinkage, discoloration, and discoloration of the leaves

  3-Wilding of the plant

  4-There is an increase in weeds as a result of the weakening of the plant and its inability to compete.

  5-Insufficient benefit from fertilization

6-Shrinkage in leaves and decrease in the number of branches fail to develop well, and become stunted.

Nematodes can be found in greater numbers and diversity in their habitats than other multicellular living groups. Today, there are more than 25000 species of nematodes identified in the Nematoda branch (Zang, 2013). Nematodes that cause damage to plants belong to the Nematoda branch, most of them are in the Thylencida and some of them are in the Dorylamida order. 52% of soils used in agriculture worldwide are infested with root-knot nematodes (*Meloidogyne* spp.; (Tylenchida: Heteroderidae) (Taylor, 1987). Root-knot nematode, a polyphagous pest, has more than 3000 host plant species (Abad et al., 2003) With the discovery of new species, this number is increasing every year.

Those that live parasitic on plants are obligate parasites and they mostly feed in the cytoplasm of their hosts (Williamson & Gleason, 2003; Jones et al., 2013). They continue to live as endoparasites, ectoparasites and semi-endo-ectoparasites in plants. Not all nematodes, known as plant parasites, cause economic losses in their hosts. It is known that plant parasitic nematodes, which can cause losses in both yield and quality, cause billions of dollars of damage every year worldwide (Nicol et al., 2011). These nematodes can cause damage mostly to the subsoil parts or sometimes to the upper parts of the plants (Prot, 1985; Manzanilla-Lopez et al., 2004; Hunt et al., 2005; Decraemer & Hunt, 2006; Perry & Moens, 2011, Kepenekçi, 2012).

2. The Situation of Plant Parasitic Nematodes in Türkiye

As a result of much research carried out around the world, many nematode species that are economically important in plants are known. Some of these can also be a problem in crops grown in urban agriculture. There are many nematode species known to damage the root, stem tuber, and seed and fruit parts of plants. Many studies have been carried out on plant parasitic nematodes in Türkiye. As a result of this research, the important plant parasitic nematode species that cause economic loss in Türkiye are as follows (Anonymous, 2008):

- Root-knot nematodes (*Meloidogyne* spp.) (Tylenchida: Heteroderidae)
- •Wheat gall nematode (*Anguina tritici* Thorne, 1949 (Tylenchida: Anguinidae)
- •Rice white tip nematode (*Aphelenchoides besseyi* Christie, 1942) (Aphelenchida: Aphelenchoididae)
- •Grain cyst nematode (*Heterodera avenae* Wollenweber 1924) (Tylenchida: Heteroderidae)
- •Potato cyst nematodes (*Globodera rostochiensis* Wollenweber, 1923 and *Globodera pallida* Stone, 1973) (Tylenchida: Heteroderidae)
- •Sugar beet cyst nematode (*Heterodera schachtii* Schmidt, 1871) (Tylenchida: Heteroderidae)
- •Fig nematode (*Heterodera fici* Kirjanova, 1954) (Tylenchida: Heteroderidae)

- Citrus nematode (*Tylenchulus semipenetrans* Cobb, 1913) (Tylenchida: Tylenchulidae)
- Strawberry nematode (*Aphelenchoides fragariae* Ritzema-Bos, 1891) (Tylenchida: Aphelenchoididae)
- Needle nematodes (*Longidorus* spp.) (Dorylaimida: Longidoridae)
- Wedge nematodes (*Xiphinema* spp. Thorne & Allen, 1950) (Dorylaimida: Longidoridae)
- Banana spiral nematode (*Helicotylenchus multicinctus* Golden, 1956) (Tylenchida: Hoplolaimidae)
- Root lesion nematodes (*Pratylenchus* spp.) (Tylenchida: Heteroderidae)
- Potato rot nematode (*Ditylenchus destructor* Thorne, 1945) (Tylenchida: Anguinidae)
- Stem and bulb nematode (*Ditylenchus dipsaci* Kühn, 1857) (Tylenchida: Anguinidae)

Among these nematodes, some of them have more incidence and economic damage than others. In this respect, root-knot nematodes take the first place both in the world and in Türkiye. When the necessary precautions are not taken in the areas where agricultural activities are carried out, it is impossible to destroy the population from there if they infect an area. Significant crop losses occur, especially in the case of soil contamination in greenhouses. Because under greenhouse conditions, the desired humidity and temperature conditions are formed for them to multiply. Recently, as a result of high damage in these areas, it has caused farmers to turn to soilless agriculture in greenhouses. In this section, information is given about root-knot nematodes, which are found in agricultural areas in Türkiye and therefore may be a problem in urban agriculture, and about the other nematodes, Potato cyst nematodes, Citrus nematode, Stem and bulb nematode, and Strawberry nematode.

3. Some Important Plant Parasitic Nematodes Harmful to Urban Agriculture in Türkiye

3-1. Root-knot Nematodes

3.1.1. Definition and Biology

Root-knot nematodes are dimorphic creatures because males and females have different morphological structures. Males are 1.2-2.0 mm in length, in the form of threads. The bodies of the second instar larvae are in the form of threads and are 0.3-0.5 mm long. The females are 0.7-0.8 mm long and 0.4-0.5 mm wide in the shape of a lemon or pear (Anonymous, 2008). In these nematodes, which have three different biological stages egg, larva, and adult, the larvae spend their first period inside the egg. They develop into the second period in the egg and exit the egg. They immediately begin to feed on plant roots. It becomes an adult after four larval stages in total. It spends the winter as eggs or larvae in the roots of the plants it infects or in the soil. If the soil temperature is above 10 °C, nematodes begin to develop; Above 15 °C, it starts to damage the plants. It cannot grow well in heavy soils. However, they grow better in light or medium soils. Females of the root-knot nematode lay their eggs en masse in a gelatinous tissue. A female lays around 400-500 eggs. Depending on the species and ecological conditions, these nematodes can lay up to 2,000 eggs per female. When the temperature is 27 °C, it gives offspring every 3-4 weeks.

It continues to multiply as long as the environmental conditions are suitable. It continues to multiply in greenhouse conditions during the winter period.

3.1.2. Hosts and damage

Female individuals of root-knot nematodes are easily recognized by their lemon or pear shape and by feeding on plant roots (endoparasite) and forming galls on the root component. These tumors formed in the roots occur when the nematode and the giant cells fed by the nematode form hyperplasia (increase in the number of cells) and hypertrophy (cell growth) in the surrounding cortical tissues (Bridge & Starr, 2007). This nematode genus has been named root-knot nematodes because of the damage (urgling) it causes to the roots of the plants they feed on (Figure 1). Root-knot nematodes are polyphagous pests. They pose a significant problem for plants due to the presence of about 2000 host sequences (Anonymous, 2008). Root-knot nematodes have a wide range of hosts, including vegetables, ornamentals, stone seeds, and weeds. It causes more damage than other nematode groups because it is a host to a large number of plants, causes serious yield loss in plants, and is common in soils used as agricultural land in the world. It is known that annual product losses caused by root-knot nematodes are 15% and can reach up to 80% in vegetables (Sasser, 1986). It has been reported that root-knot nematode causes product loss of 42-54% in tomatoes, 30-60% in eggplants, and 18-33% in melons (Netscher, 1990). Infected plants with galls on their roots absorb water and nutrients from the soil more slowly, so plant growth slows down or stops. The result is stunting. It prevents the flow of water and nutrients by destroying the plant vascular bundles. In case of heavy contamination, plants may die. It causes both product loss and a decrease in product quality. They cause significant yield loss in economic terms throughout the world.

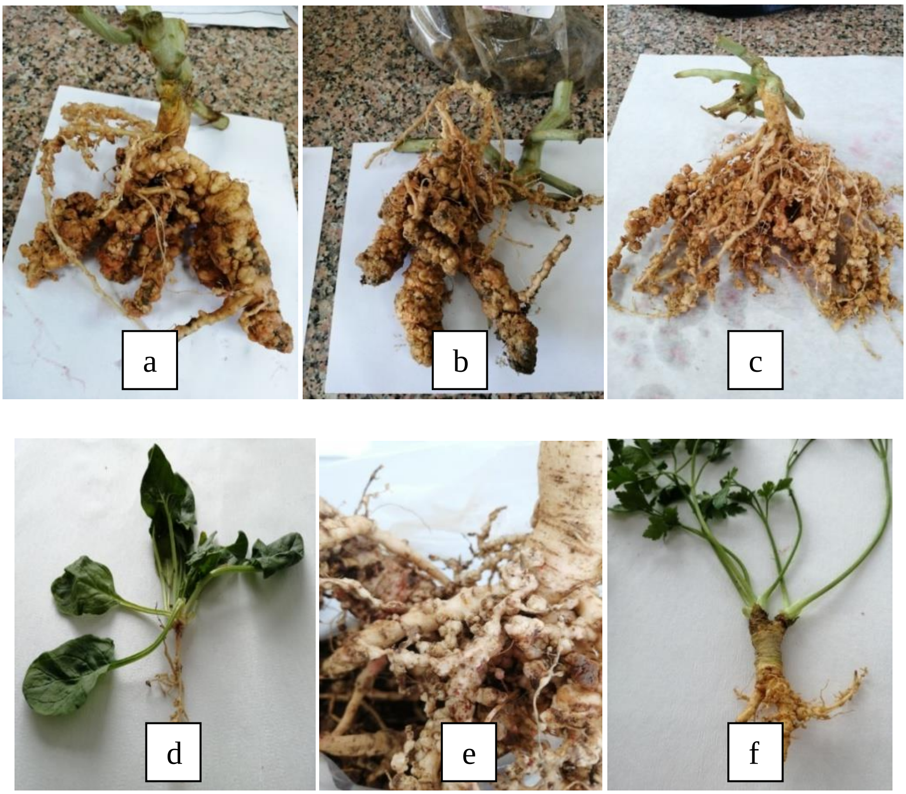

Figure 1. Deformations in the roots of various plants infected with root-knot nematode. Cucumber (a, b), Melon (c), Spinach (d), Okra (e) and Parsley (f) (Demir Ergin, 2021)

These nematodes cause damage not only directly but also indirectly. Many fungal and bacterial microorganisms entering the root wounds of nematodes can cause secondary diseases. Weakened plants cannot adequately protect themselves against secondary infections. Thus, plants infected with nematodes are more affected by soil-borne bacterial and fungal diseases than healthy plants. The damage of root-knot nematodes on soil is similar to nutrient deficiency and many disease factors. However, they are easily recognized by forming large and small galls on the roots. In this respect, these nematodes are the most recognized and studied species. Root-knot nematodes have many species. Root-knot nematodes (Siddiqi, 2000), of which more than 90 species have been identified in the world, also have many races depending on the host nematode relationship. There are four economically important species of these nematodes, which are most common in tropical and subtropical regions. These are *Meloidogyne incognita* (Kofoid & White, 1919) Chitwood, *M. javanica* (Treub, 1885) Chitwood, *M. arenaria* (Neal, 1889) Chitwood and *M. hapla* (Netscher and Sikora, 1990) Chitwood (Tylenchida: Heteroderidae) .

3.1.3. Control

Root-knot nematodes live in soil and plant tissues. Therefore, their struggle is quite difficult. They are easily transmitted to clean areas by the use of infected plants in production. It is also transmitted to agricultural areas by nematode-contaminated soil, plant-growing media (peat), or the use of tools, equipment, and vehicles.

In general, quarantine, cultural struggle, physical control, chemical control (nematicides), and biological control methods are used in its control (Nyczepir & Thomas, 2009). Root-knot nematodes are included in the quarantine. Production materials obtained from areas or areas infested with these nematodes should not be moved to clean areas. It is difficult to combat culture in irrigated agricultural areas because there are too many host plant species and they like moist soils. Hygiene conditions must be observed at every stage of production. In order to reduce the population density in contaminated areas, it is recommended to till the soil by turning it upside down in summer and to use seedlings or saplings resistant to root-knot nematodes. It is very difficult to be successful in controlling soil-borne diseases and pests only by chemical means. It should be integrated with cultural and physical struggle methods. Against these nematodes, it is tried to reduce the nematode population by using the solarization method in the hot summer months and by partially disinfecting the soil. Root-knot nematodes cause significant damage to plants, especially in the early stages of vegetation. For this reason, it is recommended to use a commercially licensed nematicide before planting seedlings or saplings. Soil spraying can be done during or after planting vegetables and some perennial plants.

3.2. Potato Cyst Nematodes (Potato Gold Nematode and Potato White Cyst Nematode)

3.2.1. Definition and Biology

The nematode's cysts are 0.6 mm long and 0.7 mm wide and are round or spherical. After female individuals die, it turns into a cyst form filled with eggs. Male individuals are in the form of a thin and long thread and do not resemble females morphologically. Since these cysts are durable period, the eggs inside may not lose their vitality for many years (10-30 years) after mixing with the soil (Anonymous, 2008). Females bury themselves in the roots up to the neck and feed. The rest of their bodies are outside the root. The females are pear-shaped and white. It then becomes round. The colors of female individuals vary according to the species. The females of the potato golden cyst nematode turn golden yellow, while the other species, the potato white cyst nematode, takes on a cream color (Figure 2). After the female nematodes, whose bodies are filled with eggs, die, their bodies turn into dark, durable cysts. Although they give one generation a year, their population can increase 100 times yearly. The nematode population density decreases from year to year in soils where potato cultivation is interrupted. As the plants enter the flowering period, feeding female nematodes appear embedded in the roots. They cannot be seen with the naked eye because they later become cysts and mix with the soil.

3.2.2. Hosts and damage

Cyst nematodes are restricted to plants belonging to the Solanaceae family, including plants such as tomatoes and eggplant. However, the most economically damaging host is the potato. The amount of damage caused to potatoes is related to the number of nematodes per unit of soil and the tuber weight of the potato produced. In the case of 20 eggs/g of soil, it is estimated to cause a loss of 2 tons per hectare. If the nematode population reaches very high levels in successive potato growing areas, yield loss can be 80% (Brown, 1969).

As a result of the nematode feeding, giant cells are formed in the plant root. Nutrient and water uptake of the plant becomes difficult. Bifurcation and mass (bulging) occur in the roots. The plant weakens, and its development is retarded. The product will decrease economically in the case of successive potato production in the same soil. Yellowing, wilting, falling of leaves, and areas with weak growth in the field stand out.

Cysts are also passively spread to clean areas by animals, humans, wind, agricultural implements, and seed potatoes.

Figure 2. Females and cysts of the potato golden cyst nematode (Anonymous, 2023a)

3.2.3. Control

Root samples should be taken during the green period to determine the areas infested with nematodes. After harvest, soil samples should be taken and analyzed. Non-host plants should be grown in nematode-infested fields. Using certified seeds in potato cultivation is essential to prevent nematode contamination. Also, quarantine measures are applied.

3.3. Citrus Nematode

3.3.1. Definition and biology

The females of the nematode are kidney or bean-shaped. Female nematodes are approximately 0.5 mm long, while males are slender and 0.3-0.4 mm long (Anonymous, 2008). Female individuals are fed singly or in colonies with their heads inserted into the capillary root. After the female nematode starts to feed, it provides in the same place all its life. Males are thread-shaped and live freely in the soil near the root. Each female lays up to 100 eggs. It lays its eggs en masse in a gelatinous substance. Depending on environmental conditions, it can give 1-3 generations per year. Each generation is completed in 6-8 weeks. Larvae can survive in the soil for up to 10 years in the egg.

3.3.2. Hosts and damage

It is seen in all types and varieties of citrus fruits. In addition, this harmful nematode is found in olive, fig, vine, persimmon, and lilac plants. Females feed on the cortex layer of the capillary roots as semi-buried. Plant sap-feeding nematodes destroy the vascular tissues of the plant. Since plants cannot supply water, symptoms such as thirst and nutrient deficiencies (iron, copper, phosphorus, and manganese) occur. There is not enough benefit from fertilization. Wilting and growth retardation are observed in the trees. Especially in old trees, leaves dry and fall on thin branches. Young trees are stunted. As a result, plants lose up to 30% of their yield. At the same time, there is a decrease in the quality of the product received. Wounds form on the plant capillary roots, where nematodes feed. Fungi, bacteria, or other parasites enter through these wounds and secondary infections occur in the plant. Roots and stems may rot due to excessive water supply to nematode-infected trees that show signs of thirst. Gluing can also be seen on the trunk. This harmful nematode is found everywhere in Türkiye where citrus is grown.

3.3.3. Control

It is included in quarantine with this nematode. It is important that the saplings to be used in the newly established gardens are healthy in order not to spread the nematode. Soil analysis should be done on orchards suspected of being infected with nematodes. Transport of soil other than from contaminated gardens should not be allowed. All kinds of agricultural tools and machinery used must be thoroughly cleaned. By opening drainage channels, rainwater should be prevented from carrying nematodes to clean gardens. Soil spraying is done with a suitable nematicide.

3.4. Stem and Bulb Nematode

3.4.1. Definition and biology

Stem and bulb nematode female and male are approximately 1 mm long and have a filamentous structure. In the onion-sak nematode, a female lays 200-500 eggs. Depending on the environmental conditions and food, it can give 3 - 5 offspring per year (Kepenekci, 2012). Population density can vary depending on soil type and host type. The nematode population and damage in heavy soils are higher than in light soils. Stem and bulb nematodes can survive in plant tissue and especially in clay soils for years as durable fourth-stage larvae. It is rarely found in the roots of usually host plants. When environmental conditions become unsuitable, nematodes leave the plant and enter the soil. Especially in temperate regions, more damage is observed. Nematode prefers moist and cool conditions. The most important factor determining the degree of damage of this nematode is high humidity. If the temperature rises above 36 °C, nematode activity stops. Nematode damage can be seen intensely in areas with temperatures between 13-18 °C and high relative humidity (90-100%). These nematodes can survive for years in clay soils. It is spread by agricultural operations with nematode-contaminated agricultural equipment and machinery. Irrigation water contaminated with nematodes is also another source of nematode spread.

3.4.2. Hosts and damage

Stem and bulb nematode is a polyphagous pest. It causes damage to many plant species (450 plant species belonging to 44 families). They can also live in weeds. It is possible to encounter the damage of this nematode in all agricultural areas.

Because of the nematode feeding on the plant, swelling and deformity occur in the plant body, flowers, and leaves (Figure 3). Leaves can be short and thick. Yellowish-brown spots on the leaves and swelling (edema) on the stem may occur. Then the corms and the stem of the plant soften. Dead tissues and decay appear. Onion layers soften and turn light gray. Infected onion heads may be lighter and misshapen than others. Sprouting and double heads may occur in the onion. Fungal and bacterial secondary infections are common and often emit a rather foul odor. During storage of onions and tubers in cold places, it does not prevent the development of nematodes, and decay in plant tissues may continue. They can also be found in the seeds of their hosts.

Figure 3. Deformities observed on onion plants infected with stem and bulb nematode (Anonymous, 2023b)

3.4.3. Control

It is necessary to avoid infecting the nematode. For this reason, certified or clean seeds should be used. If certified seeds are not to be used, the seeds must be analyzed. Seed potato tubers should be selected one by one by hand and taken from uncontaminated fields. No tuber infected with nematodes should be left in the field and should be collected and destroyed. It should prevent the spread of the nematode in clean areas. For this, it is very important to use clean irrigation water. Plants that are not hosts of this nematode (such as carrots, spinach, and lettuce) should be grown. It should be applied for 2-4 years. Weed control should be done. Soil tillage tools and machines used in dishwashing areas must be thoroughly cleaned before being used in clean areas. There is no licensed preparation against the onion-sac nematode in potatoes in Türkiye.

3.5. Strawberry Nematode

3.5.1. Definition and biology

It is the most important of the nematodes that damage the strawberry plant. Both the male and female of the strawberry nematode are threadlike. Males are 0.48-0.65 mm and females are 0.45-0.80 mm tall. It spends the winter as adults, eggs, or larvae among the sepals surrounding the leaf bud of the plant. In the spring, they enter the soil when the rainwater washes the plants. They begin to feed on the growth points and buds of the plant. These nematodes feed ectoparasitically on petioles and leaflets at the growth tips. However, it is an endoparasite in leaf tissue. Temperature and humidity greatly affect their growth. This harmful nematode gives offspring every 10-11 days at 18 °C (Anonymous, 2008).

3.5.2. Hosts and damage

Strawberry nematode is commonly seen on strawberry plants immediately after the increase in relative humidity in the spring. It starts to cause damage in the early spring period when the plant starts to grow. As a result of feeding, wrinkling, and discoloration of the leaves are seen. The petioles are shortened. It prevents the development of buds and leaves. The nematodes, which then pass to the fruit buds, cause the fruits to become smaller and lighter in color. In some strawberry varieties, red color formation can be seen on the leaves. This nematode species, which is polyphagous, can be found in almost every place where strawberry production is made in Türkiye. In addition to strawberries, it also damages many ornamental plants (lily, primrose, African violet, chrysanthemum, and begonia).

3.5.3. Control

Although there are many natural enemies in nature, none of them can sufficiently suppress the population of this nematode. It is recommended to grow non-host plants for 3 years in soils infested with this nematode. Contaminated plants should be removed from the soil and burned somewhere outside the production area. Production materials (stolon) contaminated with this nematode should not be used to prevent contamination of clean areas. Stolons contaminated with nematodes should be kept at 46 °C for 8 hours before use. The temperature of the water should be constant. Irrigation water used in clean areas should also be clean (Abad et al., 2003).

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Soil-Borne Pests in Urban Agricultural Areas

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1. Introduction

Cities are living spaces where population, production, and consumption are concentrated, and at the same time, they are residential areas with a certain population in terms of human relations, where the physiological, economic, social, and cultural needs can be met in societies are met at certain levels (İsbir & Açma, 2002). Agriculture is a comprehensive word for providing food and other products to sustain the human population, from crop plants to domestic animals (Harris & Fuller, 2014). Urban agriculture, on the other hand, is defined as "the cultivation, processing, and distribution of food and other products through intensive plant cultivation and animal husbandry" in and around the city, as a concept that encompasses forms of "subsistence production and processing, from processing at the household level to commercialized agriculture." Entertainment and leisure activities that can serve different purposes, commercial enterprises that will bring economic vitality, use of space to achieve individual well-being and social health and welfare, landscape works, environmental restoration, and improvement are some of the urban agriculture activities (Philips, 2013). When all these recipes are combined, in addition to the benefits that agriculture produces and processes food, contributes to the natural resources of cities, provides food security, entertainment, and education for citizens, it also contributes to the solution of economic, environmental and social problems in cities (Kayasü & Durmaz, 2021). With the global pandemic process, the concept of urban agriculture has become even more important in terms of food safety, access to food, and ecosystem maintenance for humans and animals. With this global epidemic we are still experiencing, the importance of nature and healthy life has been better understood. The most important thing created by the pandemic process is the major challenge is access to economically accessible, fresh, and nutritional food for the growing population (Lal, 2020). Therefore, the factor that epidemics, disasters and wars, etc. indicate is that the "agricultural sector" has an important place in countries' economic policies. (Akın et al., 2020). In terms of environmental quality and ecosystem, urban agriculture, it contributes to the city's sustainability by maintaining biological diversity, reducing heat islands and carbon emissions in cities, increasing the city's air quality, and utilizing urban waste and wastewater (Tandoğan & Özdamar, 2022). As the years go by, it will be inevitable for the population to increase, the limited resources to decrease, and, as a result, the environmental problems to increase. Therefore, these activities will increase, especially in megacities that are the centers of activities such as tourism, trade, industry, and agricultural production, and more undesirable negative pressure will occur on the environment. The increasing number of people living in cities and the resulting rapid urbanization bring about undesirable environmental problems. It is a known fact that today, most of the natural resources are consumed in cities due to the population. As a result, fertile lands, food, clean water, and clean air are gradually decreasing, and the world is rapidly approaching a state of famine (Kayasü & Durmaz, 2021). Especially in developing countries, cities are expanding rapidly, so the proportion of people living in cities is increasing rapidly. In our country, due to migration from villages to cities in recent years, high population density in urban areas and heavy vehicle traffic for industry, agriculture, and transportation causes water, soil, and air pollution. Among these, climate change stands out as the biggest ecological problem of our age on a global basis, and the negativities it creates are better understood day by day. As a result of greenhouse gas emissions resulting from energy, industry, and related wastes, urban and conventional agricultural activities on the earth, the climate crisis is causing the climate crisis to reach increasingly dire situations. In the future, food security and climate change discussions will continue to be critical issues to be considered. Bulkeley (2010) states that cities are responsible for approximately 75 percent of human-caused global greenhouse gas emissions, and Hoornweg et al. (2011) reported that more than 80 percent of total emissions may originate from activities carried out in cities. The effects of regime change in climates and the problems caused by these effects continue to negatively affect human and environmental health and the social dynamics of societies and economies. This situation will continue to increase exponentially over the years. Therefore, one of the biggest problems for humanity is ensuring food security in this deteriorating ecological environment. Otherwise, it will affect all processes of agricultural products from field to table. Thus, significant problems will arise for food processing, storage, transportation, and consumption. It has been reported that by 2050, food prices may increase between 3% and 84% due to climate change (Porter et al., 2014). As a result, the risk of contamination with heavy metals increases as a result of the increased use of chemical products in the production of energy and industrial products. In order to obtain more products from unit areas, the problem of more pollution of soil, water, and air to be used in agricultural activities will increase. Thus, pollution risks from chemical pesticides and fertilizers will increase in areas where urban agriculture is carried out. Using chemical fertilizers in agricultural areas is one of the most important activities that cause greenhouse gas emissions that cause climate change. Bahçeci (2019) reported that fertilizer use decreased considering the urban gardening example Istanbul data. In the same study, it was stated that this result, on the one hand, means a reduction in greenhouse gas emissions of at least 2.7 to 21.3 million kg of CO_2 equivalent per year, and on the other hand, it means health and sustainable food. For these reasons, measures need to be taken to reduce the negative effects of chemicals in these areas on health and the environment. In summary, measures must be taken to increase people's awareness levels to reduce health and environmental risks in urban agriculture.

The products produced in urban gardens, which are increasing daily, must be protected against harmful pests. Due to the polluted nature of these areas and the resulting decrease in species diversity, products in production areas are more susceptible to problems. Therefore, to minimize product losses due to pests in urban agricultural areas, it is first necessary to have information about agricultural pests that may occur in the plants grown. There are many pests on cultivated plants in areas where agricultural activities are carried out. Among these, species known as underground pests have an essential place. These pests are among the most important problems that limit the production of cultivated plants in urban areas. Critical factors such as soil type, soil moisture, and rainfall amount determine the extent of damage caused by subsoil pests and their distribution (Nyamwasa et al., 2018). Additionally, outbreaks may be associated with pest responses to temperature changes. This may increase the number of annual generations or extend the breeding season of pests (Kiritani, 2012; Kroschel et al., 2016), both of which can lead to severe crop losses (Nyamwasa et al., 2018). Apart from these environmental factors, some other factors are effective in causing these pests to be a problem. Several agricultural practices, including crop rotation, solarization, appropriate tillage, autumn tillage, use of clean materials, resistant plant varieties, grafted plant material, mulching, planting of trap plants, use of non-soil material, planting timing, and source removal, can reduce their population densities. It affects. Uncultivated soils close to production areas serve as an essential source of contamination for soil-borne pests in cultivated areas. Because these areas are not developed, they are rich in vegetation and provide suitable environments for developing these pests. Additionally, a production area's history is a critical factor in identifying potential soil-borne insect problems. Because of the color of the leaves of some plants, their smell, and plant-specific characteristics such as pollen can attract some insects. Therefore, the number of species and population density in an area depends on the vegetation present in previous years. In the case of preferred plants, they lay eggs there and continue to live in the soil, feeding on plant roots. When plant diversity increases, especially when weeds are not controlled, the more narrow and broad-leaved plant species there are, the more soil-borne pest species and numbers there will be. Although it is prevented by pest and disease control methods, 30-40% of the produced products are lost every year due to their effects on agricultural products. (Alimuhammedov & Khujaev, 1991; Caballero et al., 1991; Arthi et al., 2019; Khudoykulov et al., 2021). In some areas, the main pests that cause these losses are soil-borne pests. If left uncontrolled, these pests can destroy 60-70% of vegetable crops over years of mass proliferation, especially 25-30% of newly planted potatoes with balls (Khudoykulov et al., 2021). Soil-borne pests cause a significant decrease in yield and deterioration in product quality. These underground pests have been reported to be the main pests of all vegetable and potato crops in Central Asia and Europe (Alimuhammedov & Khujaev, 2020).

So, why do these pests appear more of a threat in production areas? Because these pests feed on the roots and tubers of plants in the soil. Here, the damage it causes can go unnoticed and thus significantly affects the plant's growth and ultimately affects the productivity of the crop. Therefore, the damage to the product is noticed only after it is done. Another reason is that these generally damage the plant in the early period, that is, in the sensitive period, causing the plant to dry out or cause problems in its development. The success of chemical control is not as high as it is for above-ground pests. Because it is difficult to deliver a lethal dose of pesticide to the pest in the soil, another critical problem is the transmission of diseases from underground soil. As a result, efficiency and the resulting product quality decrease. To protect the quantity and quality of the products produced in urban agriculture, it is essential to recognize these pests that damage plants and to have some basic information about their fight against them. The best way to determine whether these soil-dwelling pest species are causing problems in urban farming areas is to examine the roots of the plants and look for damage. To do this, it is necessary to find the pests in question by digging the bottoms of damaged seedlings or the areas with weak plants opened between the rows. On aboveground plant parts, most of these pests cause similar symptoms, such as the presence of sparse vegetation in the cultivated field or the row and wilted or weak plants that have not developed. It is imperative to find solutions using new technologies to improvise and solve such problems faced by producers in agriculture (Arthi et al., 2019). Recently, remote sensing has significantly contributed to detecting and controlling many diseases and pests. However, the visibility and monitoring of soil-borne pests during the young period, which is the critical growth stage of crops, remains a significant concern. Playing seeds before planting against these pests in areas with intense damage is essential. In the later development period of the plant, only after the roots are entirely damaged and rotted, the color of the parts of the plant above the ground changes, and growth retardation occurs. Thus, significant product losses occur. For this reason, new approaches have recently been tried in the fight against underground pests to solve these problems. One of these is to detect the presence of pests in the soil using a thermal sensor device and to destroy the pest by applying pesticide directly with the warning of the related system (Arthi et al., 2019). The mechanism here is primarily that the soil maintains a certain thermal level range. Larvae in the ground have different thermal levels; hence, the thermal level will be higher than the average temperature level of the soil where the grubs or worms are located. The problem can be solved by spraying a sufficient amount of pesticide on the affected area, depending on the difference in temperature levels.

The problem caused by species that damage plants increases every year. Important soil-borne insects that cause damage in areas where agricultural production is carried out are sapling bottomworms, June and May beetle larvae, wireworms, turnip moths, fly grubs, mole crickets, termites, crickets, etc.

2. The Situation of Soil Borne Pests in Türkiye

As a result of many studies conducted worldwide to date, many soil-borne pest species that are economically important in production areas are known. Some of these cause serious problems, especially in vegetables and fruit trees, in the early and later stages. These can also be a problem in plants grown in urban agriculture. It damages especially the roots, stems, and tubers of plants. Our country has many pests, especially belonging to the orders Coleoptera, Diptera, Lepidoptera, Homoptera, Orthoptera, and Isoptera. Many studies have been conducted on many species belonging to these orders. As a result of this research, the species known as important soil-borne pests that cause economic crop losses are given below:

- Sapling flat-headed borers (*Capnods* spp.) (Coleoptera: Buprestidae).
- May and June bugs (*Melolontha* spp., *Polyphylla* spp. and *Anoxa* spp.) (Coleoptera: Scarabaeidae).
- Wireworms (*Agriotes* spp.) (Coleoptera: Elateridae).
- Turnip moth (*Agrotis segetum* (Schiff.)) ve Black cutworm (*A. ipsilon* Hüfnagel) (Lepidoptera: Noctuidae).
- European mole cricket (*Gryllotalpa gryllotalpa* (L.)) (Orthoptera: Gryllotalpidae).
- Cicadas (*Lyristes plebejus* Scopoli, *Cicadatra adanai* Kartal, *Cicadivetta tibialis* (Panzer) (Hemiptera: Cicadidae).
- Crop humpback beetle (*Zabrus* spp.) (Coleoptera: Carabidae).
- Cabbage Gall Beetle (*Ceutorrhynchus pleurostigma* Msh. (Coleoptera: Curculionidae).
- Cabbage fly (*Delia radicum* (L.)) (Diptera: Anthomyiidae).
- Carrot fly (*Psila rosae* F. (Diptera: Psilidae).

Apart from these pests, many soil-borne pests cause damage to different products. Of the above, the first 5 species cause more economic damage than the others. For this reason, brief introductory information is given below about economically important soil-borne pests found in Türkiye's agricultural areas and, thus, may be a problem in urban agriculture.

3. Some Important Soil Borne Pests Harmful in Urban Agriculture in Türkiye

3-1. Flat-headed borers (*Capnodis* spp.) (Coleoptera: Buprestidae)

Many species belonging to the genus *Capnodis*, known as sapling bottomworms. The adult individual is given in Figure 1. Among these species, sapling bottomworm (*Capnodis porosa* Klug.), Pistachio bottom worm (*C. cariosa* Pall.), Plum bottomworm (*C. carbonaria* Klug.), Poplar bottomworm (*C. miliaris* Klug.), Little bottomworm (*C. tenebricosa* Oliv.) and Cherry dipworm (*C. tenebrionis* L.) are the ones that cause significant damage in our country. These cause damage to stone fruits such as plums, apricots, nectarines, peaches, and cherries, especially in the early stages. It causes significant damage to many ornamental plants, especially hard-shelled fruit trees such as pistachios and almonds and soft-stoned apples, pears, and quinces. Except for developing nurseries, especially in large orchards, if left untreated, they can cause the death of their hosts in as little as a few years. The larvae of this pest open galleries by feeding under the tree root bark, between the soil level and the primary roots. If many larvae are on a plant, providing towards the primary roots continues. They leave sawdust-like feces under the bark where they feed. Sapling bottomworm larvae feed by gnawing the cambium layer with their biting-chewing mouthparts. As a result, even a single larva damages the vascular bundles of young plant saplings when it feeds all around the underground stem.

Figure 1. The adult of sapling flat-headed borer

As a result, it prevents the tree from absorbing nutrients and water from the soil, causing the plant to dry out. As a result of the damage it causes to mature trees, it first slows down the growth of trees over time, resulting in loss of productivity. If more than one larvae attack a plant, it may cause the plant to die. This pest spends the winter in tree cavities, under plant materials, and in soil cracks and cracks, where they can be protected under the root bark of plants during the larval stage or as adults. Those that overwinter in this way as adults feed voraciously by gnawing on grafts and fresh shoots when the weather warms up in the spring. When the air temperature rises above 25 °C, they mate and start laying eggs. The mated adult lays its eggs, individually or in groups, in cracks and crevices in the tree trunk close to the root collar of plants, in bark gaps, in graft buds, or the soil around the root collar of its host. Each female can produce up to 2.000 eggs. Larvae go under the shell immediately after hatching. These pests have one generation in two years. Adult individuals that emerge in the first period lay their eggs between July and October, and individuals that emerge in the second period lay their eggs between May and July of the following year. The larvae cause the primary damage of this pest. Conversely, adults damage the above-ground parts of fruit trees by gnawing the buds and young shoots and eating the fresh leaves. To be successful in the fight, it is necessary to follow their biology and start spraying before the adults lay eggs, and continue spraying every two weeks during egg laying. Otherwise, the fight fails because the larvae burrow under the bark. For this reason, it is difficult to fight against pests. Fighting adults should be done in the spring, before the adults lay eggs before the air temperature reaches 25 ºC. Then, the adults that emerge from the pupa in the summer should be fought against in July-August. If adults are combated, the population level can be kept at low levels.

3.2. May and June bugs (*Melolontha* spp., *Polyphylla* spp., and *Anoxa* spp.) (Coleoptera: Scarabaeidae)

Many species belong to the *Melolontha, Polyphylla,* and *Anoxa* genera, known as May and June bugs. The adult and larva of this pest are given in Figure 2. The adult individuals of these pests can be easily distinguished from others by their lamellar fan-shaped antennas. The antennae of males are larger than those of females, and the lamellar is prominent. The first pair of wings (elytra) does not cover the entire abdominal segment. A few segments remain outside. Scarabaeid form larvae are easily recognized because they are large and curved in the letter "C" shape. The hard mandibles are well-developed and dark in color. There are 3 pairs of legs in the thorax, which are unsuitable for much movement. The larva completes its period in the soil. The movement of larvae in the soil depends on the temperature and moisture content of the earth. The larvae form membranes between March and October when environmental conditions, soil temperature, and humidity conditions are suitable. The June bug larva feeds on host plant roots. The larvae also cause damage by eating tuberous plants. Its damage is incredibly intense on beaches and humus-rich soils. They spend the winter in the larval stage at a depth of 50-90 cm, depending on the quality of the soil. As the weather warms in spring, they move towards plant roots near the soil surface. Larvae enter the third instar in early June and remain in the third instar until May of the following year. They complete the pupation period in their cell-shaped pupa nest in May. Adult emergence from the pupa occurs in June-July.

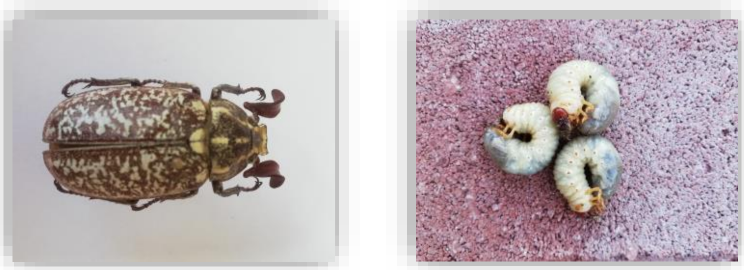

Figure 2. Adult and larvae of June bug

Mated females lay their eggs in a nest they create approximately 1-20 cm deep in the soil close to the host plant. The hatch larvae from these eggs feed on nearby plants' roots and tubers. Depending on environmental conditions, the larvae burrow deeper into the soil to protect themselves from heat and drought in summer and cold in winter. Thus, they create a new generation by feeding on the roots and tubers of the host plant in the soil for 2-3 years. Chemical control of this pest is difficult. Because it is not easy to deliver the pesticides to the larvae in the soil. Mechanical damage to the larvae during soil cultivation within the scope of cultural control affects the population.

3-3. Wireworms (*Agriotes* spp.) (Coleoptera: Elateridae)

There are many species belonging to the genus *Agriotes*, known as wireworms. The larvae of this pest are given in Figure 3. Adult individuals jump and turn when turned upside down, and a typical feature of them is that they make a "snap" sound while doing so. That's why they are called click bugs. Many species of this genus are in our country, including *Agriotes lineatus* L., *A. obscurus* L., *A. sputator* L., *A. paludum* Kiesenwetter, and *A. cilicencis* Platia & Gaudenzi. Among these, *A. lineatus* is the most common and causes significant damage. These polyphagous species are widely found in almost every part of our country. They cause considerable damage, especially to vegetables. These pests spend the winter as larvae or adults in the soil, descending from the surface. As the weather warms up in the spring, they feed on plant roots towards the soil surface. Adults, who feed and mate for a while, lay their eggs at a depth of 10-15 cm in the soil until the end of July, depending on seasonal temperatures. They lay eggs individually or in groups near host plants. A female lays approximately 100-300 eggs. The larvae that emerge from the laid eggs immediately feed on plant capillary roots. They can open galleries in plant roots in the young period. They also cause damage by opening galleries in tuberous plants. Tubers damaged in this way have no market value. Larvae are cylindrical, 2-3 cm long and have a hard body. Larvae complete their development in 2-5 years. The nymph, which has completed its development, descends to a depth of approximately 40 cm into the soil and pupates there. They become adults after a few weeks of pupation.

Figure 3.The larva of Wireworm

Although adults cause damage by eating fresh parts of host plants, it is not essential. The larvae cause the main damage to the products. If pest larvae are detected in the soil one year ago, precautions must be taken the following year. Seed spraying should be done before planting to prevent damage in such areas. During the seedling period, spraying can be done in the form of seedling spraying and soil spraying in the field. Bare-root seedlings should be planted after their roots are dipped in medicated soil slurry. Seedlings planted from the viols into the ground should be treated with pesticides and life water. It is known that soil tillage and irrigation that fully saturates the soil are effective in killing wireworms.

3-4. Turnip moth (Agrotis spp.) (Lepidoptera: Noctuidae)

In our country, the turnip moth (*Agrotis segetum* (Schiff.)) and the black cutworm (*A. ipsilon* Hüfnagel) belonging to the *Agrotis* genus are the most common species that cause damage. Apart from these two species, there are also *A. crassa* Hübner and *A. spinifera* (Hübner). The Turnip moth larva is given in Figure 4.

Figure 4. The larva of turnip moth

These species are available almost everywhere in our country. It is a polyphagous pest and causes significant damage to vegetables, especially tomato, pepper, eggplant seedlings, and potatoes. It also causes significant losses in the seedling period of plants such as melon, watermelon, cucumber, and squash. The turnip moths generally spend the winter as mature larvae in the soil. As the weather warms up in the spring, they begin to feed on host plants. Then we pupate. In our country, adult emergence occurs in April and May, depending on the temperature, which varies depending on the altitude. After mating, females lay their eggs individually or in groups on plants' leaves, stems, or soil. A female can lay more than 1.000 eggs. It lays approximately 300-400 eggs per female. The larvae that emerge from the laid eggs feed on the fresh leaves and shoots of the plants in the first two periods. In later larval stages, they feed at night. During the day, they wait curled up in the soil near the roots of plants. The larvae cause pests by cutting or gnawing the root neck of plants close to the soil level at night. They also feed on newly planted germinating seeds or tubers of tuberous plants. Thus, they create plant-free spaces in the rows by cutting young plants from the root neck. In years when there is a high population, replanting may be necessary. It prevents the development of plants that have developed in later stages by eating various parts of them. Thus, it causes poorly growing plants to yield less. Later, the matured larvae create a chamber in the soil and become pupae there. The turnip moth, which survives this way, gives 2-4 generations per year, depending on the altitude. The management against this pest is the same as in wireworms. In other words, seed spraying means dipping the roots of the seedlings into the medicated slurry and giving the medicated water as life water to the seedlings that will be removed from the viols and planted. Additionally, poisoned bait is applied. For this purpose, the medicine and wheat bran are mixed dry in the recommended dosage. After a homogeneous distribution is achieved, it is thoroughly moistened with water in which sugar is dissolved. The poisonous bait prepared in this way is distributed homogeneously to the root collar of the plants at the rate of 5-8 kg per decare, close to sunset. To get a successful result, it is recommended that the application be done after irrigation.

3-5. European mole cricket (*Gryllotalpa gryllotalpa* (L.)) (Orthoptera: Gryllotalpidae)

The adult individual of *Gryllotalpa gryllotalpa* (L.), the European mole cricket, is given in Figure 5.

Figure 5. Adult individual of *Gryllotalpa gryllotalpa*

This pest generally chooses cultivated soils suitable for opening galleries, moist, humus-rich, clayey-sandy soils as its habitat. During the day, it is found in the galleries it creates underground. They spend most of their lives underground. They come to the soil surface at night. They also sometimes come to the soil's surface when the land is irrigated or to find their mate. This pest carries out its activity intensively at night. After the spring rains or the field irrigation, their activities increase, especially in the hot summer months. Their front bases (Figure 5) specialize in digging into the soil. Adults and nymphs create galleries close to the soil surface and hunt for worms and other insect larvae that fall into these places or that they encounter. Therefore, it is an omnivorous creature. However, they also damage the plant roots and tubers that come across them while creating these galleries. Plants damaged in this way dry out or experience retardation in their development. They spend the winter as adults or nymphs in a chamber they create in the soil. As the weather warms up in spring, wintering individuals become active. Depending on the temperature, adults who develop and mate due to their nutrition, lay their eggs between April and May. They lay their eggs in the nests they make in the soil. Each female can lay approximately 300-500 eggs during her lifetime. Females care for and protect the young individuals in the first two nymph stages that hatch by feeding them (Weiss & Dickerson, 1918). The young become adults after 5 nymphal steps. While they produce one generation every two years in cold countries such as Russia, in our country, they produce a new generation once a year (Ulusoy et al., 2016).

This pest is controlled with different methods. As a cultural precaution, in case of problems in narrow areas, the field is flooded, and the individuals that emerge are collected and destroyed. With good soil cultivation at the appropriate time, the individuals are crushed to death. Another method is to create piles of horse manure in pits that will be opened every 15-20 steps in the production areas towards the end of summer, as this pest prefers hot and fertile places. These clusters are mixed before spring before the weather gets warmer, and the nymphs and adults are collected and destroyed. Chemical control is carried out with poisoned bait, using a drug containing dandruff in appropriate doses, as in the case of turnip moth. Irrigation of the field before spraying increases success. Spraying is carried out towards sunset. The spraying area must be checked at dawn on the morning of that day. Dead or dying individuals in the area are collected and buried deep in the ground in a suitable area. Thus, birds of prey or other creatures are prevented from eating the poisoned individuals.

As a result, there are critical soil-borne pests in areas where urban agriculture is carried out. Basic introductory information about these has been compiled for people dealing with urban agriculture. Thus, basic information about critical soil-borne pests' importance, biology, hosts, and control is presented. Ulusoy et al. (2016) provide more detailed information about these pests.

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Biodiversity-Friendly Cities as a New Concept Against Climate Change

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1. Introduction

In the UN development report, it is stated that by the year 2050, nearly 70% of the global population will begin to live in urban areas. As a result of this, due to the increasing urban population both globally and in our country, various urbanization movements have emerged, leading to:

- Rapid loss of urban green spaces and agricultural lands (Figure 1),
- In cities, a multitude of environmental issues are being experienced, including transportation, infrastructure, energy, health, nutrition problems, air pollution, visual pollution, and solid waste,
- Inadequate open and green spaces, obstruction of wind corridors, misguided urban planning, and the increasing reflection of light from glass and shiny surfaces in urban spaces contribute to the formation of urban heat islands,
- Insufficient attention to natural and ecological thresholds in physical development results in cities suffering from difficult-to-reverse damage to natural ecosystems, rendering them vulnerable to disasters.

Urbanization leads to the deterioration of productive landscape areas such as urban green spaces and agricultural lands, fragmenting habitats and increasing pressure on urban biodiversity. Climate change scenarios, which are currently relevant and are expected to become a significant environmental issue in the future, are predicted to have ecological, economic, and sociological implications for urban ecosystems. Therefore, sustainability takes precedence in all urban planning decisions and physical developments. There is a growing need to maintain and expand biological diversity for more livable cities.

Figure 1. As a result of increasing population movements, cities are becoming more urbanized

Urbanization destroys or alters local habitats while creating new infrastructure. Due to these changes, non-native species are gradually decreasing in urban landscapes. However, cities also give rise to diverse habitats and species, and especially in temperate cities, the diversity of vascular plants and birds can surpass that of surrounding landscapes. Nonetheless, the actual formation of a species depends on habitat presence and quality, spatial arrangements of habitats, species pools, the adaptability of a species, and its natural history and area history (Müller et al., 2013).

According to the Intergovernmental Panel on Climate Change (IPCC), global temperatures have already risen by 1,1°C, and this change is progressing towards 1.5°C. In recent years, significant efforts have been made by the United Nations (UN) to mitigate the pressures of climate change on both natural and cultural environments.

To mitigate the adverse effects of climate change on ecosystems:

- The Quito Declaration on Sustainable Cities and Human Settlements was established in 2016 in Ecuador.
- Focusing on environmental sustainability, well-connected open spaces, accessibility, safe green areas, and resilient urban planning and practices.
- Improving and preserving urban ecosystems and environmental factors.
- Protecting sensitive productive areas for sustainable land use, preserving urban agricultural areas, ensuring food security, and reducing environmental issues.
- Decisions were made to protect urban agricultural areas and enhance urban biodiversity.
- The Paris Agreement (COP21) was adopted in 2015 with the participation of 194 countries.
- The UN Climate Change Conference (COP26) took place in Glasgow in 2021.
- The 27th Conference of the Parties to the UN Framework Convention on Climate Change was held in 2022 in Egypt with the participation of 190 countries. During this meeting, it was decided to develop action plans to keep global climate change at 1.5 degrees Celsius by the end

of the century. Additionally, targets were set to reduce greenhouse gas emissions by 43% by 2030, prevent deforestation, and provide financial support to developing countries for climate change impacts (URL 1; Müller et al., 2013).

2. Urban Biodiversity and the Relationship with Green Spaces

Urban biodiversity refers to the diversity of flora and fauna in various habitats within urban ecosystems. According to Müller et al. (2013), urban biodiversity encompasses the variety and abundance of living organisms, including genetic diversity, as well as the habitats present in and around urban areas. Species diversity can vary from the rural outskirts to the urban core. There is a long history of humans transporting plant species and influencing local biodiversity. The survival and proliferation of wildlife species, much like plants, are directly linked to the presence of urban landscape areas. The interaction between plants and animals in cities, along with the presence of social and ecological systems, often gives rise to unique and specific biotic communities.

The rapid physical changes in urban infrastructure lead to the loss of open and green spaces, and urban biodiversity is increasingly exposed to pressures from climate change. However, there are relatively few planning and urban landscape designs that support urban biodiversity. Various studies have shown that biological diversity within cities is higher compared to the surrounding areas. Larger urban landscapes have been found to host more non-native species than smaller ones (Pyšek et al., 2004). The same pattern applies to urban fauna, where areas with intense human activity tend to have greater insect diversity (Demir and Aydın, 2020).

Urban ecosystems in colder regions, being warmer, provide longer periods for plant growth, sheltered built environments, localized irrigation and moisture, conscious or unconscious food availability, and thus contribute to the biodiversity advantage of food production. According to Sukopp and Wurzel (2003), although ecological and socio-economic factors influence urban vegetation, it has been observed that many of the naturalized non-native invasive species in cities come from warmer regions and take advantage of more favorable climates.

Urban green and blue infrastructure (UGBS) plays a crucial role in conserving urban biological diversity. While numerous studies focus on the benefits of UGBS for urban well-being, research that fully elucidates the ecological impact of urban biodiversity remains limited (Aznarez et al., 2022). A green infrastructure network connects ecosystems and landscapes through centers, connections, and areas (Aslan & Yazıcı, 2016; Mell et al., 2017).

Blue-green infrastructure planning is one of the structural solutions adopted to make rapidly growing cities more sustainable and adaptable to climate change due to the increasing population. Green infrastructure is becoming increasingly important in ensuring that communities have clean air and water and a livable environment for future generations (Hepcan, 2019; Chatzimentor et al., 2020; Morpurgo et al., 2020; Parlak & Atik, 2020; Hoover et al., 2023; URL, 2).

Urban green spaces serve numerous functions such as ecological, aesthetic, economic, socio-psychological, recreational, and contributing to biodiversity (Fuller et al., 2007; Yılmaz et al., 2008; Kendal et al., 2014; Middel et al., 2015; Peschard et al., 2016; Yılmaz et al., 2018; Bartesaghi-Koc, 2020; Abd Elraouf, 2022; Alves et al., 2022; Balany et al., 2022; Quyang et al., 2023; Young et al., 2023). They create urban environments that are more livable in terms of regulating climate, reducing adverse impacts, and enhancing thermal comfort. Especially due to climate change, the significance of urban green spaces in mitigating the growing urban heat island effect is becoming increasingly crucial (Yılmaz et al., 2021).

Urban tree species are significant components of floristic diversity and represent essential building blocks in cities' resilience against urbanization. Research shows that as the number of tree species increases, ecosystem resilience improves, and it's emphasized that no single tree species should exceed 10-20% of the total tree species (Kendal et al., 2014). Urban trees and shrubs are important living natural elements that connect people with the biosphere (Liu et al., 2021). The composition of urban plant diversity with natural/native species not only ensures the sustainability of urban greenery but also brings numerous advantages, including sensitivity to climate change, support for wildlife and local fauna, and lower maintenance costs.

The utilization of fruit-bearing plant materials is more prevalent in privately owned gardens in our country (standalone houses, residential complexes, certain institutional gardens, etc.) (Dikmen & Yılmaz, 2021). Fruit trees in urban settings contribute to visual landscape quality through their flower and fruit colors, and autumn leaf color changes, and they are not only of economic value but also crucial ecological components that support wildlife (birds, bees, butterflies, certain insect species, etc.).

Urban agricultural areas, fruit-bearing plants in green spaces, hobby gardens, small production areas on roofs and balconies, orchards, and edible gardens serve ecological, economic, and recreational roles, acting as insurance for urban biodiversity (Figure 2).

Figure 2. Urban productive landscapes play a vital role in the continuity of biodiversity

Conservation, restoration, and expansion of urban biodiversity rely on vital roles played by various habitats: in the city and its surroundings, forests, agricultural lands, groves, grasslands, meadows, farmlands, valleys, rivers, botanical and hobby gardens; within the urban area, parks, roadside trees, residential gardens, water surfaces, rooftop and façade plantings, cemeteries - all contribute to urban flora and fauna and thus, to urban biodiversity (Figure 3).

Figure 3. Urban green infrastructure contributes to the urban ecosystem

3. A New Concept: Biodiversity Friendly City (Biofrendly City)

In urban environments, using plant species with edible fruits is a crucial criterion in establishing biodiverse-friendly cities. The concept of biodiversity-friendly Street trees was first introduced in a study conducted in China (Liu & Slik, 2021). In this research, street trees in 59 Chinese cities were categorized as natural species and trees with fleshy fruits. The conclusion drawn was that these plants were not adequately integrated into the cities.

In this study, the aim is to introduce and promote the concept of "BIOFRENDLY Settlement/City" as a new approach in urban landscape planning to address climate change scenarios and to provide a new dimension to urban biodiversity.

The goal of this study is to seek answers to the following questions:

- What should be the components/criteria of the BIOFRENDLY Settlement/City concept?
- Can the biodiversity-friendly city concept be a novel approach in urban landscape strategies against climate change scenarios?
- What strategies should be employed for area implementations of urban green spaces to meet the BIOFRENDLY CITY criteria?
- Can this concept be propagated to other cities in our country? How can this concept gain brand value at a national level?

Criteria of the BIOFRENDLY Settlement/City Concept

The concept of BIOFRENDLY Settlement / City is based on the analysis of open-green spaces (such as parks, street trees, public institution gardens, residential gardens, urban woodlands, cemeteries, squares, sports areas, etc.) within urban areas using a novel approach. In this study, a criteria form has been prepared as a method to determine whether any urban open-green space or the city itself qualifies as a BIOFRENDLY Settlement/City For each criterion, scores have been assigned based on area-specific attributes on a scale of 0 to 100 (Table 1).

For each land usage, the number of native species and the number of species bearing fleshy fruits were considered, following the works of Liu & Slik (2021). Additionally, the rule that no single tree species should exceed 15% of the total tree species count in an area, as established by Kendal et al. (2014), was adapted and incorporated. Other criteria and the scoring system were proposed as a new method. Plant species within the area will be evaluated based on trees and shrubs, and the criteria outlined in the first four items of Table 1 must be met.

By assigning scores to various types of open-green spaces (such as parks, public institution gardens, residential areas, street trees, cemeteries, etc.), the BIOFRENDLY Value of the settlement will be calculated through averaging, which will ultimately contribute to the city's overall biodiversity.

Green areas that score above 60 out of a total of 100 points from the main criteria provided above will qualify for the BIOFRENDLY title. Throughout the research process, practical application will be carried out on a sample area, and the adequacy of these criteria will be assessed based on experiential knowledge, leading to the refinement of these criteria for future studies.

Table 1. Criteria for determining BIOFRENDLY settlement/city

Criteria No.	Evaluation Criteria	Criteria Condition	Score	
1	Natural species use	Natural species are more than 10% of the total number of species	15 compulsory	
2	The use of fleshy-fruited species	Fleshy-fruited species are more than 10% of the total number of species	15 compulsory	
3	Number of plant species	Contains at least 25 species	10 compulsory	
4	The ratio of plant species to other plant species	A plant species not exceeding 15% of the total number of plant species	15 compulsory	
5	Age of plants	Be at least 5 years old	5	
6	Field size	less than 500 m^2	2	10
		500 m^2-1 acre	4	
		1-5 acre	6	
		5-10 acre	8	
		more than 10 acres	10	
7	The ratio of green areas to hard impermeable surfaces	less than 10%	2	10
		%10-20	4	
		%30-50	6	
		%50-75	8	
		More than 75%	10	
8	Positive ecosystem components	More than 100 m from the main transportation axis	2	20
		Green corridor link	2	
		Presence of natural habitat (natural shrub, forest, wetland, natural meadow or pasture	4	
		No fertilizer or pesticide application in the area	2	

		Natural stream or lake in the area	8
		Artificial pond	5
		Small pool	3
		Tree top cover closure status	
		-fully closed,	5
		-half-closed	3
		-quarter off	2
		Control and maintenance, no hard pruning	2
		Clean air quality	3
9	Negative ecosystem components	Polluted air	-2
		High noise	-2
		Intensive use of pesticides and fertilizers	-5
		Exposure to excessive night light	-2
		No clean water source nearby	-8
		Unmaintained and uncontrolled green space	-2

Each type of open green space (such as parks, public institution gardens, residential areas, roadside trees, cemeteries, etc.) will contribute to the overall Biodiversity Friendly Value of the settlement based on the assigned point values. By calculating averages, the city's total Biodiversity Friendly Value will be determined. Green spaces that score a total of 60 points or more out of 100 possible points from the main criteria provided above will be eligible to receive the title of "BIOFRENDLY". Throughout the research process, a practical application will be carried out on a specific case, evaluating the adequacy of these criteria based on field experiences. As a result of the research, the developed criteria will be presented for future studies in order to guide subsequent endeavors.

4. Conclusion and Suggestions

The consequences of these impacts, such as climate change, seasonal disruptions, drought, species losses, etc., are becoming increasingly tangible day by day. As a result, the importance of conserving and enhancing biological diversity is growing. Rapid physical changes in urban environments not only negatively affect human comfort and health but also lead to a range of environmental issues, significantly harming urban biodiversity and causing habitat destruction. In order to minimize the negative consequences of rapid urbanization, the United Nations established 17 global Sustainable Development Goals under the theme of "Sustainable Cities and Communities" in 2015 (URL, 3). These overarching goals particularly align with topics such as sustainable development for healthy and quality living, sustainable cities and communities, climate action, life below water, and terrestrial life, and are in harmony with this study.

Rapid urbanization and global biodiversity loss necessitate new research to provide insights into policies, management, and conservation in urban ecology. These novel pursuits include understanding the socio-economic and socio-ecological drivers of biodiversity loss against biodiversity gain, biological diversity's response to technological changes, biodiversity-ecosystem service relationships, urban areas as refuges for biodiversity, species dynamics, community changes, underlying processes and focus on ecological networks. To establish the capacity for research, education, and implementation of urban biodiversity against global environmental issues in urban areas, communication, public awareness, and collaboration should be fostered across multiple fields and disciplines (Knapp et al., 2021).

Climate change scenarios, which are currently relevant and expected to become increasingly significant environmental issues in the future, are predicted to bring about ecological, economic, and sociological challenges in urban ecosystems. Hence, sustainability takes precedence in all planning decisions and physical developments in cities, as these scenarios could have far-reaching effects. The need to sustain and expand biological diversity is more crucial than ever for creating more livable cities.

It's well-known that urbanization alters local conditions and could render urban habitats unsuitable for native plant species (Sjöman et al., 2016).

Nevertheless, native plant species are more resilient to urban climates and have a positive impact on at least one biodiversity measure (Figure 4).

The contribution of different plants to urban biodiversity should be a contemporary topic of discussion in the design of new settlements (Berthon et al., 2021).

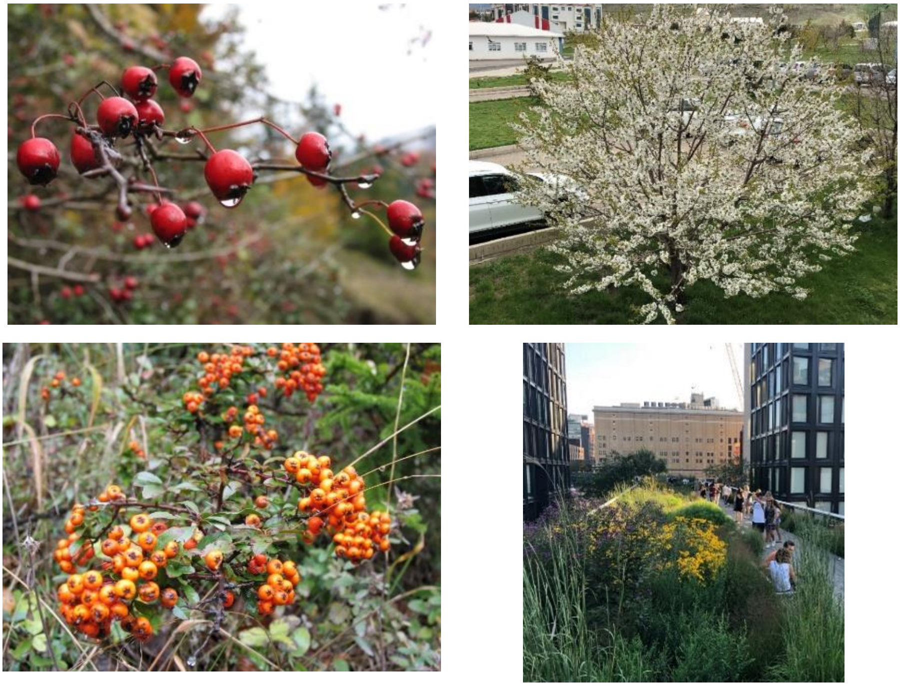

Figure 4. Native and fruit-bearing plants enhance urban biodiversity resilience

Regarding Biodiversity-Friendly Settlements/Cities:

- The concept of a biodiversity-friendly city in urban landscape approaches could potentially offer a new approach in response to climate change scenarios.
- Although the components/criteria of Biodiversity-Friendly Settlements have been identified, these criteria could be further developed through field applications.
- Strategies for implementing field applications to meet the Biodiversity-Friendly City criteria for urban green spaces can be achieved through

the involvement of urban decision-makers, subject experts, and public participation.

- It has been concluded that this concept could be expanded to other cities in our country by implementing it in any urban green area and promoting it, thus adding brand value to this concept.
- It is anticipated that Biodiversity-Friendly Settlement/City practices could bring about the following benefits:
- The concept of a Biodiversity-Friendly City (BIOFRENDLY CITY) will be discussed for the first time in this study, and its potential to become a brand value for cities in our country and globally will be debated in the scientific community and public sphere. This will be a significant step towards developing strategies.
- A research conducted solely on roadside trees (Liu & Slik, 2021) in 2021 explored the concept of a biodiversity-friendly Street trees. Therefore, the novelty of this idea or concept arises from the fact that no similar study has been conducted in our country or abroad.
- Significant contribution to understanding, creating awareness for, conserving, and enhancing urban biodiversity.
- Opportunity to analyze urban green spaces, unveil plant diversity and promote conservation and enhancement of urban green areas.
- Evaluation within a new sustainable urban green area approach, the Biodiversity-Friendly Settlement concept, in urban landscape approaches against climate change scenarios.

- Opportunity for collaboration among diverse professional disciplines (Landscape Architects, Flora and Fauna Experts, Agricultural Engineers, decision-makers, public participation, etc.).
- Contribution to urban life quality, and enhancement of visual impact.
- Promotion of sustainable use of natural resources.
- Contribution to resilient cities through the creation of a green area system sensitive to climate change scenarios. Reduction of urban irrigation and maintenance costs, mitigation of heat island effect.
- Contribution to increasing environmental awareness.
- Opportunity for enhancing city brand value.
- Efficient and economic resource utilization.
- Contribution to the economy through potential developments in plant nurseries and related sectors focused on the cultivation of native plants.
- Alignment with Sustainable Development Goals.
- Spreading successful practices to other cities within the region and the country, in collaboration with relevant ministries, decision-makers, local governments, and public participation, alongside other professional disciplines, contributing to the development of a new climate-resilient urban model in our country and worldwide in response to climate change scenarios.

In conclusion, urban population growth continues both globally and in our country, underscoring the vital importance of preserving open green spaces for the sustainability of urban ecosystems. The concept of a Biodiversity-Friendly City (BIOFRENDLY CITY) is proposed for the recognition, conservation, and enhancement of urban biodiversity. It is believed that generating public awareness about this concept could prove beneficial for the continuity of all life forms and the creation of more livable cities.

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ARCHITECTURAL SCIENCES AND URBAN AGRICULTURE II