



HORTICULTURE: SCIENTIFIC CONCEPTS AND APPLICATIONS

EDITORS
Prof. Dr. Zeliha GÖKBAYRAK
Assoc. Prof. Dr. Burçak İŞÇİ
Assoc. Prof. Dr. Nurhan KESKİN

İKSAD
Publishing House

HORTICULTURE: SCIENTIFIC CONCEPTS AND APPLICATIONS

EDITORS

Prof. Dr. Zeliha GÖKBAYRAK
Assoc. Prof. Dr. Burçak İŞÇİ
Assoc. Prof. Dr. Nurhan KESKİN

AUTHORS
Prof. Dr. Adalet MISIRLI
Prof. Dr. Hakan ENGİN
Prof. Dr. Hatice DUMANOĞLU
Prof. Dr. Köksal DEMİR
Prof. Dr. Müttalip GÜNDOĞDU
Assoc. Prof. Dr. Ayşen Melda ÇOLAK
Assoc. Prof. Dr. Çiğdem GÖZEL
Assoc. Prof. Dr. Hakan BAŞAK
Assoc. Prof. Dr. Nihal ACARSOY BİLGİN
Assist. Prof. Dr. Arda AKÇAL
Assist. Prof. Dr. Fatih Cem KUZUCU
Assist. Prof. Dr. Burcu Begüm KENANOĞLU
Assist. Prof. Dr. Canan ÖZTOKAT KUZUCU
Res. Assist. Hatice Nihan ÇİFTCİ
PhD. Fatma ALAN
PhD. Mehmet Ali GÜNDOĞDU
PhD. Suna BAŞER
PhD. Selma KURU BERK
Agri. Eng. Irmak ESKİAR
M. Sc. Koray AKEV

İKSAD
Publishing House

Institution of Economic Development and Social
Researches Publications®
(The Licence Number of Publicator: 2014/31220)
TURKEY TR: +90 342 606 06 75
USA: +1 631 685 0 853
E mail: iksadyayinevi@gmail.com
www.iksadyayinevi.com

ISBN: 978-625-8246-35-3
Cover Design: İbrahim KAYA
October/ 2022
Ankara / Türkiye
Size = 16x24 cm

CONTENTS

PREFACE

In an ever-changing world of agriculture, it is not a surprise to see the advent of new information or technologies in the field of horticulture. The more the population of the world is on the rise every year, the more the producers are under pressure to increase yield. However, producing more vegetable and fruit is a challenge as more lands suitable for farming are allocated to housing and industry, and climate change forces to move arable lands to places previously out of consideration. Horticultural food production is a field frequently changed by the consumer preferences. People now ask for not only finding whatever they want in the stores but also requiring the produce to promote their health. The outcome of these changes is to promote underutilized or new-to-the region species and creating new income sources through drying fruits and vegetables.

Delving into physiological aspects of plant growth and development has been a challenging and rewarding field in horticulture. Information gained through scientific studies and field observations has enable the knowledge to grow and urge interested people to explore more. Overcoming stress conditions has been and will be an area to compel both farmers and scientists because new physiological constraints along with reports of new pests and diseases are emerging.

Vast diversity in ornamental plants have intrigued people to utilize them to beautify their environment. In the recent years, however, it is more common to see landscaping with otherwise income-generating plants to enjoy either evergreen canopies or create a walk and harvest food-forests in the heart of the cities. In the end, horticultural plants present more ways to be used in everyday lives.

This book was intended as a reference to increase and dispense the scientific knowledge in selected subjects. We are greatly in debt to all authors in this book for their scientific efforts and professionalism.

EDITORS

CHAPTER 1

PAPAYA GROWING AND OPPORTUNITIES IN TÜRKİYE

Prof. Dr. Hakan ENGİN[1]

[1] Çanakkale Onsekiz Mart University, Department of Horticulture, Çanakkale. hakanengin@comu.edu.tr, Orcid ID: 0000-0001-6897-8708

INTRODUCTION

Papaya is one of the most important fruit species grown in tropical and subtropical regions. Papaya (*Carica papaya* L.), which belongs to Caricaceae family, has different genera: Carica, Jacaratia, Jarilla and Cylicomorpha. Papaya is dicotyledon plant that 18 of number somatic chromosome (Nakasone and Paull, 1998). Papaya, also known as in Australia (pawpaw) and in Brazil (Mamao) is the most consumed fruit in the world after banana, mango and pineapple among tropical fruit species (Ahmed and Engin, 2021). Although the origin of *C. papaya* is thought to be different in United States of America, this is estimated *C. papaya* spread from mountainous regions as far as eastern and central America, Mexico and Panama (Borokini, 2011). In the 11th century, it spread to the Caribbean islands and Southeast Asia and from there to Africa and the Pacific during the Spanish explorations (Villegas and Adelson, 2000). At the beginning of 13th century, it started to be consumed in Hawaii and became a type of fruit exported in 1948 (Fitch, 2005).

Today, papaya cultivation is carried out in about 50 different countries with tropical and subtropical climates (McGuire, 2013; Williams et al., 2013). Although papaya is a tropical fruit species, it can be grown economically in subtropical climate conditions (Allan, 2005). Considering the different regions of the world with different ecology and the ripening times of the varieties, papaya is seen in the markets for a very long time, without the need for storage in cold storage. Subtropical regions of Turkey, especially the Mediterranean Region, seem to have potential for papaya cultivation. The rapid development of papaya, its high adaptability, easy cultivation and economic return in a very short time may enable the cultivation of this fruit species to become widespread in subtopic regions of Turkey. Due to its ecological conditions, many subtropical fruit species can be grown economically in Turkey. Economically among tropical fruits in Turkey, banana is one of the leading fruit species cultivated. Papaya is a species that has the chance to be grown economically in many countries in both tropical and subtropical climates, as in banana cultivation. Papaya can be grown economically only under greenhouses or screenhouses and in some microclimatic areas of the Mediterranean region of Turkey. It is grown as a hobby in the gardens of some of our curious producers in Alanya and Gazipaşa districts of Antalya.

Plant systematics of papaya

There are several types of fruit under the name of "papaya" in the world. Although there are some differences between these species in terms of tree characteristics and fruit characteristics, they also have many similarities. Papaya has 6 different genera and about 40 species (Carvalho et al., 2014).

1; Africa, *Cylicomorpha*; 2 species,
2; Mexico, *Horovitzia*; 2 species,
3; America, *Jacaratia*; 9 species,
4; America, *Jarilla;* 4 species,
5; America, *Vasconcelea*; 20 species,
6; America, *Carica*; 1 species,

It is reported that there are about 20 species included in the genus *Vasconcelea* in the world. Most of them are located in the tropical zone of the World. Among such many different genera, the number of economically ones is quite low.

Cultural history and distribution of papaya

The cultural history of papaya goes back to 1700 years ago. It is understood that beautiful cultivars existed in ancient Mexico and America. Spaniards introduced these papaya varieties to the World. It is estimated that the origin of papaya is America, Mexico and Panama (Borokini, 2011). It spread from there to the Caribbean islands, Southeast Asia, Africa and the Pacific (Heywood et al., 2007). It was started to be consumed in Hawaii by the Spanish explorer Don Francisco Marin at the beginning of the 18th century and became an exported plant in 1948 (Fitch, 2005). Today, papaya is produced in more than 54 countries with tropical and subtropical climates (McGuire, 2013; Williams et al., 2013). The origin and distribution of papaya is shown in Fig. 1.

Fig. 1. Origin and distribution of papaya (www.authorstream.com, 2019).

Usages and nutritional facts of papaya

It is reported that the nutritional value of papaya fruit is very high and it ranks first among thirty five commonly consumed fruits according to the recommended daily intake for antioxidant vitamins such as ascorbic acid, beta carotene and alpha tocopherol and B1, B11, B3, fiber, calcium, potassium and iron (Chandrika et al., 2003; Ming et al., 2008). Papaya fruits are usually consumed fresh (ripe papayas) and beverages (papaya juice and nectar). But it is also used in unripe papaya. Green papaya is frequently boiled and served as a vegetable. In the East Indies, young leave of papaya is cooked and eaten like spinach. Papaya seed is sometimes used as a spice, like black pepper in India.

It produces a proteolytic enzyme called papain (EC: 3.4.22.2), which is widely used in food processing for gum production and milk coagulation in the food industry. Papain can also be used in a wide variety of medicinal applications, such as aiding digestion, reducing swelling, treating fevers and ulcers. It is also used in the production of soap, shampoo, lotion, skin care products and toothpastes in the chemical and pharmaceutical industries (Aravind et al., 2013). Food value per100 g of edible portion of papaya is shown in table 1.

Table 1. Food value of ripe papaya (per100 g of edible portion)

Fruit composition	Nutritional values
Calories	23.1 - 25.8 kcal
Moisture	85.8 - 92.6 g
Protein	0.08 - 0.34 g
Fat	0.05 -0.96 g
Carbohydrates	6.16 - 6.74 g
Fiber	0.5 - 1.3 g
Ash	0.31 - 0.66 g
Ca	12.9 - 40.8 mg
P	5.3 - 22.1 mg
Fe	0.24 - 0.77 mg
Vitamin A	0.004 - 0.675 mg
B1	0.02 - 0.03 mg
Riboflavin	0.024 - 0.58 mg
B3	0.22 - 0.55 mg
C	35.5 - 71.3 mg
Tryptophan	4 – 5 mg
Methionine	1 mg
Lysine	15 – 16 mg

Papaya production and trade

Global papaya production is estimated at 13.7 million tons. In terms of production amount, India ranked first. In other words, about half of the world's papaya production was obtained from this country. The Dominican Republic, Brazil, Mexico, Indonesia and Nigeria are the major papaya producing countries. Papaya growing countries and productions are shown in Table 2. World papaya export was 150,093 tons. Mexico was the top exporter with 86,016 tons and followed by Brazil. Major papaya importer markets are European countries (Ahmed and Engin, 2021).

Table 2. Papaya growing countries and productions (ton)

Countries	Production
India	6.050.000
Dominican Republic	1.171.336
Brazil	1.161.808
Mexican	703.800
Indonesia	695.214
Nigeria	616.215
Democratic Republic of Congo	212.170
Venezuelan	199.853
Cuba	184.342
Peru	171.667

Botanical description of papaya

Habitus: Papaya produces tall (8-10 m) and vertically growing trees. The plant has a single stem and is a perennial. They form an upright, smooth stem and its stem is soft-wood (Fig. 2).

Fig. 2. Habitus of papaya

Root: Papaya has a superficial root structure. The root system develops transversely in the upper layer of the soil. Roots tends to form many small, lateral and thin roots near the soil surface.

Leaves: They are star-shaped, broadly sliced and toothed on the edges, directly attached to the stem with the petiole and the life of the leaves is 4-6 months (Morton, 1987). Both the leaves and the stem contain plenty of latex.

Buds: Buds form as apical and lateral. Lateral buds occur in the leaf axils. Leaves or flowers may form these.

Flowers: Papaya flowers are formed from the axils of papaya leaves. The flowers are tubular or trumpet-shaped flowers. The length of the flowers varies in the range of 2 - 5 cm. The flowers, which have a waxy and sweet perfume structure, form a color between a pale ivory and golden yellow. The papaya flower is the most complex part of a papaya tree. Papaya Flowers are not characterized by their shape and appearance. It is also characterized by the presence of flower stamens, pistils and ovaries. Three different types flowers (male, female and bisexual) occur according to sex status. Male flowers only produce pollen (Fig. 3a). The female flowers (Fig. 3b) form small inedible fruits when pollination does not occur. Bisexual flowers (Fig. 3c) have both stamens and pistils.

Fig. 3. Different types of flowers seen in papaya cultivars. a) male flowers, b) female flowers, c) bisexual flowers.

The female papaya flower contains a reproductive organ (pistil). The pistil has a five-lobed stigma and an egg-shaped ovary. The ovary is absent in the male papaya flower. The male papaya flower has 10 functional stamens that contain pollen grains. Bisexual flowers contain both male and female parts and are capable of self-pollination. Also called 'perfect flowers', develop from 5 to 10 stamens and contain ovaries that range in shape from smooth and bulbous to oblong, taut or irregular folds and ridges.

Fruit: Papaya fruit is an oval or pear-shaped fruit measuring 10 to 20 cm in size and usually weighing 500 to 1,000 g, but weighing up to 5 kg. It is a berry of thin skin, of orange colour and green yellowish. The pulp is of yellow or red orange colour, sweet and very juicy. There are three different types of papaya, Hawaiian (Fig. 4a), Mexican (Fig. 4b) and Malaysian (Fig. 4c).

Fig. 4. Types of papaya fruits. a) Hawaiian, b) Mexican), c) Malaysian.

Some important papaya varieties

The main papaya varieties come from Mexico and Hawaii. Most of the popular papaya varieties available in supermarkets are grown in Hawaii. Other varieties are cultivated in Mexico, Malaysia and tropical countries. The most commonly grown papaya varieties and some of their characteristics are reported below.

‘Tainung’: This papaya variety is also known as Formosa papaya. It is a hybrid of the Sunrise papaya. It weighs about 3-4 pounds when mature. Tainung is pink or light red, with sweet flesh and an elongated shape (Fig. 5a).

‘Sunrise’: Known as strawberry papaya, the red-orange flesh is similar to strawberries, melons, and peaches. The seed cavity is quite shallow, making it easy to remove seeds (Fig. 5b). This variety is available in grocery stores all year round.

‘Royal Star’: It is a hybrid of Mexican red. The papaya features deep orange skin with sweet and juicy pulp (Fig. 5c).

‘Sunset’: It is a dwarf papaya variety originating from Hawaii (University of Hawaii). Sunset papaya has an orange-red skin and flesh. The fruits have a smaller size than sunrise. It has a longer shelf life with a uniform color and shape (Fig. 5d).

‘Gold’: This papaya variety is native to Western Australia. It produces pear-shaped fruits with golden yellow peel and flesh (Fig. 5e). Fruit weight is more than 2-3 kilograms and matures in 14-17 months.

‘Golden’: This papaya variety is native to South Africa. The bright yellow skin looks beautiful and produces heavy fruits weighing up to 3-4 kilograms each with yellow flesh (Fig. 5f)

‘Oak Leaved’: This variety is native to Western South America (Andes Mountains). The fruits of ‘Oak Leaved’ papaya form 5-10 cm long, oval-shaped small fruit (Fig 5g). The seeds of this cultivar are edible along with orange-colored sweet pulpy flesh.

‘Waimanalo’: This cultivar is grown in Oahu. It is a dwarf variety and has a high vitamin C content. ‘Waimanalo’ cultivar is a fast-growing which produces fruits in 9-10 months (Fig. 5h).

‘Samba’: ‘Samba’ is the newest variety of papaya introduced to the markets in 2018. Fruit grows in yellow-green spotted skin with an oval shape (Fig. 5ı). The pulp is dark orange and slightly sweet in taste.

Fig. 5. The most commonly grown papaya varieties. a) Tainung, b) Sunrise, c) Royal Star, d) Sunset, e) Gold, f) Golden, g) Oak Leaved, h) Waimanalo, ı) Samba.

The number of papaya varieties that can adapt to subtropical climatic conditions is quite limited. The most commonly grown papaya varieties that can adapt to subtropical climatic conditions and some of their characteristics are listed below (Villiers, 1999).

'Solo': Hermaphrodite and female plants produces. Fruit peel is smooth, orange and reddish-orange color, hard flesh, very sweet and of excellent quality is diverse. Fruit weight between 0.6-1.2 kg. In female trees, fruits are round, on hermaphrodite trees while it is pear-shaped (Fig. 6a) (Villiers, 1999).

Sunrise Solo': Fruits are pear-shaped, average fruit weight 400 g, sugar content quite high and the fruit flesh is a hard variety (Fig. 6b).

'Red Lady': Fruits are starting at an average of 1.5-2 kg and a sweet, round-oval (Fig. 6c). Although 'Red Lady' is a susceptible variety to fungal diseases, it is resistant to papaya ring spot virus disease (Villiers, 1999).

Fig. 6. The most commonly grown papaya varieties that can adapt to subtropical climatic conditions. a) Solo, b) Sunrise Solo, c) Red Lady

Fertilization biology of papaya

In papaya trees, sex changes according to the biological structure of the flowers. According to the characteristics of the flowers, different gender situations arise. Hermaphrodite flowers (bisexual), female and male flowers are on separate trees (trioecism). In other words, there are three different groups of plants that differ in terms of sex: hermaphrodite flowering plants, male plants and female plants (trioecious). Flowers that are functional male are dropped after full bloom. The excess of male flowers causes loss of yield. Fruit can only be obtained from female and bisexual flowers. Except for male, sex appears to be dependent on pistil development in papaya flowers. It is necessary to investigate and reveal some characteristics of the flowers (sex status of the flowers, periods of flowering, structures and positions of the flowers) of different papaya varieties.

Male papaya trees, which bear many flowers in a branched form and have one anther in each flower, but lack female stamens are unproductive (Fig. 7a). Since the male organs of the flowers in male papaya trees are functional, they provide pollination. Pollen produced in sticky clumps is carried to female flowers by insects (Chan, 1995).

Female papaya trees bear female flowers, each with a fully developed pistil, on short stems (Fig. 7b). The flowers on the female trees develop after pollination and fertilization to form the papaya fruit.

Hermaphrodite papaya trees are rare (Fig. 7c, d). In order to get a good yield in today's cultivation, papaya trees with bisexual flowers are replacing male and female trees. Most hermaphrodite papaya trees have functional male and female organs. Even if the flower does not open, the anthers open and the pollen is dispersed on the stigma and fruit set occurs (Ahmed and Engin, 2021). In 'Somalia Papaya', male and female flowers are on separate trees (dioecious). Although male flowers occur on male trees of the 'Somali Papaya', small fruits of no economic value are formed with the development of the ovary, which is rarely found in the male flower (Ahmed and Engin, 2021).

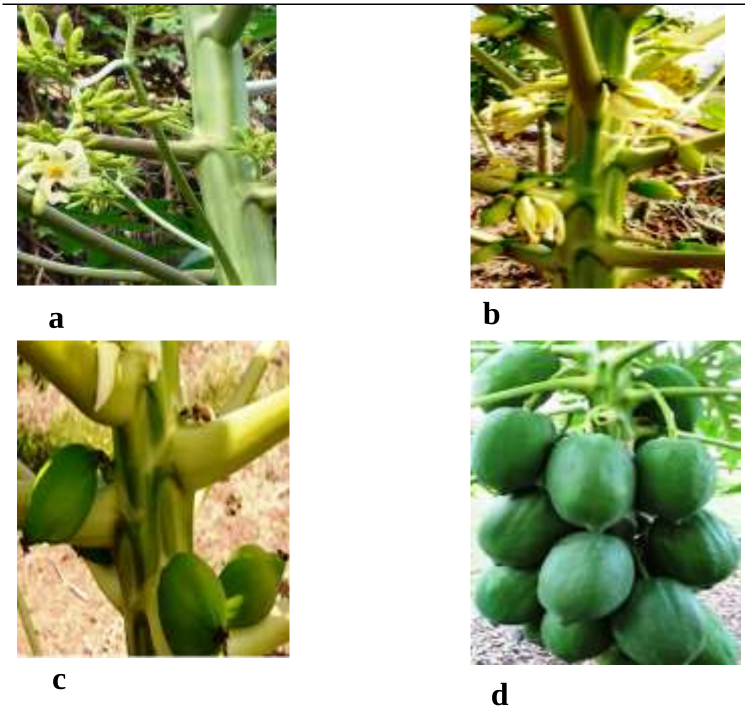


Fig. 7. Male, female and hermaphrodite papaya trees. a) male trees of the ‘Somalia Papaya', b) female trees of the ' Somalia Papaya', c) hermaphrodite papaya trees, d) 'Exotica II' papaya trees (bisexual).

It first came to the attention of researchers at the Hawaii Research Center that 'Solo' papaya trees have bisexual flowers. Fruits are round on 'solo' female papaya trees, and pear-shaped on bisexual trees (Villiers, 1999). The bisexual papaya fruit, developed through breeding in Hawaii, is called "Solo". Later, bisexual 'Solo' became the standard papaya variety, followed by bisexual papaya 'Exotika' and 'Exotika II' varieties today.

Climate and local conditions of papaya

Although papaya is a tropical climate plant, it can also be grown economically in the subtropical climate conditions (Allan and Carlson, 2007). Economically, its cultivation is located 32^0 north and 32^0 south of the equator and it is limited to the regions between 32^0 north and south (Morton, 1987). Temperature and humidity are among the most important factors in papaya cultivation. Papaya needs high temperatured. The optimal temperature for growing papaya ranges from 21^{o}C to 33^{o}C. In papaya cultivation, if the temperature drops below 14 ^{o}C, the growth and development of the fruits are delayed. If the temperature drops below -0.5 ºC, it causes cold damage and death in papaya plants (Morton, 1987). It is important for the monthly precipitation is over 100 mm and the relative humidity is over 65% during the development period (Storey, 1941; Storey, 1969).

Propagation of papaya

Papaya is usually propagated by seed. Papaya seeds taken from mature fruits are washed until the gel-like substance is removed and then dried in a shaded place (Villegas, 1997). Papaya seeds are sown and germinated in viols containing peat (Fig. 8).

Fig. 8. Papaya seeds, sowing and germination.

It is stated that the germination rate of seeds of different papaya (*Carica* papaya L.) varieties varies between 3% and 70% in vivo and between 70% and 74% in vitro (Bhattacharya and Khuspe, 2001). In vivo, papaya seeds sown in viols containing maxpeat peat germinate in about 2 weeks. Before planting papaya seeds, keeping them in water, hot water, sulfuric acid, alcohol, gibberellic acid (GA), ethylene, cytokinin, potassium nitrate (KNO) and vitamin increases the germination percentage (Villegas, 1997). In addition to seed propagation, papaya can also be propagated by cuttings. For this purpose, cuttings with 3-4 small leaves and a pencil thickness taken in the middle of summer can be rooted in a short time in a bottom-heated (temperature adjusted to 30 ºC) sprinkling environment (Allan, 2005).

Planting of papaya

One of the most important steps in establishing and growing a vigorous and productive papaya orchard is to plant a papaya tree properly. Papaya seedlings reaching approximately 50 cm (Fig. 9a) are grown by planting in the garden at 3x3 meters (Fig. 9b). It is of great importance to determine the ratio of male and female trees in order to obtain yield. The sexes of the trees are determined when the first flowers appear. It is necessary to plant two or three plants in each hole to ensure the ratio of male and female trees. After pollination is completed, 75% of unproductive male trees are cut and removed from the garden (Fig. 9c).

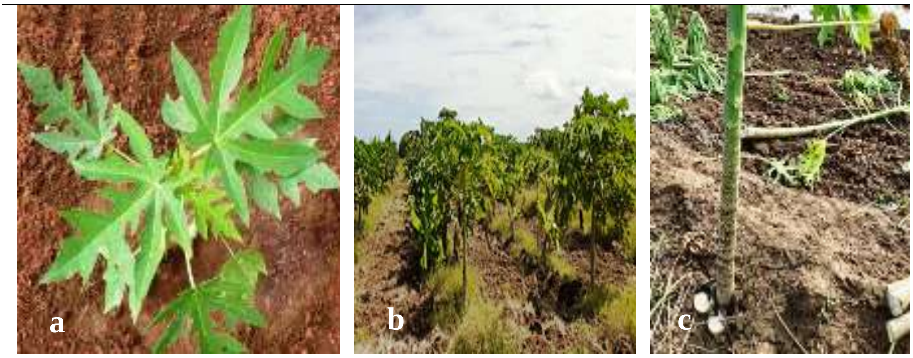


Fig. 9. Papaya seedlings about 50 cm (a), papaya trees grown in 3x3 m spacing (b), cutting male papaya trees (c).

Papaya is usually planted in the field in March-April, and the first fruits are harvested in November-December (Villiers, 1999). If the papaya is planted in the field in the beginning or mid-summer, the growth period will not coincide with the winter months. Therefore, the fruits can only be harvested 10-12 months after planting. In addition, late planting, it causes sun burns on the fruits and also decreases the sugar content of fruits. Therefore, in subtropical climatic conditions, it is recommended that papaya be planted in March and April (Morton, 1987).

Irrigation of papaya

Papaya cultivations require regular irrigations during its growth, fruit development period and high yield. The soil should be kept constantly moist, but excessive irrigation should also be avoided (Malo and Campbell, 1986). In general, irrigation to grown-up papaya plants is given once in one week in winter and 3-6 days in summer. Water stress inhibits the growth and also promotes male floral characters. Insufficient irrigation during the flowering period causes flower drop (Kumar and Kumar, 2016; Malo and Campbell, 1986). Sprinkler and drip irrigation are the most commonly used irrigation systems in papaya (Villiers, 1999) (Fig. 10).

Fig. 10. İrrigation systems in papaya

Fertilization of papaya

Quality yield from fast growing papaya depends on fertilizer application according to development periods (Villegas, 1997). Papaya should be fertilized once every two months. Although which fertilizer and how much to use in a particular area depends on soil and leaf analysis results and the developmental periods of the plant, 70-80 g urea, 200-300 g superphosphate and 13-150 g muriate of potash are generally recommended for each tree. In addition, it is recommended to apply farm manure to improve the physical structure of the soil and increase its water holding capacity before planting (Allan and Carlson, 2007).

Pruning of papaya

In papaya cultivation, pruning is not applied as in other fruit species. One of the reasons pruning is not practiced is the main growth points are terminal. The second of the reasons why pruning is not practiced may not produce branched trees either. During the development period, only dried and aged leaves are cut and removed (Mulyoutami et al., 2009).

Pests and diseases of papaya

Papaya is susceptible to diseases especially bacterial canker, leaf spot, black rot, internal yellowing, alternaria fruit spot and phytophthora fruit rot (Tennant et al., 2001). Some of the papaya insects are the papaya fruit fly, red spider mites, papaya webworm, thrips and papaya whitefly.

Harvesting of papaya

Papaya is a climacteric fruit. Therefore, the fruits reach maturity after harvest. Therefore, early harvesting causes deterioration of fruit quality characteristics. Fruit flesh firmness, dry matter content and fruit skin color are the most important criteria in determining the harvest time (Carvalho et al., 2014). In papaya harvesting, fruit may be picked when yellow colour covers 1/2 to 3/4 of the surface peel (Fig. 11a). Fruits are harvested manually depending on the size of the tree. When harvesting larger trees, platforms, ladders or rigged to tractors are used to lift workers (Fig. 11b). During harvesting, sharp knives are used to trim the stem close to the base of the fruit. Tools are used to collect fruit when trees are much taller (Fig. 11c). It is preferable to harvest the papaya fruit late in the morning until early afternoon.

a b c

Fig. 11. Harvesting in papaya trees. a) ripe fruits of papaya, b) tractors used to lift workers, c) tall papaya tree.

Post harvest and packaging of papaya

The post-harvest processing of papaya fruit is to prepare the fruit for the market and at the same time maintain the quality of the fruit so that it can be offered to the market as demanded. It is also important in postharvest diseases of papaya (Alvarez and Nishijima, 1987). Purposes of post-harvest technology applications; maintaining quality in appearance, taste, texture and nutritional value, ensuring food safety and also reducing losses along the supply chain between harvest and consumption. There is one type of packaging commonly used for papaya fruits. For export markets, the fruits are wrapped in white polyurethane sheaths that act as cushioning material that prevents the fruits from bruising during transport.

Researches and projections of papaya

The papaya industry faces three major problems. The first major problem is papaya ringspot virus (PRSV) that is a disease that greatly reduces fruit yield, fruit size and quality, and in some cases causes total loss of production. PRSV (Papaya Ringspot Virus) carried by aphid has destroyed all papaya plants in many countries. PRSV has severely restricted the worldwide expansion of papaya production. Development of genetically modified varieties of papayas able to resist Papaya Ringspot Virus (PRSV) such as SunUp and Rainbow is important. The second major problem is post-harvest losses along the marketing chain (Evans and Ballen, 2015). Post-harvest losses in papaya can be caused by a variety of factors, including mishandling of the fruit, improper harvesting, improper storage and packaging, transportation and post-harvest diseases. Proper post-harvest management of papaya will reduce post-harvest losses, which will provide the best returns to farmers and agro-industries as well as food security. Third major problem is sex type identification. Because the sex of the papaya plant cannot be predicted morphologically at early seedling stages, the study of sex type identification is valuable in papaya. Among the three sex, hermaphrodite plants are grown for their pyriform shaped fruit, which is preferred for consumption, and female plants are important for commercial papaya production, while male plants are undesirable (Urasaki et al., 2002). Papaya seeds produce seedlings that cannot be sexed, so farmers have to remove male trees from the orchard and leave female and hermaphrodite trees on flower morphology that can be achieved only 90 to 120 days after germination. If sex estimation of papaya could be made at early seedling, the expected ratio of male to female trees by removing male trees could be maintained. This will save resources such as water, fertilizers or land needed for planting wasted on unwanted male trees. Some researchers have tried to predict papaya sex at the seedling stage using morphological features, but success has begun to be achieved with advances in molecular tools and techniques. Sex determination techniques will also be important in future studies on papaya.

It has been perceived by consumers that papaya fruits produced in subtropical regions such as the Mediterranean regions are not of the desired quality at certain times of the year. Therefore, the development of technical and management strategies to optimize yield and quality of fruit requires studies of crop phenology. 'Sunrise Solo', 'Red Lady' and 'Tainung' papaya cultivars were used in a study examining the phenological properties and yields of different papaya cultivars under subtropical conditions. It has been shown that 'Red Lady' papaya cultivar is more advantageous than other cultivars in terms of plant height, first flowering date, first flowering height, time from flowering to harvest and yield values and 'Red Lady' papaya cultivar is recommended for cultivation under greenhouse (Güneş and Gübbük 2009). Tulasigeri et al., (2017) conducted a study to determine the growth performances of 6 different papaya cultivars in the North region of Karnataka, India. As a result of the study, Amrita cultivar has the highest plant height (146 cm), number of leaves (29), number of flowers (172), average number of flowers per plant (103) and average number of fruits per plant (26) was recorded. The highest plant width (41 cm), early flowering (72.6 days), early fruit formation (79.7 days), early fruit harvest (134.5 days) and minimum sowing time (214.3 days) were recorded in Red Lady variety. Fruit set was determined most in Vinayaka (36) genotype. Among the six cultivars, Amrita and Coorg Honey Dew were superior to other cultivars. Named "Fruit yield and growth parameters of several Carica papaya cultivars in temperate climate", in the growth and productivity parameters of early hybrid papaya cultivars and standard papaya cultivars under both greenhouse and field conditions in the Santa Fe region of Argentina, which has a temperate climate considered the changes. Eight early hybrid papaya cultivars H1, H2, H3, H4, H5, H7, H8 and H9, described by alpha-numeric code, and the cultivar of the region were used. They conducted the experiment in two different environments, field and greenhouse. In the light of the above information, the aim of the research is to identify other genotypes that are more suitable for the cultivation of this species in temperate climates and to demonstrate the need for the use of semi-controlled systems to enable the cultivation of these promising genotypes in latitudes. It was found that the average yield in the greenhouse was 291% higher than in the field. Hybrid papaya cultivars used in the experiment more than doubled in both media when compared to Standard papaya cultivars. Considering the behavior in height, leaf area index and yield parameters, hybrids H2 (mainly) and H4 showed great adaptation for use in semi-forced systems. Greenhouse and short stature hybrid papaya will allow growing papaya in non-tropical climates and certainly a profitable cultivation.

Papaya cultivation in Turkey can be an economic opportunity due to its proximity to the European market and diversification of agricultural production. Meteorological variables such as relative humidity, air temperature, photosynthetically active radiation and morphological characteristics of papaya must be known throughout the crop cycle. In subtropical areas of Turkey, papaya must be grown within environmental modification structures such as greenhouses or screenhouses to adjust meteorological conditions to crop requirements to achieve optimum fruit production and quality. Papaya variety and cultural techniques for its production are also important considerations.

REFERENCES

Ahmed, H.E. and Engin, H. 2021. Phenological characteristics and yields of Eksotika-2 and Somali local papaya cultivars under Somali conditions. Usbık 2021 Onlıne Internatıonal Congress On Natural Scınencess E-Book 26-28 Feb.

Allan, P. 2005. Phenology and production of Carica papaya 'Honey Gold' under cool subtropical conditions. I International Symposium on Papaya 740 (pp. 217-223).

Allan, P. and Carlson, C. 2007. Progress and problems in rooting clonal Carica papaya cuttings. South African Journal of Plant and Soil, 24(1), 22-25.

Alvarez, A.M. and W.T. Nishijima. 1987. Postharvest diseases of papaya. Plant Dis. 71:681-686.

Aravind G., Bhowmik D., Duraivel S., Harish G., 2013. Traditional and medicinal uses of carica papaya, Journal of Medicinal Plants Studies, 1:7-15.

Bhattacharya, J. and Khuspe, S., 2001. In vitro and in vivo germination of papaya (Carica papaya L.) seeds. Scientia Horticulturae 91, 39-49.

Borokini, T. I. 2011. Ethnomedicinal significance, mineral composition and phytochemical constituents of carica papaya in Oyo State, Nigeria. International Journal of Current Research, Vol. 4, Issue, 03, pp. 043-048.

Carvalho, C. P., Velasquez, M. A., Rooyen, Z. 2014. Determination of the minimum dry matter index for the optimum harvest of 'Hass' fruits in Colombia. Agronomía Colombiana, *32*(3), 399-406.

Chan, Y. K. 1995. Development of F1 hybrids of papaya (*Carica papaya* L.) seed production and performance of F1 hybrids. Chan Ying Kwok (Doctoral dissertation, University of Malaya).

Chandrika U.G., Jansz E.R., Wickramasinghe S.M.D.N.,Warnasuriya N.D., 2003, Carotenoids in yellow- and red-fleshed papaya (*Carica papaya* L), J Sci Food Agric, 83:1279-1282.

Evans, E. A. and Ballen, F. H. 2015. Eight steps to developing A simple marketing plan1. FE967, UF/IFAS Extension, University of Florida.

Fitch, M. M. 2005. Carica Papaya. General Editor. Gabrielle J. Persley, The Doyle Foundation, Glasgow, Scotland., 174.

Güneş, E. and Gübbük, H. 2009. Performances of phenological properties and yield quantities of different papaya cultivars under ubtropical conditions. Akdeniz University Journal of the Faculty of Agriculture. 22(1), 121–128.

Heywood, VH; Brummitt, RK; Culham, A; Seberg, O 2007. Flowering plant families of the world. Firefly Books. ISBN 9781554072064.

Kumar, R. and Kumar, V. 2016. Physiological disorders in perennial woody tropical and subtropical fruit crops-A review.

Malo S.E and Campbell C.W 1986. The papaya. University of Florida, Cooperative Extension Service Fruits Crops Fact Sheet FC-11. Gainesville.

McGuire, S. 2013. World food programme, and international fund for agricultural development. The state of food insecurity in the world. Economic growth is necessary but not sufficient to accelerate reduction of hunger and malnutrition. Rome, FAO. *Advances in Nutrition*, *4*(1), 126-127.

Ming R., Hou S., Feng Y., Yu Q., Dionne-Laporte A., Saw J.H., Wang W., Ly BV., Lewis K.L., 2008, The draft genome of the transgenic tropical fruit tree papaya *(Carica papaya* Linnaeus), Nature, 452(7190):991-996.

Morton, J. F. 1987. Fruits of warm climates. JF Morton.

Mulyoutami, E., Rismawan, R., Joshi, L. 2009. Local knowledge and management of simpukng (forest gardens) among the dayak people in East Kalimantan, Indonesia. Forest Ecology and Management, 257(10), 2054-2061.

Nakasone, H. Y. and Paull, R. E. 1998. Tropical Fruits. Oxon: CAB International.

Storey, W.B. 1941. The botany and sex relationships of the papaya. Haw. Agric. Expt. Sta. Bull. No.87. P arti, p.1-22.

Storey, W.B. 1969. Papaya (*Carica papaya*) F.P. Outlines of perennial crop breeding in the tropics. Ferwerda and F. Wit (eds.). Wageningen Netherlands. p. 389-407.

Tennant, P., Fermin, G., Fitch, M. M., Manshardt, R. M., Slightom, J. L., Gonsalves, D. 2001. Papaya ringspot virus resistance of transgenic Rainbow and SunUp is affected by gene dosage, plant development, and coat protein homology. *European Journal of Plant Pathology*, *107*(6), 645-653.

Urasaki N., Tokumoto M., BanY., Kayano T., Tanaka H., Oku H., Chinen I., and Terauchi R., 2002, A male and hermaphrodite specific RAPD marker for papaya (*Carica papaya* L.), Tag.theoretical and Applied Genetics, 104(2):281-285.

Villegas V.N 1997. Carica papaya L. In: EWM Verheij, RE Coronel, eds. Plant resources of Southeast Asia 2: Edible fruits and nuts. PROSEA Foundation, Bogor, Indonesia.

Villegas, M. F., and Adelson, N. 2000. Civil Society Participation in World Bank and Inter-American Development Bank Programs: The Case of Mexico. *Global Governance*, *6*, 473.

Villiers, E. A. 1999. The Cultivation of Papaya Book. Institute for tropical and subtropical crops, ISBN 0-0620-23282- X, 98 p.

Williams, D., Pun, S., Chaliha, M., Scheelings, P., Hare, T. 2013. An unusual combination in papaya (*Carica papaya*). The good (glucosinolates) and the bad (cyanogenic glycosides). Journal of Food Composition and Analysis, 29(1), 82-86.

CHAPTER 2

BERBERIS SPECIES (BERBERIDACEAE)

Assoc. Prof. Dr. Ayşen Melda ÇOLAK[1]
PhD. Fatma ALAN[2]

[1]Usak University, Faculty of Agriculture Science, Department of Horticulture, Uşak, Türkiye aysenmelda.colak@usak.edu.tr, ORCID ID: 0000-0003-0113-2104
[2]Erciyes University, Faculty of Agriculture Science, Department of Horticulture, Kayseri, Türkiye fatmaalan1979@gmail.com, ORCID ID: 0000-0001-5266-6339

INTRODUCTION

Today, the increasing world population, the decimation of available resources, and the understanding of the positive relationship between health and nutrition lead people to search for new food sources. Therefore, in recent years, wild fruit cultivation has been gaining importance in many regions of the world. These wild fruits, which have a high nutritional value, are also suitable materials in the food processing industry. In addition, they can grow very comfortably in unproductive soils and under adverse environmental conditions (Darrow, 1975; Smatana, Kytka and Kadarova, 1988; Kuhnlein, 1989).

Located between the Asian and European continents and at the intersection of three different phytogeographic regions, our country has a decently rich plant diversity in terms of edible wild plants that grow naturally due to its geopolitical location, different climate types, and soil characteristics (Güner, 2012).

Its scientific name is *Berberis crataegina* DC. and in different regions of Anatolia, *Berberis sp*. L., thorn grape year's Bush, amberparis, known by different names such as bunny bread (Baytop, 1999) wild species that grow naturally in fruit, class magnoliopsida, Ranunculales team, entering the family berberidaceae *Berberis* genus of over 200 species and 12 genera and *Berberis sp*. although it is known that this species is more temperate climate regions of the northern hemisphere, Asia, Europe, North Africa, and perennial herbaceous or shrub distributed in the form it is known that in America. *Berberis vulgaris, Berberis integerrima*, *Berberis cretica* and *Berberis rataegina* DC. can be represented by 4 species in the flora of Türkiye. *Berberis crataegina* DC. the species grows naturally in the provinces of Izmir, Kırklareli, Ankara, Kastamonu, Çankırı, Kayseri, Konya, Niğde, and Sivas in Türkiye (Yaltırık and Efe, 1989; Say, 2021; Davis, 1965).

It is a plant that can grow up to about 2 meters, sheds its leaves in winter, its flowers are yellow in color (Figure 1), in large numbers and in the form of a panicle-shaped perennial prickly shrub (Figure 2) (Gülsoy et al., 2011).

B.crataegina DC. which is found in groups between arid and rocky slopes and thickets (Anşin and Özkan, 1993) it grows at altitudes of 800-1500 m (Arslanoğlu and Ayna, 2019). The leaves of the species are larger than the thorns, the leaf edges are coarsely toothed, their length Decays between 1-4 cm (Kayacık, 1981). There are no black lenticels on shiny dark brown young shoots

(Davis, 1965). June-May decurrent flowers in the form of panicles and consist of a combination of 6 to 15 flowers. The fruits, which are the size of a grain of rice, are red at first and blue-black in color when they ripen (Davis, 1982). The elliptical, fleshy grape-like fruit structure of the *berberis* tastes slightly sour and contains one or more seeds (Baytop, 1999). September October in the autumn, the fruit is collected according to the maturity status. The juice obtained by squeezing *berberis* fruits contains tannins and organic acids (citric, malic, lactic, tartaric acids), which significantly affect the flavor balance, chemical stability, and pH of the fruit, hence the quality of the fruit. It also carries vitamin C and a high percentage of anthocyanins. Thanks to the anthocyanins contained in the *berberis sp*. plant, fresh or dried roots or bark are used as a coloring agent. Fruit juice obtained by squeezing from fresh caramel can be drunk, as well as fruits, are evaluated as jam, marmalade or tea (Eroğlu et al., 2020).

Figure 1. *Berberis* flower form (Anonymous, 2022a)

Figure 2. *Berberis* fruit (Anonymous, 2022b)

The *Berberis sp*. L. nutritional content

Berberis is quite rich in macro and micro nutrients (Table 1, Table 2, Table 3). The component values are for 100 g of edible food.

Table 1. The *Berberis crataegina* DC. nutritional content (Anonymous 2022c)

Component	Unit	Average	Minimum	Maksimun
Energy	kcal	259	259	259
Energy	kJ	1083	1083	1083
Water	g	14,12	14,12	14,12
Ash	g	3,66	3,66	3,66
Protein	g	1,68	1,68	1,68
Nitrogen	g	0,27	0,27	0,27
Oil total	g	3,42	3,42	3,42
Carbohydrate	g	33,52	33,52	33,52
Fiber, total diet	g	43,60	43,60	43,60
Iron, Fe	mg	11,83	11,83	11,83
Phosphorus, P	mg	184	184	184
Calcium, Ca	mg	479	479	479
Magnesium, Mg	mg	113	113	113
Potassium, K	mg	754	754	754
Sodium, Na	mg	4	4	4
Zinc, Zn	mg	1,78	1,78	1,78
Riboflavin	mg	0,076	0,076	0,076
Niacin	mg	0,443	0,443	0,443

Table 2. Phenolic compounds in the leaves and fruits of *B. crataegina* DC (Gülsoy, Özkan and Özkan, 2011)

Phenolic compounds		Leaf (µ/g)	Fruit (µ/g)
Phenolic acids	Klorojenik acid	0,00±0,00	70,24±1,54
	p-Kumarik acid	0,00±0,00	1,10±0,01
Flavanonlar	Eriodictiol	0,15±0,00	0,00±0,00
Flavonlar	Apigenin7-0-glukozid	0,00±0,00	20,08±3,71
	Luteolin	0,24±0,02	0,00±0,00
	Vitexin	0,29±0,02	0,00±0,00
Flavanoller	(-) Epikateşin	0,00±0,00	1,60± 0,00
	(+) Kateşin	0,00±0,00	8,41±0,08
Flavonol	Rutin	170,87±2,99	27,09±0,97

Table 3. Organic acid concentrations in the leaves and fruits of *B. crataegina* DC (Gülsoy et al., 2011)

Organic acids	Leaf (µg/g dried sample)	Fruit (µg/g dried sample)
Malik acid	4338,00±8,00	96,00±6,00
Sitrik acid	155,00±5,00	15,00±2,00

Üçer (2011), determined that the substances contained in the roots of the *Berberis* plant are effective against oriental boils, prevent the development of bacteria, and have an antipyretic effect. Özkal and Ertürk (1996) *B. crataegina* DC. found that berberine alkaloids and extracts obtained from the plant have strong antifungal activity. Toroğlu and Çenet (2006) stated in their study that the *berberis* plant is used in the treatment of colds and diabetes such as bronchitis. In traditional use, *Berberis crataegina* D.C. is observed that it is used in the treatment of infertility, yeast, eye, skin, mouth, rheumatism, headache, respiratory, circulatory, and gynecological diseases (Tuzlacı, 2016).

Fresh roots of Denizli, Tunceli, Kahramanmaraş, Muğla, Malatya, Kayseri, Karaman, Erzincan; fruits of Iğdır, Sivas, Kayseri, Tunceli; leaves of Kayseri and flowers are also used in the treatment of diabetes in Karaman regions. In different parts of the country against hemorrhoids, blood pressure lowering, blood, stomach ailments, intestinal disorders, diarrhea, gallstones, constipation, jaundice, treatment of the common cold fruit; against hemorrhoids, bronchitis, colds, in the treatment of jaundice, roots; diarrhea, stomach, intestine, to treat wounds and cuts branches; leaves sputum and blood pressure lowering; jaundice has been reported to be against the use of flowers and hemorrhoids (Tuzlacı, 2016).

Berberis crataegina DC. in order to determine the physicochemical properties of fruit in a study conducted in different regions of Türkiye, (Say, 2021) the substance of the samples, the amount of total phenolic 80,76-110,92 mg GAE/g, Total flavonoid 77,71 the amount of the substance-KE 120,35 mg/g, the amount of condensed tannin 50,50 - KE 62,14 mg/g and the amount of total anthocyanin 2,75-3,21 mg/g has been determined in the range of. It has been thought that *berberis* fruit contains high levels of phenolic and anthocyanin components and has a strong antioxidant structure, and with these properties, it can be a potential functional food in the treatment and prevention of diseases.

Sarı (2016), in a study of *Berberis crataegina* DC. in order to increase the stability of the anthocyanins possessed by, he used some phenolic acids (ferrulic, tannic, gallic acids), which have different pigments. Depending on the applied phenolic acids and molar concentrations, anthocyanin degradation in pigmented samples was lower than in non-pigmented samples, and it was also found that the increase in pigment numbers gave different results for each phenolic component.

In his study, Eroğlu (2019) investigated some important physicochemical properties, antioxidant capacities, phenolic substance profiles, and antimicrobial activities of naturally occurring *berberis* fruit in the districts and villages of Bayburt. As a result of the physicochemical analyzes carried out in his study, he determined the amount of dry matter December 28,47-41,61%, SSKM 18,10%- 27,75%, ash amount 0,65%-2,13%, water activity value 0,931-0,947, pH 2,44-3,25. The total phenolic substance in *berberis* fruits was determined as 148.0-448.3 µg/GAE/mg KM, DPPH radical removal activity was determined as 11.92%-40.44%, β-carotene bleaching activity was determined as 62.83%-92.19%, ABTS+ radical removal activity was determined as 33.06%-92.85% December.

In another study, Gülsoy, Özkan and Özkan (2011) obtained *B. crataegina* DC from the Eğirdir Lake basin of Türkiye obtained *B. crataegina* DC from the Eğirdir Lake basin of Türkiye they aimed to determine the elemental composition, organic acids, and phenolic compound concentrations of their fruits and determined that calcium is the most abundant element in the leaves and potassium in the fruits according to the results they obtained. In addition, they noted that the predominant major phenolic compounds of leaves and fruits are rutin and chlorogenic acid; rutin, apigenin, and naringenin are at the highest concentration in fruits, and malic acid and citric acid are also found at a higher rate in leaves.

Charehsaz et al. (2015) carried out in the Bayburt region according to the results obtained in the work they are ferric-induced oxidative stress and protective effects against oxidative DNA damage have shown relatively good antioxidant activity in lymphocytes which reveals that have a protective effect against H_2O_2-induced DNA damage and lipid peroxidation have identified that you have good activity against improves.

In another study conducted in the Bayburt region, *B. crataegina* the number of phenolic substances and antioxidants of fruit *B. crataegina* according to Vulgaris, it was higher; it could not detect significant differences between the dry matter, vitamin C, pH values, and water activity results of the fruit samples. In addition, when comparing fruit types, there was a difference between the brix and ash values, while significant differences were observed in the glucose, total sugar, and malic acid values (Karabulut, 2018).

Aslaner et al. (2017) within the scope of their research, concluded that it would be appropriate to evaluate the fruit in terms of freezing technology by using the *berberis* fruit grow wild in and around Erzincan province in ice cream production. They determined the average pH value of the *berberis* ice cream samples as 6.47, and determined the volume increase as 18.89%.

Say (2021) used *berberis* fruits as materials in his study, *berberis* (*Berberis crataegina* DC), which grows naturally from various parts of Taşhan village of Yahyalı district of Kayseri. collecting fruits from the plant phenolic compounds, total anthocyanin content, and antioxidant capacity, he worked as a reaction to antiradical multifactor optimization of the parameter with the highest value obtained for each solvent and a mixture of bioactive and 70% methanol and 30% water as determined. Then, by investigating the effect of different extraction conditions, the total phenolic content of the samples was 80.76-110.92 mg GAE/g, the total flavonoid substance amount was 77.71-120.35 mg CE/g, and the condensed tannin amount was 50.50-62.14 mg KE/g and total anthocyanin amount in the range of 2.75-3.21 mg/g, DPPH radical scavenging activity was 25.02-63.09%, ABTS radical scavenging activity was 122.48-256.09 µgTE/ in the g range determined. The antioxidant capacity values are in the range of 66.12-110.83 mgAAE/kg for the iron reduction method, 108.88-137.36 mgAAE/g for the phosphomolybdenum method, and the linoleic acid oxidation inhibition values are in the range of 85.69-89.72%. determined.

Berberis crataegina DC in the Eğirdir Lake basin in the Lake District of Türkiye. to determine the elemental composition of fruits and leaves, phenolic compounds, and organic acid concentrations (Gülsoy et al., 2011) in their studies, they determined that calcium and potassium are the most abundant elements in leaves and fruits, respectively. The calcium concentration in the leaves (11130,00 µg/g) according to the fruit of (2389.00 µg/g), the concentration of potassium in the fruit (11210,00 µg/g) according to the leaves (7857,00 µg/g) have a higher risk of. The predominant main phenolic compounds of leaves and fruits were rutin 170.87 mg/kg and chlorogenic acid 70.24 mg/kg, respectively. On the other hand, the highest concentration of rutin and apigenin 7-O-glucoside were found in fruits. Malic acid and citric acid in the leaves were found to be 4338.00 and 155.00 µg/g, respectively.

Gholizadeh-Moghadam, Hosseini and Alirezalu (2019) evaluated the characterization of phytochemical and antioxidant activities of 18 *berberis* fruits belonging to 3 different species collected from Iran in their study and obtained the highest total phenolic and flavonoid amounts from G3 (*Berberis vulgaris*) fruit extracts. The highest total anthocyanin content and antioxidant activity, respectively, in G8 (*B. Vulgaris*) and in G16 (*B. Vulgaris*) they observed. Of phytochemicals (gallic acid, caffeic acid, chlorogenic acid, p-coumaric acid, cinnamic acid, rutin and apigenin) for HPLC analysis, gallic acid and p-coumaric acid is the most abundant phytochemical compounds shows that there is.

Eroğlu (2019) investigated some important bioactive activities of three naturally grown *berberis* fruits collected in various regions of Bayburt in a study. According to the results of some physicochemical analysis in the research, it has been revealed that the regions where the fruits grow have an effect on the dry matter, ash amount, pH, and water activity values in the fruits. The total phenolic substance in fruits was determined as 148.0-448.3 µg GAE/mg KM, ABTS+ radical removal activity was determined as 33.06%-92.85%, β-carotene bleaching activity was determined as 62.83%-92.19%, DPPH radical removal activity was determined as 11.92%-40.44% December. Phenolic compounds such as caffeic acid, trans-ferulic acid, gallic acid, vanillic acid, syringic acid, and synaptic acid, which are the most chlorogenic acids, were detected while creating a phenolic substance profile.

In a study investigating the use of *B. Crataegina* extract, which is an alternative to red as a natural colorant, 1%, 5% and 10% *berberis* extract were used in marshmallow, chewing gum and jelly samples and it was found that the total amount of phenolic substance was higher. In addition, according to the results of the color analysis of the samples, it was determined that there was a serious change in the value of ΔE, which expresses color differences (Çoban, 2020).

A study conducted in 2019 studied the fruits of *Berberis* (*Berberis Vulgaris*) grown in the Divriği region of Sivas, the chemical content analysis and antioxidant properties of which had not been studied before. The fruits dried at room temperature were extracted with methanol. The total amount of flavonoid and phenolic substances of the obtained extract was determined. The phenolic content of *berberis* (*Berberis Vulgaris*) fruits was 10.74 mg GAE /g, the total flavonoid content was 36.24 mg CATEQ/G as a sample, they determined that it inhibited DPPH free radical by 60% (Elmalı Gülbaş et al., 2019).

The *berberis* (*Berberis aristata* DC) grows naturally in three different locations (Topa, Banjosa and Neriyan Sharif) in the north of Pakistan. Regarding the characterization of germplasm and morphological characteristics and nutrient composition, Ahmed et al. (2012) Neriya collected from individuals in the work they conducted in 2012, the Sharif with significantly more plant height, the higher number of branches per plant, long flowering period (day), that took longer maturation (days) and the total amount of leaves and fruits have found that too large. The nutritional composition of fruits, the fruit juice was significantly higher in the pH of the Sinai from the ball of individuals with higher carbohydrate, ash, acidity, and total soluble solids content and low Mn; Neriya individuals from the Sharif also had significantly higher moisture, protein, fat, and fiber to K, Ca, Na, Fe, Cu, Pb and Cr content, indicating that you are quite acidic.

In the studies conducted by Arslaner and Salık (2020), *Berberis integerrima Bunge*, which grows naturally in Bayburt and Trabzon provinces, *Berberis vulgaris* L., *Rosa pimpinellifolia* L., *Rosa canina* L., *Malus sylvestris Miller*, and *Vaccinium corymbosum* L. they determined some physicochemical and microbiological properties and mineral compositions of marmalades produced by traditional method using wild fruits. According to the research results, the samples of marmalade; 2,56 pH-4,18, titratable acidity (expressed as citric acid) %0,62-3,40, dry matter %53,65-64,90, water-soluble dry matter %52,28-64,53, water activity 0,818-0,894 and HMF (5-hydroxymethyl-2-furfural) 5,81-53,40 mg/kg range were detected. Also the macro minerals in samples of marmalade, Ca, K, P and Mg, respectively 23,56-425,12 mg/kg, 1275,74-5918,10 mg/kg, 21,98-921,26 mg/kg and 125,50-776,23 mg/kg showed a change in the range of micro-minerals in FE 4034,85-22346,74 µg/kg, Mn 531,63-15065,91 µg/kg, Zn 345,40-6250,76 µg/kg, B 2872,99-7300,37 µg/kg) and Ba 689,31-6455,24 µg/kg were between state.

CONCLUSION

Literature related to the culture and cultivation in the study conducted in our country in the geography of species *Berberis crataegina* that is not naturally present in the production techniques of the economically important species naturally grown in Anatolia and has not been demonstrated in any scientific study. As a medicinal plant, it is necessary to increase the amount of use of *Berberis* species, which are of great importance both in terms of berberine and other alkaloids, as well as phenolic compounds and flavonoids. It has been determined that *berberis* fruit contains high levels of phenolic and anthocyanin components and has a strong antioxidant structure. With these properties, it is thought that these fruits, which can grow spontaneously in almost every region of our country, can contribute to the food industry and the national economy in the treatment and prevention of diseases. With the increasing consumption of these fruits, which can have positive effects on human health, the evaluation areas of these fruits should be expanded and new research that will allow them to reach our tables should gain momentum.

REFERENCES

Anonim2022a.www.google.com/search?q=karamuk+%C3%A7i%C3%A7ek&rlz

Anom 2022b. https://www.google.com/search?q=karamuk+meyve&rlz =gws-wiz

Anonim 2022c. (http://www.turkomp.gov.tr/food-karamuk-734-2022)

Anşin, R., Özkan, Z.C. 1993. Tohumlu Bitkiler (*Spermatophyta*) Odunsu Taksonlar, 1. Baskı, K.T.Ü. Orman Fakültesi Yayın No:19,Trabzon.

Arslaner, A., Çakır., Ö., Çakıroğlu K., 2017. Karamuklu Dondurma. International Erzincan Symposium. https://www.researchgate.net/publication/312553167

Arslanoğlu, S.F., Ayna, O.F. 2019. Anadolu Coğrafyasında Yayılış Gösteren *Berberis* Türleri ve Geleneksel Kullanımı. International Journal of Life Sciences and Biotechnology. 2(1): p. 36-42.

Arslaner, A., Salık, M.A. 2020. Some Quality Properties, Mineral and Heavy Metal Composition of Wild Fruit Traditional Marmalades.Turkish Journal of Agriculture - Food Science and Technology, 8(3): 678-687, 2020 DOI: https://doi.org/10.24925/turjaf.v8i3.678-687.3190

Baytop, T., 1999. Türkiye'de bitkiler ile tedavi (geçmişte ve bugün). Nobel Tıp Kitabevleri. İstanbul.

Charehsaz, M., Sipahi, H., Celep, E., Üstündağ, A., Cemiloğlu Ülker, Ö., Duydu, Y., Aydın, A., Yeşilada, E. 2015. The fruitextract of Berberis crataegina DC: exerts potent antioxidant activity and protects DNA integrity. Journal of Pharmaceutical Sciences, 23(1), 24 DOI 10.1186/s40199-015-0108-7

Çoban, B., 2020. Şekerleme Üretiminde Doğal Renklendirici Olarak Karamuk (B*erberis Crataegina*) Ekstresinin Kullanımı Üzerine Bir Araştırma. Tekirdağ Namık Kemal Üniversitesi Fen Bilimleri Enstitüsü, Gıda Mühendisliği Anabilim Dalı, Yüksek lisans tezi, 67s, Tekirdağ.

Darrow, G. M. 1975. Minortemperatefruits. (Advances in fruit breeding). (Ed.J. Janick and J. N. Moore). West Lafayette, İndiana: Purdue University Press.

Davis, P.H. 1965. Flora of Türkiye and the East AegeanIslands. Vol.1, Edinburgh University Press, Edinburgh.

Davis, P.H. 1982. Flora of Türkiye and the East AegeanIslands, Vol.4, Edinburgh University , Edinburgh.

Eroğlu, A., 2019. Yabani Kızamık (*Berberis vulgaris* L.) ve Karamuk (*Berberis Crataegina* Dc.) Meyvelerinin Bazı Fizikokimyasal Özellikleri ile Antioksidan ve Antimikrobiyal Kapasitesinin Tespit Edilmesi. Bayburt Üniversitesi, Fen Bilimleri Enstitüsü, Gıda Mühendisliği Ana Bilim Dalı, Yüksek Lisans Tezi, 90s, Bayburt.

Eroğlu, A.Y., Çakır, Ö., Mustafa Sağdıç, M., Dertli E., 2020. Bioactive Characteristics of Wild *Berberis vulgaris* and *Berberis crataegina* Fruits. Hindawi Journal of

Chemistry Volume 2020, Article ID 8908301, 9 pages https://doi.org/10.1155/2020/8908301

Elmalı Gülbaş, H., Bulduk, İ., Çolak, A.M. 2019. Sivas Divriği İlçesinde Bulunan Karamuk (*Berberis Vulgaris*) Bitkisinin Kimyasal Yapısının, Biyoaktif İçeriğinin ve Antioksidan Özelliklerinin Karakterizasyonu. 1 st İnternational, Congres on Medical Sciences and Biotechnology, Uşak, 14-16 October, 2019.

Gholizadeh-Moghadam, N., Hosseini, B., ve Alirezalu, A., 2019. Classification of barberry genotypes by multivariate analysis of biochemical constituents and HPLC profiles.

Gülsoy, S., Özkan, G. ve Özkan, K. 2011. Mineral elements, phenolics and organicacids of leaves and fruitsfrom *Berberis crataegina* DC. Asian Journal of Chemistry, 23(7), 3071- 3074.

Güner, A. 2012. Türkiye bitkileri listesi (Damarlı bitkiler). İstanbul: Nezahat Gökyiğit Botanik Bahçesi ve Flora Araştırmaları Derneği Yayını.

Karabulut, A. 2018. Bayburt ilinde doğal olarak bulunan *Berberis vulgaris* L. ve *Berberis crataegina* DC. yabani meyvelerinin biyokimyasal karakterizasyonu (Yüksek lisans tezi). Yükseköğretim Kurulu Ulusal Tez Merkezi'nden edinilmiştir. (Tez No: 504625)

Kaşıkcı, İ., 2013. *Acer Platanoıdes* L. *Krimson Kıng Berberis Thunbergii* DC *Atropurpurea* ve *Prunus crasıfera* EHR. *Pısardii nigra* Türlerinin Sera Koşullarında Çelikle Üretimi., Peyzaj Mimarlığı Dergisi,

Kayacık, H. 1981. Orman ve Park Ağaçlarının Özel Sistematiği, Cilt 2, 4. Baskı, İ.Ü. Orman Fakültesi Yayın No:2766, Bazak Matbaası, İstanbul.

Kuhnlein, H. V. 1989. Nutrientvalues in indigenous wild berries used by the nuxalk people of bellacoola, British Columbia. Journal of Food Composition and Analysis, 2(1), 28- 36. DOI: 10.1016/0889-1575(89)90059-8

Maqsood Ahmed, Muhammad Akbar Anjum, Raja Mohib Muazzam Naz, Muhammad Riaz Khan, Sajjad Hussaın. 2012.Characterization of indigenous barberry germplasm in Pakistan: variability in morphological Characteristics. Fruits, 2013, vol. 68, p. 409–422 © 2013 Cirad/EDP Sciences All rights reserved DOI: 10.1051/fruits/2013085 www.fruits-journal.org and nutritional composition. http://publications.edpsciences.org/

Özkal, N., Ertürk, K. İ. 1996. *Berberis crataegina* DC. Bitkisinden elde edilen berberin alkaloidi ve ekstrelerinin antimikrobiyal aktiviteleri. Bitkisel İlaç Hammaddeleri Toplantısı, Ankara Üniversitesi Eczacılık Fakültesi, Ankara.

Say, R. 2021. Farklı Ekstraksiyon Şartlarının Karamuk Meyvesinin (*Berberis crataegina* DC.) Biyokimyasal Karakterizasyonu Üzerine Etkilerinin

Araştırılması, Yüksek Lisans Tezi, Erciyes Üniversitesi Fen Bilimleri Enstitüsü, Kayseri.

Sarı, F. 2016. The Copigmentation Effect of Different Phenolic Acids on *Berberis crataegina* Anthocyanins. Journal of Food Processing and Preservation Volume 40, issue 3.

Smatana, L., Kytka, J., Kadarova, S. 1988. Results of Breeding and Growing Minor Fruit Species in czechoslovakia. Acta Horticulturae, 224, 83-87. https://doi.org/10.17660/ActaHortic.1988.224.9

Toroğlu, S., Çenet M. 2006. Tedavi Amaçlı Kullanılan Bazı Bitkilerin Kullanım Alanları ve Antimikrobiyal Aktivitelerinin Belirlenmesi İçin Kullanılan Metodlar. Kahramanmaraş Sütçü İmam Üniversitesi Fen ve Mühendislik Dergisi, 9(2), 12-20.

Tuzlacı, E. 2016. Geleneksel İlaç Bitkileri. İstanbul Medikal Yayıncılık, İstanbul.

Üçer, M. 2011. Bitkilerle tedavi sempozyumu (Sivas yöresinde yerel bitkilerden yapılan ilaçlar). İstanbul: Merkezefendi Geleneksel Tıp Derneği.

Yaltırık, F., Efe, A. 1989. Otsu Bitkiler Sistematiği, İ.Ü. Orman Fakültesi Yayın No:3568, Dilek Matbaası, 1989, İstanbul.

CHAPTER 3

VEGETABLE SEED SCIENCE

Assist. Prof. Dr. Burcu Begüm KENANOĞLU[1]

[1] Uşak University, Agricultural Faculty, Uşak, Türkiye
burcu.kenanoglu@usak.edu.tr, ORCID ID: 0000-0001-5307-5194

INTRODUCTION

Seed as the main propagation material of vegetative diversity, is extremely important not only for vegetable species, but also for ornamental plants, field crops, fruits and forest species. They are also valuable in terms of nutrition in species that belong to the family of rice, wheat and legumes. Seeds are also an important commercial material as production and breeding material. A significant barrier to agricultural development is low seed quality. The volume of the global seed trade is reportedly 45 billion dollars. It is reported that losses in agricultural production can reach up to 20% on a global scale due to low germination, late and irregular emergence, hypersensitivity to stress or pathogens, and inadequate seed quality that causes negativities in seedling development. Ensuring quality seed production is the main task of the vegetable seed industry.

1. Seed Formation (chemistry of seeds)

The physiological and biochemical germination mechanisms are represented in the vast variations in internal morphology and obvious outward form of seeds, which determine how embryos expand and emerge from the seed. In his acclaimed thorough descriptive investigation, Martin (1946) divided the gymnosperm and angiosperm taxa into 12 main anatomical groups based on form, function, and compositional properties. Compared to the entire seed, embryos can be: (1) small, slim, or dominant; (2) thin, broad; simple, curved, bent, or folded; and (3) located near the edges, at the side, or in the middle, quite tucked between the endosperm or perisperm tissues, which may be living or wholly or probably largely dead and have soft or hard layers. Several seeds that are significant to agriculture have embryos that are comparatively unrestricted by the tissues around them, such as grains, Brassicas, and many legumes and grasses. Germination in these seeds only refers to the start of embryonic growth. Contrarily, restricting components including the endosperm, testa, and pericarp in many crop seeds significantly increase the mechanical obstacles to embryo expansion. For example, in mature celery and carrot seeds, the embryo is immature and completely entrenched in the endosperm. The embryo must expand 2 to 3 times at its expense across both cell development and cell division before noticeable radicle emergence occurs (Gray, Steckel, and Hands, 1990). The generally sluggish germination in umbelliferous species is due to this embryonic development pattern and the varying presence of endogenous inhibitory components. Many seeds with rather large embryos are also constrained in their growth by the endosperm, which is also thought to play a significant physiological role in determining the hydrotime threshold water potential. The focus of a lot of recent research has been on the role of endo-ß-mannanase in reducing mechanical restriction by separating the polysaccharide substrate system in the endosperm cell walls of many examined species. There is currently a lot of data to support the idea that these species' radicle emergence is actually influenced by -mannanase activity, however it is unlikely that the enzyme is the only factor. There is currently a lack of knowledge regarding the physiological importance and processes underlying the thinning of the membranes that surround embryos. Also in seeds that are high in mannan, mannanase is by no indicates the only significant enzyme or activity that should be functioning. Polygalacturonase, arabinosidase, and expansin genes appear to play roles in cell wall alteration or tissue weakening in germination of tomato seeds. These genes are primarily expressed in the endosperm cap and radicle tip areas (Bradford et al., 2000)

2. Seed Germination

Seed germination and seedling development are the stages of the vegetation period that are most vulnerable. The phrase "germination" refers to a series of intricate processes that start the growth of the dormant embryo in seeds, the development of seedlings, and their emergence from the soil. At seed germination, a number of substrates that have been stored are activated, repaired if necessary, and transformed into new building materials needed for the embryo's early development, ongoing growth, and seedling development in its natural environment (Koller and Hadas, 1982). Much more respiratory energy is needed to hydrate and reactivate cell membranes, cell organelles, and enzymes than is needed to keep the dry seed alive (Bewley and Black, 1982). The outcome of biochemical and physiological mechanisms, the seed germinates. Imbibition, enzyme interaction, embryonic development, seed coat shattering, and root emergence occur in sequence during seed germination. Environmental conditions can directly affect seed growth by changing the abilities of the plant, which temporarily inhibits or completely stops germination in seeds. These environmental factors can be listed as water, temperature, light, oxygen, salt, heavy soil structure and abiotic and biotic factors. Beginning with the seed absorbing water, germination continues until rootlets form as a result of the embryo developing linearly. Generally, dry seed moisture content is between 5-13% on fresh weight basis, with the seed moisture content is up to 40-50% (Bewley et al., 2013). Germination is the initial absorption of water and the re-establishment of membrane integrity (Simon, 1974), activation of many enzymes and metabolic events is required (Mayer and Shain, 1974), finally, it includes various biophysical and biochemical processes up to root elongation. Stage I, in which rapid water uptake occurs in the seed, can last between 1-8 hours, depending on the species. Also called lag period II. Water intake is limited at this stage. However, thanks to the production of amylase, endoxylanase and phytase enzymes, new proteins needed for germination are synthesized. Many metabolic changes take place, such as the conversion of storage materials for germination, mRNA synthesis, and the breakdown of sugars for energy production. This stage ends when rootlets emerge from the seed coat. The third stage begins with the appearance of rootlets, the first visible sign of germination. Immediately after, cell division occurs at the tip of the rootlet, and the rootlet begins to elongate and continues to develop (Lutts et al., 2016). In some studies carried out; it has been shown that carrot, cucumber, zucchini, melon, pepper, onion and cabbage species can germinate easily in low humidity environments, beans, peas, beets and lettuce can easily germinate in medium humidity environments, and species such as celery can easily germinate in high humidity environments (İlbi and Duman, 2003). Temperature is the second-most crucial environmental component impacting seed germination after imbibition. Temperature variations have an impact on a variety of biochemical processes that aid in seed germination, including membrane permeability, membrane protein function, and cytosolic enzymes (Bewley et al., 2013). Since the seed is a respirator, oxygen is needed for the oxidation of nutrients in the seed during germination. For germination to occur, the seed must be in contact with at least 20% oxygen. Oxygen is also used in non-respiratory reactions in the seed coat and endosperm. In addition, nitrates are the most important elements that the seed needs before it starts active water uptake with its roots. Because nitrates increase the demand for light for photosynthesis and even germination in the seed, while increasing vegetative development when the seed becomes a seedling. However, nitrates can play a limiting role in germination (Bewley et al., 2013). All seeds must germinate in conditions that include water, oxygen, and a optimum temperature, but some species also require light. It has been determined that the light is filtered while passing through the seed coat and that the light of the appropriate wavelength penetrates the embryo (Widell and Vogelman, 1988). Generally, large seeds do not need light to germinate, as they have enough nutrients to grow in the dark. In addition, species with small seeds require light to germinate. In the studies, it was found that the germination of lettuce species was stimulated by red light, whereas it was inhibited by infrared light, and it was determined that it was governed by the phytochrome pigment (Flint, 1936). In the most general sense, the function of phytochromes is to continuously monitor their physical parameters such as presence/absence, color, intensity, direction and daily duration of light signals coming from the environment (Dalkılıç, 2018). Light of appropriate wavelength and intensity causes an increase in gibberellin hormone thanks to phytochrome and thus increases germination. Another environmental factor affecting germination is soil structure. Stating that there is an important positive relationship between germination and soil texture, the researchers showed that soil texture has an important role in maximum germination rate. Salinity occurs when soluble salts in the soil rise to the soil surface through capillarity with a high amount of ground water and accumulate on the surface as a result of evaporation. These effects can be listed as reduced water entry into the seed due to low osmotic potential, change in enzymatic activity in the seed due to toxicity, inhibition of protein metabolism, deterioration of the balance of plant growth regulators, decreased use of nutrients in the seed, and inhibition of mitosis of cells (Aydın and Atıcı, 2015). Among the vegetables, melon (Mavi et al., 2010), watermelon (Mavi et al., 2010), tomato (Demir and Ermiş, 2003), pepper (Demir and Mavi, 2008) and reported that salt stress causes serious decreases in both germination and seedling growth. The type and amount of mineral substances in the soil for feeding the mother plant can also affect germination. It was determined that the germination percentages increased as a result of the application of fertilizers containing nitrogen, phosphorus and potassium, which are the most widely used in agriculture.

3. Seed Dormancy

The inability to germinate due to an internal impediment that stops the germination process from being fully completed is known as dormancy (Black, Butler and Hughes, 2019). According to Roberts (1988), temperature regulates germination in seeds in three ways: These; (a) determination of capacity and germination rate of non dormant seeds, (b) elimination of primary and secondary dormancy and (c) induction of the secondary dormancy state. Small seeds remain dormant without germination even if they have received water when planted at a depth where they cannot access light. The effect of light on seeds varies according to genotype and environmental conditions during seed maturation, breaking dormancy and germination. A dormant seed is one that lacks the ability to germinate in a given amount of time despite the presence of all other regular physical environmental conditions that are favorable for germination. Morphological dormancy inhibits germination because embryo growth and radicle emergence must occur after the mature seed has been dispersed. Primary dormancy, which emerges during seed development on the mother plant, is the state in which a newly matured dormant seed is said to be (Toorop *et al.*, 1998). On the other hand, a non-dormant seed can grow in the widest variety of normal physical and ecological parameters that are suitable for the genotype. There are five different types of dormancy in the system: physical dormancy (PY), morphophysiological dormancy (MPD), morphological dormancy (MD), and physiological dormancy (PD). For the sake of completeness, it should be noted that dormant seeds may even sprout in such a conditions as non-dormant seeds. Due to our poor understanding of the genetic, physiological, and environmental factors that affect dormancy, it is very difficult to restrict the period of dormancy break to a definite and constrained timespan. According to reports, ABA content peaks around physiological maturity and then drops as the grain desiccates (Benech-Arnold et al., 1999). Contrary to expectations, no associations between ABA embryonic concentration during seed development and the date of departure from dormancy have been discovered. It has been suggested that endogenous GAs control germination by reducing the structural strength of the tissues encircling the embryo and increasing its potential for growth (Bradford et al., 2000), therefore counteracting ABA's effects (Schopfer and Plachy, 1985). According to Nikolaeva (1977), PD into three levels: deep, intermediate, and non-deep. Non-deep PD occurs in the external most of seeds with PD. Five forms of non-deep PD are also based on change in physiological effect to temperature after dormancy break. The embryo in seeds with morphological dormancy (MD) is tiny and distinction, making it possible to tell cotyledon(s) and hypocotyl-radicle apart from one another (Baskin and Baskin, 1998). This type of dormancy results in an embryo that is undeveloped and has a physiological dormant state. Consequently, they need a dormancy-breaking procedure in order to germinate. Embryo development and radicle protrusion take much longer in seeds with morphophysiological dormancy (MPD) than in seeds with MD. The seed or fruit coat contains one or much more layers of palisade cells that serve as water-tight barriers to encourage physical dormancy (PY) (Baskin et al., 2000).

4. Seed Quality and Viability

Seed quality generally refers to the genetic (cultivar purity, longevity), physical (analytical purity, moisture content, size, appearance and presence of other undesirable materials), pathological (health) and physiological (germination capacity, vigor, viability, vitality, dormancy) conditions of the seed, and seed quality is an important indicator of the seed not only under optimum conditions but also under stress conditions (Huda, 2001). In addition, seed quality is affected by many environmental factors such as drought, light and temperature (Delouche, 1980). Numerous genetic and physiological variables affect the quality of seeds. The physiological component consists of variances between seed lots of a single genetic line, whereas the genetic component contains variations between two or more genetic lines. Physical seed quality is the proportion of pure seed from the appropriate crop in a seed lot; occasionally, seed size is also taken into consideration. Analytical purity, moisture content, size, shape, color, insect bites, and the presence of other unwanted items are some of the factors used to measure it. The term "physiological quality" describes a seed's capacity to germinate and encompasses elements such as viability, vigor, and dormant features. Pathological seed quality, or seed health, refers to the presence or absence of plant disease in or on the seed. All stages in seed production affect each other and the overall effect is cumulative, deteriorating seed quality. For this reason, it is stated that seed quality begins at the time of the formation of the mother plant and the setting, development and ripening of the seeds of the seed fruits. The term "seed vigor" is used in the seed industry to describe how well seeds perform in the field, specifically the rate and uniformity of seed germination and seedling growth, the ability to emerge from soil under unfavorable conditions, and the ability to retain these qualities after storage (FinchSavage and Bassel, 2015).

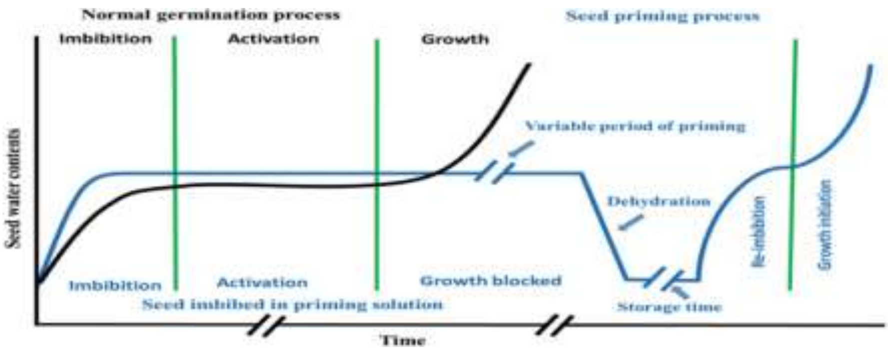
The viability of a seed refers to its capacity to initiate germination or grow a seedling naturally under optimum growth conditions during a typical germination examination. For environmental scientists, the viability of a seed is defined as its ability to germinate and grow into a robust plant in a given environment. Farmers determined a seed's viability by looking at its yield. After harvest, a number of factors, such as aging, incorrect storage techniques, high temperatures during drying, quick drying, or over drying, can impair the viability and quality of seeds. Physiological maturity is the point at which a seed's potential for viability reaches its greatest before degradation sets in. Genetic characteristics, initial seed quality, moisture content, storage conditions including relative humidity (RH), temperature, and exposure time all play a significant role in the rate of deterioration (Crocker and Barton, 1957). Viability in seeds is best determined by the standard germination test. In addition, tests such as tetrazolium and electrical conductivity can be used to determine seed viability. However, seed viability alone is not considered sufficient as a determinant of seed quality.

Physical treatments are external treatments without applying any hydration or chemicals to the seeds. These treatments are; magnetic field applications (Araújo et al., 2016), plasmas treatments (Zhang et al., 2017), gamma radiations (Kiong et al., 2008), X-radiation (Kotwaliwale et al., 2014, Demir et al., 2008, Memiş et al. 2022). Computer aided image analysis techniques, which have developed rapidly in recent years, have come to the fore as a physical technique in determining seed quality and estimating seedling quality. The most important feature of the machine vision systems used for seed quality classification and analysis in plant production is that it gives fast and accurate results. These computer aided image analysis methods include chlorophyll fluorescence (Jalink, 1999; Thomson et al., 1987; Kenanoğlu et al., 2013; Demir et al., 2013; Suhartanto, 2002), CCD camera, flat-bed scanner, RGB (color) imaging, X-ray scanning and slant-board technique (Chen and Sun

1991). In addition to the morphological observations in the seed with the specified systems, the examination of cell activity and water content with cellular imaging made it possible to follow the physiological, biochemical, molecular and biophysical mechanisms in seed development (Dell'Aquila, 2006). Another seed quality improvement application is coating (pellet, film, shell, nanofiber) processing. Coating application is used for commercial and research purposes in different types of vegetables, including film coating, encrusting, pelleting and nanofiber coating (Taylor, 2020).

5. Seed priming

Priming, which increases seed quality for seedling development by promoting pre-germination metabolic processes and enhancing seed germination rate and performance, is the general term for pre-sowing physiological techniques. When it comes to seed applications, it is all the applications made to break the dormancy, germination, emergence and seedling development in agricultural production. Ells (1963) stated that fertilizers and Heydecker (1974) for the first time stated that polyethylene glycol, an osmotic material, promoted germination. Treatments such as coating and liquid sowing began to be used in the field of seeds in the early 1990s. Seed priming of smoke obtained from plants, especially in dormant species, was first used by Baxter and Van Staden (1994). They published one of the first studies showing the potential of nanomaterials to affect seed germination (Khodakovskaya et al. 2009). Priming treatments are methods to increase the quality of pre-sowing seeds in which the seed is dried after moistening in a certain environment for a period of time (Mavi et al., 2006; Demir et al., 2012). All priming treatments are the absence of rootlets, while allowing the embryo to develop up to the seed coat from the start of metabolic activities before germination with water intake (Forti et al., 2021). Keeping the seeds in a humid environment below the critical humidity level required for germination allows rootlets not to emerge, but to initiate metabolic processes that will accelerate germination (graph 1) (Ibrahim, 2019, Bradford, 1986). Even if the seeds do not germinate, the stored nutrients turn into the embryo. When treated seeds come across favorable environmental conditions, these metabolic alterations enable them to move on to the third stage of germination (Ibrahim 2019). In the quality of the seed with priming applications; physiological changes, changes in cellular cycle, changes due to seed moisture relationship, changes in storage nutrients and changes in the regulation of oxidative substances occur. As a result of water intake in priming applications used to increase seed quality, basic cellular processes such as synthesis of nucleic acids and proteins, production of ATP, accumulation of sterols and phospholipids, activation of DNA repair and formation of antioxidant substances are triggered.



Graph-1 . Seed Priming Technology Processing. Ibrahim E.AA. (2019) Fundamental Processes Involved in Seed Priming. In: Hasanuzzaman M., Fotopoulos V. (eds) Priming and Pretreatment of Seeds and Seedlings. Springer, Singapore.

Nowadays, priming methods with different names are used, such as hydropriming, halopriming, osmopriming, thermopriming, solid matrix priming, hormonal priming, micronutrient priming and smoke priming. Priming provides an increase in enzyme and respiratory activities and stimulates germination with various biochemical, cellular and molecular events including RNA, DNA and protein synthesis. And also reduces the negative effects of the aging process of the seed. It regulates the activities of SOD, CAT and GR enzymes in old seeds by increasing the respiratory activity of seeds (Bailly et al., 1997). DNA, RNA, proteins and enzymes have an effect on the repair of cell membranes in the repair mechanism that occurs during water uptake in seeds. Priming promotes enzyme activity by reducing the effect of lipid peroxidation in the seed. Low temperatures delay the physiological processes necessary for germination, and germination is inhibited, increasing the efficiency of application, while microbial contamination is also reduced (Bradford, 1986). When the priming treatment temperature is low, it may require a longer application time to obtain an effective result.

Hydropriming is the simplest approach to hydrating seeds and minimizing the use of chemicals. Hydroprimed seeds result in healthy seedlings, uniform seedling emergence, drought resistance, early planting and high emergence rate. In onion, eggplant and radish seeds, hydropriming application increased dehydrogenase activity in cells and decreased peroxidation formation (Choudhuri and Basu, 1988). Of the priming applications, osmopriming is one of the most widely used. In osmopriming applications, osmotic substances such as polyethylene glycol (PEG), mannitol, glycerol, sucrose can be used (Parera and Cantliffe, 1994). For osmotic conditioning, a balance of water potential is required between the medium and the seed, and different, slower penetrating substances such as organic solutes and salts are used for this purpose. All the salts provide the germinating seed with nutrients such as nitrogen, which is necessary for protein synthesis during the germination period. Although priming applications increase the enzyme level in the seeds of many plant species, it has been determined that osmopriming application decreases the enzymes associated with rootlet emergence in some species. On the other hand, osmopriming application increases ATP synthesis (Mazor et al., 1984) and RNA content in seeds of many plant species (Bray et al., 1989). In different gourd genotypes, more effective and better results were obtained from the application of KNO_3 than the application of NaCl, and the positive effect of the application of KNO_3 was observed better as the germination temperature decreased but it can be changed according to tje species and seed physiological age (Kenanoglu et al. 2007, Kenanoglu et al., 2018). Hormone priming is the general name given to priming practices that affect seed metabolism by exposing the seed to a hormone solution. In priming studies, auxins, GA_3, salicylic acid, abscisic acid, ethylene, ascorbic acid, cytokinins and methyl jasmonate (MeJA) can be used (Bucker-Neto et al. 2017). Many factors such as the concentration of the hormone used, the application time, the genetic structure of the seed, the initial viability of the seed used can change the effectiveness of the application. Priming with optimum cytokinin concentration is known to increase the germination, development and harvest yield of many species. Gibberellic acid is known to break seed dormancy, improve germination, hypocotyl growth, internode length and cell division (Demir et al., 1994). Abscisic acid can be used to increase germination as well as increased tolerance of different plant species to various stresses (Gurmani et al., 2013). Salicylic acid is that regulates growth, development, and the physiological process is promoted (Habibi and Abdoli 2013). It promoted seedling emergence and early seedling growth in priming cucumber with salicylic acid (100 mg) (Rehman et al. 2011). MeJA (Korkmaz, 2005) and brassinosteroids (Shah et al., 2020) can be used to stimulate seed quality and seedling growth in vegetable species. In agriculture, it is used as a natural plant food by being applied to the soil and plants in the form of suspensions and extracts (Senn, 1987). With organic materials, seed germination percentage and seedling emergence uniformity can be increased. It has been reported that different organic substances such as seaweed, humic acid, fulvic acid, Moringa oleifera leaf extract, marigold herbal tea and grapefruit juice can be used in seed applications (Mavi, 2014). Seaweed extract contains macro and micro nutrients (Senn, 1987), growth regulators such as cytokinin, auxin and abscisic acid (Tarakhovskaya et al., 2007), polysaccharide, amino acid (betains) (Mackinnon et al. 2010), vitamins (It contains B12, vitamin E, vitamin K), fats, proteins, sugars (mannitol and alginic acid), phenols and antibiotics (Craigie, 2011). Seedling development is supported by affecting the cellular metabolism of the seeds applied with it (Stirk et al., 2004). Medicinal plants such as thyme and laurel are used as supplements in antifungal and antibacterial products, especially against plant bacteria and fungi (Toroğlu, 2007). Positive effects were determined in terms of germination rate, seedling emergence, mean emergence time and fresh-dry weight under salt stress in eggplant seeds primed with marigold herbal tea (Mavi and Matthews, 2013). It is seen that plant extracts obtained from different organs of many different species such as basil (leaf extract), turmeric (rhizome extract), ginger (rhizome extract) and garlic (onion extract) have been tested for seed application as organic priming agents (Masuthi et al., 2015). It can be used in volatile compounds obtained from plants as an organic priming agent. Antibacterial and antimicrobial properties of essential oils show an inhibitory effect on germination and disease formation in the emergence (Atak et al., 2016). Micronutrient (Zn, B, Mo, Mn, Cu, Co) priming is the technique in which seeds are kept in a nutrient solution and increase seed nutrient content. So this application improve seed quality with better germination and seedling formation (Imran et al., 2013). Seed priming with micronutrients has recently gained momentum in various research programs, especially in Asian countries

(Harris et al., 2001). In tomato (El-Saifi et al., 2010), and pepper (Uche et al., 2016), greater germination performance was obtained with the application. It has been reported that the negative effects of salinity are reduced by seed priming at two different concentration levels (100-200 ppm) of copper and zinc micronutrients. In addition, micronutrient priming in the form of onfarm (on-farm) priming is widely accepted to increase productivity in other resource-poor agricultural areas of the world (Harris et al., 2001). So commercial companies develop and use their own patented priming applications using micronutrients. Thermopriming takes place in the form of keeping the seeds in pure water enriched with high temperature oxygen for certain periods in dark environments. Thermopriming application have positively affects on seed germination, seedling emergence, plant growth and development with its positive effects on enzyme activity. As a result of thermopriming (0, 10 and 20 minutes) applied at different times in cowpea seeds; parameters such as germination percentage, seedling dry weight, seedling viability and seedling length were investigated (Farahani, (2011). Their results stated that the highest germination percentage (90%), seedling dry weight (2.05 g), seedling viability (184.5) and seedling length (8.58 cm) were obtained with 10 minutes of thermopriming (Khalil et al., 1983). With the thermopriming application made on the seeds of different eggplant varieties, positive effects were obtained on the seedling quality and performance of the mature seeds. Among the priming applications, the thermopriming application showed the best results compared to the other applications (Özmen and Kenanoğlu, 2020, Çelik and Kenanoğlu, 2020). In the matrix priming application, a much more airy environment is provided compared to other priming applications, therefore no additional ventilation is required (McDonald, 2000). Vermiculite, expanded calcined clay, agro-lig and synthetic calcium silicates are used as matrix, that is, solid medium can be used (Hacısalihoglu, 2007). It has been proven that solid matrix priming applications increase seed emergence percentages and seedling growth in various vegetables (tomatoes, peppers, broccoli, okra and beans). Increased germination, anti-oxidative enzyme activity and antioxidant levels were determined at sub-optimal temperatures in seeds applied with solid matrix priming (Kepczynska et al., 2007). After matrix priming with vermiculite of 20 onion seed lots, changes in seed quality were tested during storage at -20°C, and it was concluded that the seeds preserved their priming effect during 15 and

30 days of storage (Özden et al., 2020). It has been reported by different researchers that the presence of oxygen in different species improves the effectiveness of the application by increasing respiratory and metabolic activities (Bujalski et al., 1991). Plant-derived smoke has been used as a priming agent in scientific studies for purposes such as breaking seed dormancy, increasing seed viability and improving seedling quality, and its effectiveness has been determined. Smoke or aqueous smoke extract can be used as a potential agent to increase seed germination and seedling viability in many plants. One of the active compounds known to be present in smoke is a butenolide type compound called carriquinolide (Van Staden et al., 2004). It has been reported that the physiological effect of smoke priming may be related to the increase in replicated DNA (Jain and Van Staden, 2007), stimulation of the cell division cycle (Soos et al., 2009) or gibberellins (Long et al., 2010). In addition, smoke priming also affects an CAT or SOD enzymatic activity (Demir et al., 2012). It is used more intensively for the removal of dormancy in forest species and species distributed in natural flora, and it is used more intensively in tomato (Kulkarni et al. 2010), pepper (Demir et al., 2018), eggplant (Demir et al., 2009) and melon (Mavi et al., 2010) have also demonstrated its effectiveness in increasing seed quality in important vegetable species. These are applications made with beneficial microorganisms. It can also be applied for the growing seedlings to gain resistance. Applications made to seeds are called biopriming. Rhizobacteria known as "plant growth promoting rhizobacteria" (PGPR) are available, soil-borne microorganisms that, when added to soil, seeds, or roots, can either stimulate plant growth or lessen the likelihood of plant pathogen-related diseases. Initially, their importance was demonstrated because of their nitrogen fixation to the soil in legumes. Endophyte beneficial bacteria are considered a good priming agent because they colonize plant roots, show good growth with their hosts and symbiotic partners, and also create a suitable environment for plant growth. In order to improve plant growth, development, and biological control, a new seed priming technique called biopriming integrates biological and physiological elements. In addition to disease control, the application of beneficial microorganisms for biofertilization is also recommended to reduce the use of chemical fertilizers (Bloemberg and Lugtenberg 2001).

6. Seed harvest-processing-drying

The seed is directly affected by late and irregular germination in the environment in which it is planted. Environmental or seed-borne factors play the main role in this late and irregular germination. These factors include the nutritional status of the mother plant before harvest, pathogenic effects during and after harvest, mechanical damage during harvest, and post-harvest storage conditions. When it comes to pre-harvest factors, cultural processes such as fertilization, irrigation, spraying applied to the mother plant to be harvested, seed fruit harvest time, the location of the seed fruit on the plant, many different factors affect the seed quality in this process. There are many publications about seed quality effect on the harvest, processing and storage of vegetable seeds. One of the most studied subjects is the studies conducted to determine the most suitable seed harvest times (Demir and Ellis, 1992a; Demir and Ellis, 1992b; Demir and Ellis, 1993; Demir and Samit, 2001; Demir et al., 2002; Demir et al., 2003; Demir and Mavi, 2004; Demir and Ermiş,, 2005; Demir and Mavi, 2008). There are two categories of seed cleaning and harvesting techniques: wet and dry processing. Harvesting seed that has already reached maturity and dried within the plant's seedpod is known as dry processing. The entire seedpod, capsule, or seed head turns brown and dries up when the seeds are prepared for processing. To separate the seed from the plant debris surrounding it after harvest, seeds are threshed. Before seeds are threshed, an air-drying phase is critical. To prevent mold, rot, and heat from decay from damaging the seeds, plant material should be spread out in thin layers until it is completely dry. The optimum time to thresh is on a dry day outside. A controlled pressure and shearing action are used to apply mechanical force during the threshing process, which can be carried out manually or mechanically. Beans, broccoli, corn, lettuce, okra, onions, sunflower, and turnips are a few examples of plants whose seeds have been dried and processed. Wet processing is used for the mature seed which is enclosed within a fleshy fruit or berry. The method consists of three steps: (1) removing the seed from the fruit; (2) washing the seeds; and (3) drying. Depending on the species, different extraction techniques are used. Tomatoes and other soft fruits are minced, mashed, and fermented. Generally cucurbits are split in half, the seeds are scraped out along with the pulpy fruit around them, and then the fruit is fermented. In the case of watermelons, both the extracted seed and the entire fleshy fruit are fermented. These particular fruits feature a germination-inhibiting gel encircling the seed. Cucumbers, melon, and tomatoes are some examples of seedlings that have undergone wet processing. Peppers and squash are two examples of vegetables that can be prepared either dry or wet.

For simple management of seed, which is delicate at every step of handling and ready to lose or gain quality throughout the processes, the handling of seed at the processing plant follows a specific path regardless of crop. Physical characteristics which can used to separate seeds are; size grader, length, mass, form, texture, colour, electrical conductivity and affinity to liquid**.** And seed processing equipments are; air screen cleaner, cleaner cum grader, disc separator, indented cylinder separator, specific gravity separator, roll (dodder) mill, magnetic separator, colour separator and spiral separator. The key factor influencing seed vigor in the seed production cycle for effective crop production is the level of maturity at harvest. Because some of the seed vigor characteristics have not yet been acquired, harvesting too early may result in low longevity, low vigor, and poor establishment. Furthermore, postponing harvest raises the possibility of seed shattering or degradation in the field as a result of unfavorable weather. The main subject determining longevity is low seed moisture content, which is a need for long-term storage. High seed moisture content is the key factor contributing to the viability and vigor loss of seeds during processing and storage. The respiratory metabolism during water removal and after subsequent reimbibition may be severely harmed by the drying of ingested seeds. In comparison to desiccation-tolerant organs, CO_2 production was much higher before and during dehydration. The phase behavior of phospholipid vesicles as determined by infrared spectroscopy was also shown to be disturbed by acetaldehyde, suggesting that it may exacerbate dehydration-induced membrane degradation. Desiccation tolerance thus seems to be linked to a balance between O_2 availability and metabolic down-regulation during drying. There is a lot of interest in processes towards the end of seed development, such as the physiology of refractory seeds that cannot survive drying following development on the mother plant, making desiccation tolerance in seeds an active research subject. Vertucci and Farrant (1993) speculate that when water is removed from seeds, different types of damage may occur: mechanical damage, metabolic damage, the breakdown of antioxidant defense systems and subcellular structural damage. It is thought that in order to prevent these types of harm and/or allow for their restoration upon rehydration, desiccation-tolerant seed tissues need the interaction of a multifactorial suite of protective mechanisms. The cytoplasm's makeup, which includes soluble sugars, the existence of putatively protective molecules like late embryogenesis abundant (LEA) proteins, the effectiveness of antioxidant systems in preventing free radicals produced during dehydration that could otherwise cause oxidative damage to membranes, and the presence and functionality of repair mechanisms during rehydration are all thought to play significant roles (Leprince, Hendry, and McKersie, 1993). Desiccation-sensitive plant cells' liquid crystalline lipid bilayers transform into gel phase domains when water is removed from their membrane surfaces. Although these changes are easily reversed upon rehydration, they are linked to signs of injury and fatal outcomes, such as extensive solute leakage and reorganization of the membrane protein complex. According to Bryant, Koster, and Wolfe (2001), the presence of tiny solutes that can form glasses in the cytoplasm, such as sugars, may restrict the close proximity of membranes and lessen the physical pressures that might otherwise trigger lipid fluid-to-gel phase transitions during dehydration. Dehydrated orthodox seeds are thought to survive by a variety of processes, one of which is their capacity to repair DNA damage following rehydration in order to ensure a transcriptionally competent genome (Boubriak et al., 1997).

7. Seed Storage and Deterioration (Aging)

Ex situ preservation of germplasm requires the capacity to store seeds for future use as a "insurance policy" against dwindling biodiversity (Hay and Probert, 2013). Natural seed life is viewed as one of the adaptive strategies to enable a plant population to disseminate in both time and space. When collecting seeds of non-cultivated species for seed banks, the maturity stage also plays a practical role. It is frequently required to gather seeds before they are completely ripe in order to ensure collection before dissemination. This approach, however, also results in the collection of a sizable fraction of immature seeds that are not suited for long-term storage (Hay and Probert, 2013). Longevity generally increases when temperature lowers, according to the typical relationship between temperature and longevity. This is true for "orthodox" seeds, or the majority of seeds that adhere to a set of broad "rules of thumb" for longevity during seed storage. The longevity of seeds doubles for every 5.6°C drop in temperature, according to the link between temperature and longevity (Harrington, 1972). Keeping seeds between 0 and 50 oC is allowed under this regulation. The lifetime of seeds is more influenced by seed moisture than by temperature. Most seeds adhere to certain "rules of thumb" in regard to moisture and durability. The lifetime of seeds often reduces by 50% for every 1% rise in seed moisture (Harrington, 1972). Seed having a moisture content of 5 to 13 percent is covered by this rule. Unless the seed is small and expensive, it is unreasonable and too expensive to use desiccant to dry it for storage when storing commercially grown seed. For short and long term storage under circumstances of relative humidity, commercial seed is typically packed. It is crucial to comprehend the connection between relative humidity and seed moisture since it has a substantial impact on seed moisture content. When the relative humidity is 50% or less and the temperature is below 5°C, seeds will remain viable for at least ten years. When humidity reaches 80% at temperatures between 25°C and 30°C, the viability of the majority of agricultural seeds immediately declines (Copeland, 1976). The effects of light on stored seed have been studied and the results are conflicting and ambiguous; some research found a benefit while others found a disadvantage. Because moisture content has the greatest impact on respiration and heating, seeds should ideally be kept dry. Most dust and insects are removed during seed harvest and cleaning, but some fungi, bacteria, and insects find their way into stored seed. Fortunately, fungus and bacteria are inhibited and insects are killed by the same conditions that are beneficial for seed preservation. Seed can be kept in short-term storage using a wide range of materials. The majority of these are non-rigid materials like cotton, burlap, paper and multi-wall paper, plastic film, or polyethylene bags, as well as composite materials. Paper bags, such as lunch bags, are cheap and suitable for storing tiny amounts of seed, but the seams are not always dependable, thus the bags should be double or triple packed to ensure integrity and prevent bursting. The most widely used containers are made of metal or glass and are properly sealed to stop the exchange of gas and moisture. They are the only trustworthy way to preserve seeds against moisture, pests, rodents, floods, and mechanical injury. Plastic shouldn't be kept for an long term of time. The most widely used containers are those made of metal or glass that have been securely sealed to keep out gas and moisture. Long-term storage shouldn't be done using plastic.

Deteriorating changes over time that make a seed more susceptible to dangers outside its control and less able to survive are known as seed degradation. Regarding seed degradation, three broad conclusions may be drawn. The first point is that seed degradation is an unfavorable aspect of agriculture. Therefore, an understanding of seed deterioration offers a model for better crop yield as well as higher agricultural earnings. Second, seed development and/or germination are different events in terms of physiology from seed degeneration. Thirdly, seed degradation happens gradually. The performance of seeds becomes more and more impaired as they age. Recalcitrant and orthodox seeds are typically separated into two types based on how well they store (Pammenter and Berjak, 2000). Big seeds from desiccation-intolerant tropical plants and shrubs with little embryos are known as recalcitrant seeds (Chin and Roberts, 1980). Contrarily, orthodox seeds are typical of the majority of agriculturally significant crops found globally, are frequently dormant, and are desiccation tolerant. The only thing that can be done to prevent seed degeneration is to regulate its rate. Seed degradation is caused by a variety of circumstances. Genetics, mechanical damage, the relative humidity and temperature of the storage environment, the moisture content of the seed, the presence of microflora, the maturity of the seed, etc. are some of these. The two most significant of these are temperature and relative humidity. Because it directly affects the moisture content of seeds being stored when they reach equilibrium with the amount of gaseous water surrounding them, relative humidity is significant. Temperature is significant because it affects how much moisture the air can store and because it speeds up the rate at which seeds deteriorate as temperature rises. According to Harrington (1972), these guidelines needed to be qualified in order to be successfully applied. First, the first criterion does not apply to seeds with moisture contents of 14 or less than 5%. More quickly than the moisture content rule predicts, increased respiration, heating, and fungal invasion occur in seeds maintained at moisture contents exceeding 14 percent, destroying their viability. A breakdown in membrane structure speeds up seed degeneration below 5% seed moisture. Regarding the second rule, it may not be applicable at temperatures below 0°C because many metabolic events linked to seed deterioration do not take place at these levels and further temperature drops only have a modest influence on seed longevity. One common misconception about seeds is that they deteriorate equally throughout, however seeds are actually made up of a variety of tissues with different chemistry and environmental exposure. It is therefore incorrect to believe that seed degradation happens uniformly across the seed. The use of the tetrazolium chloride (TZ) test, which turns living tissues in a seed red, may be the finest illustration that this does not happen (AOSA, 2000). Different rates of degeneration of seed tissues have been seen in investigations on seeds under controlled natural and artificial aging environments. It is yet unknown what physiological factors lead to the degradation of chlorophyll during late seed maturity. Most species' seeds develop their resistance to desiccation while they are still green, showing that chlorophyll does not pose a threat to their ability to survive drying. Retention of chlorophyll, though, might be harmful to longevity.

REFERENCES

Atak, M., Mavi, K., & Uremis, I. (2016). Bio-herbicidal effects of oregano and rosemary essential oils on germination and seedling growth of bread wheat cultivars and weeds. *Romanian Biotechnological Letters*, *21*(1), 11149-11159.

Aydın, İ., & Atıcı, Ö. (2015). Tuz stresinin bazı kültür bitkilerinde çimlenme ve fide gelişimi üzerine etkileri. *Muş Alparslan Üniversitesi Fen Bilimleri Dergisi*, *3*(2), 1-15.

Bailly, C., Benamar, A., Corbineau, F., & Come, D. (1997). Changes in superoxide dismutase, catalase and glutathione reductase activities in sunflower seeds during accelerated ageing and subsequent priming. In *Basic and applied aspects of seed biology* (pp. 665-672). Springer, Dordrecht.

Baskin, J. M., Baskin, C. C., & Li, X. (2000). Taxonomy, anatomy and evolution of physical dormancy in seeds. *Plant species biology*, *15*(2), 139-152.

Baskin, J. M., Nan, X., & Baskin, C. C. (1998). A comparative study of seed dormancy and germination in an annual and a perennial species of Senna (Fabaceae). *Seed Science Research*, *8*(4), 501-512.

Baxter, B. J. M., & Van Staden, J. (1994). Plant-derived smoke: an effective seed pre-treatment. *Plant Growth Regulation*, *14*(3), 279-282.

Benech-Arnold, R. L., Enciso, S., & Sánchez, R. A. (1999). Fluridone stimulus of dormant sorghum seeds germination at low temperatures is not accompanied by changes in ABA content. In *Proceedings of the VIII International Symposium on Pre-Harvest Sprouting in Cereals, Part II. Germany* (pp. 76-80).

Bewley, J. D., & Black, M. (2013). *Seeds: physiology of development and germination*. Springer Science & Business Media.

Bewley, J. D., & Black, M. (1982). Dormancy. In *Physiology and biochemistry of seeds in relation to germination* (pp. 60-125). Springer, Berlin, Heidelberg.

Black, M., Butler, J., & Hughes, M. (2019, April). Control and development of dormancy in cereals. In *Fourth International Symposium on Pre-harvest Sprouting in Cereals* (pp. 379-392). CRC Press.

Bloemberg, G. V., & Lugtenberg, B. J. (2001). Molecular basis of plant growth promotion and biocontrol by rhizobacteria. *Current opinion in plant biology*, *4*(4), 343-350.

Boubriak, I., Kargiolaki, H., Lyne, L., & Osborne, D. J. (1997). The requirement for DNA repair in desiccation tolerance of germinating embryos. *Seed Science Research*, 7(2), 97-106.

Bradford, K. J. (1986). Manipulation of seed water relations via osmotic priming to improve germination under stress. *HortScience*, *21*(5), 1105-1112.

Bradford, K. J., Chen, F., Cooley, M. B., Dahal, P., Downie, B., Fukunaga, K. K., ... & Yim, K. O. (2000). Gene expression prior to radicle emergence in imbibed tomato seeds. In *Seed biology: advances and applications. Proceedings of the Sixth International Workshop on Seeds, Merida, Mexico, 1999.* (pp. 231-251). CABI Publishing.

Bray, C. M., Davison, P. A., Ashraf, M., & Taylor, R. (1989). Biochemical changes during osmopriming of leek seeds. *Annals of Botany*, *63*(1), 185-193.

Bryant, G., Koster, K. L., & Wolfe, J. (2001). Membrane behaviour in seeds and other systems at low water content: the various effects of solutes. *Seed Science Research*, 11(1), 17-25.

Bujalski, W., Nienow, A. W., & Petch, G. M. (1991). The bulk priming of leek seeds the influence of oxygen-enriched air. *Process biochemistry*, *26*(5), 281-286.

Chen, P., & Sun, Z. (1991). A review of non-destructive methods for quality evaluation and sorting of agricultural products. *Journal of Agricultural Engineering Research*, *49*, 85-98.

Chin, H. F., & Roberts, E. H. (1980). Recalcitrant crop seeds. Recalcitrant crop seeds.

Choudhuri, N. I. L. A. N. J. A. N. A., & Basu, R. N. (1988). Maintenance of seed vigour and viability of onion *(Allium cepa L.)* (No. RESEARCH).

Copeland, L. O. 1976. Principles of Seed Science and Technology. Burgess Publishing Co., Minneapolis, MN

Craigie, J. S. (2011). Seaweed extract stimuli in plant science and agriculture. *Journal of applied phycology*, *23*(3), 371-393.

Crocker, W., & Barton, L. V. (1957). Physiology of Seeds; Chronica Bot. Co.: Waltham, MA, USA, 267.

Çelik, Y., & Kenanoğlu, B. B. (2020). Priming uygulamalarının farklı gelişim dönemlerindeki patlıcan tohumlarının canlılık ve kalitesi üzerine etkisi. *Uluslararası Doğu Anadolu Fen Mühendislik ve Tasarım Dergisi*, *2*(2), 348-369.

Dalkılıç, Z. (2018). Bitkilerdeki Fitokrom Işık Algılayıcıları. *Adnan Menderes Üniversitesi Ziraat Fakültesi Dergisi*, *15*(1), 107-114.

Dell'Aquila, A. (2006). Computerised seed imaging: a new tool to evaluate germination quality. *Communications in Biometry and Crop Science*, *1*(1), 20-31.

Delouche, J. C. (1980). Environmental effects on seed development and seed quality. HortScience 15: 775-780.

Demir, I., & Ellis, R. H. (1992). Changes in seed quality during seed development and maturation in tomato. *Seed Science Research*, *2*(2), 81-87.

Demir, I., & Ellis, R. H. (1992). Development of pepper (Capsicum annuum) seed quality. *Annals of applied Biology*, *121*(2), 385-399.

Demir, I., & Ellis, R. H. (1993). Changes in potential seed longevity and seedling growth during seed development and maturation in marrow. *Seed Science Research*, *3*(4), 247-257.

Demir, I., & Ermis, S. (2003). Effect of controlled hydration treatment on germination and seedling growth under salt stress during development in tomato seeds. *European Journal of Horticultural Science*, *68*(2), 53-58.

Demir, I., & Ermis, S. (2005). Effect of harvest maturity and drying method on okra seed quality. *Seed Technology,* 81-88.

Demir, I., & Mavi, K. (2004). The effect of priming on seedling emergence of differentially matured watermelon (*Citrullus lanatus* (Thunb.) Matsum and Nakai) seeds. *Scientia horticulturae*, *102*(4), 467-473.

Demir, I., & Mavi, K. (2008). Effect of salt and osmotic stresses on the germination of pepper seeds of different maturation stages. *Brazilian Archives of Biology and Technology*, *51*, 897-902.

Demir, I., & Samit, Y. (2001). Seed quality in relation to fruit maturation and seed dry weight during development in tomato (No. RESEARCH).

Demir, I., Kenanoglu, B. B., Jalink, H., & Mavi, K. (2013). Chlorophyll fluorescence sorting method to improve seedling emergence potential and vigour of commercial tomato and cucumber seed lots. *International Journal of Agriculture and Forestry*, *3*(7), 333-338.

Demir, I., Light, M. E., Van Staden, J., Kenanoglu, B. B., & Celikkol, T. (2009). Improving seedling growth of unaged and aged aubergine seeds with smoke-derived butenolide. *Seed Science and Technology*, *37*(1), 255-260.

Demir, I., Mavi, K., Sermenli, T., & Ozcoban, M. (2002). Seed development and maturation in Aubergine (*Solanum melongena* L.). *Gartenbauwissenschaft*, *67*(4), 148-154.

Demir, I., Ozden, E., Yıldırım, K. C., Sahin, O., & Van Staden, J. (2018). Priming with smoke-derived karrikinolide enhances germination and transplant quality of immature and mature pepper seed lots. *South African Journal of Botany*, *115*, 264-268.

Demir, I., Ozuaydın, I., Yasar, F., & Van Staden, J. (2012). Effect of smoke-derived butenolide priming treatment on pepper and salvia seeds in relation to transplant quality and catalase activity. *South African Journal of Botany*, *78,* 83-87.

Ells, J. E. (1963). The influence of treating tomato seed with nutrient solutions on emergence rate and seedling growth. In *Proc. Amer. Soc. Hort. Sci* (Vol. 83, pp. 684-687).

El-Saifi, S. K., Ahmed, H. M. I., Hasan, S. M., Morsi, M. M., & El-Shatoury, R. S. (2010). Seed priming influences seed germination and seedling growth of tomato under different salinity levels. *Journal of Plant Production*, *1*(2), 159-170.

Farahani, H. A., Moaveni, P., & Maroufi, K. (2011). Effect of thermopriming on germination of cowpea (*Vigna sinensis* L.). *Advances in Environmental Biology*, 1668-1674.

Flint, L. H., & McALISTER, E. D. (1936). The action of radiation of specific wave-lengths in relation to the germination of light-sensitive lettuce seed. *Proc. Int. Seed Test. Assoc*, *8*, 1-4.

Forti, C., Ottobrino, V., Doria, E., Bassolino, L., Toppino, L., Rotino, G. L., ... & Balestrazzi, A. (2021). Hydropriming applied on fast germinating *Solanum villosum* Miller seeds: impact on pre-germinative metabolism. *Frontiers in plant science*, 12, 639336.

Gray, D., Steckel, J. R., & Hands, L. J. (1991). Responses of Vegetable Seeds to Controlled Hydration. *Annals of Botany*, *67*(1), 95-a.

Gurmani, A. R., Bano, A., Ullah, N., Khan, H., Jahangir, M., & Flowers, T. J. (2013). Exogenous abscisic acid (ABA) and silicon (Si) promote salinity tolerance by reducing sodium (Na+) transport and bypass flow in rice (*'Oryza sativa indica*). *Australian Journal of Crop Science*, *7*(9), 1219-1226.

Habibi, A., & Abdoli, M. (2013). Influence of salicylic acid pre-treatment on germination, vigor and growth parameters of garden cress (*Lepidium sativum*) seedlings under water potential loss at salinity stress. *International Research Journal of Applied and Basic Sciences*, *4*(6), 1393-1399.

Hacisalihoglu, G. (2007). Germination characteristics of three warm-season turfgrasses subjected to matriconditioning and aging. *HortTechnology*, *17*(4), 480-485.

Harrington, J. F., & Kozlowski, T. T. (1972). Seed storage and longevity. *Seed biology*, *3*, 145-245.

Harris, D. B. S. R., Raghuwanshi, B. S., Gangwar, J. S., Singh, S. C., Joshi, K. D., Rashid, A., & Hollington, P. A. (2001). Participatory evaluation by farmers of on-farm seed priming in wheat in India, Nepal and Pakistan. *Experimental Agriculture*, *37*(3), 403-415.

Hay, F. R., & Probert, R. J. (2013). Advances in seed conservation of wild plant species: a review of recent research. *Conservation physiology*, *1*(1).

Heydecker, W. (1974). Germination of an idea: the priming of seeds. *Rep. Sch. Agric. Univ. Nott*, *1973*, 50-67.

Huda, M.N., 2001. Why quality seed? Reality and vision, Bangladesh context. Bangladesh-German Seed Development Project, Dhaka, Bangladesh. 90p.

Ibrahim EA (2019). Fundamental processes involved in seed priming. In: Hasanuzzaman M, Fotopoulos V (Eds.). Priming and Pretreatment of Seeds and Seedlings. Springer, Singapore. doi:10.1007/978-981-13-8625-1_4.

Imran, M., Mahmood, A., Römheld, V., & Neumann, G. (2013). Nutrient seed priming improves seedling development of maize exposed to low root zone temperatures during early growth. *European Journal of Agronomy*, *49*, 141-148.

İlbi, H., & Duman, İ. (2003). Pırasa kereviz ve lahana tohumlarının yüksek sıcaklık stres ve tarla koşullarındaki çıkış özelliklerinin iyileştirilmesi. *Türkiye IV. Ulusal Bahçe Bitkileri Kongresi*, 08-12.

Jalink, H., Van der Schoor, R., Birnbaum, Y. E., & Bino, R. J. (1999, May). Seed chlorophyll content as an indicator for seed maturity and seed quality. In *VI Symposium on Stand Establishment and ISHS Seed Symposium 504* (pp. 219-228).

Kenanoglu BB, Ozmen K, Celik Y (2018). Assessment of viability of stored wintery vegetable seeds with seed vigor and priming treatments. 6th ASM International Congress of Agriculture and Environment. 11-13 October 2018, Antalya.

Kenanoglu, B. B., Demir, I., & Jalink, H. (2013). Chlorophyll fluorescence sorting method to improve quality of Capsicum pepper seed lots produced from different maturity fruits. *HortScience*, *48*(8), 965-968.

Kenanoğlu, B. B., Demir, I., Mavi, K., Yetişir, H., & Keleş, D. (2007). Effect of priming on germination of Lagenaria siceraria genotypes at low temperatures. *Tarım Bilimleri Dergisi*, *13*(3), 169-175.

Kepczynska E, Piekna-Grochala J, Kepczynski J (2007). Seed germination of two tomato cultivars following matrix-conditioning under optimal and stress temperatures. Seed Science and Technology 35: 749-753.

Khalil, S., Moursy, H. A., & Saleh, S. A. (1983). Wheat plant reactions to pre–sowing heat hardening of grains. II. Changes in photosynthetic pigments, nitrogen and carbohydrate metabolism. *Bull Egyptian Soc Physiol Sci*, *3*, 161-175.

Khodakovskaya, M., Dervishi, E., Mahmood, M., Xu, Y., Li, Z., Watanabe, F., & Biris, A. S. (2009). Carbon nanotubes are able to penetrate plant seed coat and dramatically affect seed germination and plant growth. *ACS nano*, *3*(10), 3221-3227.

Kiong, A. L. P., Lai, A. G., Hussein, S., & Harun, A. R. (2008). Physiological responses of Orthosiphon stamineus plantlets to gamma irradiation. *American-Eurasian journal of sustainable agriculture*, *2*(2), 135-149.

Koller, D., & Hadas, A. (1982). Water relations in the germination of seeds. In *Physiological Plant Ecology II* (pp. 401-431). Springer, Berlin, Heidelberg.

Korkmaz, A. (2005). Inclusion of acetyl salicylic acid and methyl jasmonate into the priming solution improves low-temperature germination and emergence of sweet pepper. *HortScience*, *40*(1), 197-200.

Kotwaliwale, N., Singh, K., Kalne, A., Jha, S. N., Seth, N., & Kar, A. (2014). X-ray imaging methods for internal quality evaluation of agricultural produce. *Journal of food science and technology*, *51*(1), 1-15.

Kulkarni, M. G., Ascough, G. D., Verschaeve, L., Baeten, K., Arruda, M. P., & Van Staden, J. (2010). Effect of smoke-water and a smoke-isolated butenolide on the growth and genotoxicity of commercial onion. *Scientia Horticulturae*, *124*(4), 434-439.

Leprince, O., Hendry, G. A. F., & McKersie, B. D. (1993). The mechanisms of desiccation tolerance in developing seeds. *Seed Science Research,* 3(4), 231-246.

Lutts, S., Benincasa, P., Wojtyla, L., Kubala, S., Pace, R., Lechowska, K., ... & Garnczarska, M. (2016). Seed priming: new comprehensive approaches for an old empirical technique. *New challenges in seed biology-basic and translational research driving seed technology*, 1-46.

MacKinnon, S. L., Hiltz, D., Ugarte, R., & Craft, C. A. (2010). Improved methods of analysis for betaines in Ascophyllum nodosum and its commercial seaweed extracts. *Journal of Applied Phycology, 22*(4), 489-494.

Masuthi, D., Chavan, M. L., Khaja Rubina, S., Ramangouda, S. H., Abdul Kareen, M., Prabhakar, I., & Haleshkumar, B. (2015). Different priming treatments on germination and viability of cluster bean seeds. *International Journal of Advanced Research*, *3*(5), 108-111.

Mavi, K. (2010). The relationship between seed coat color and seed quality in watermelon Crimson sweet. *Horticultural Science*, *37*(2), 62-69.

Mavi, K. (2014). Use of extract from dry marigold (Tagetes spp.) flowers to prime eggplant (*Solanum melongena* L.) seeds. *Acta Scientiarum Polonorum-Hortorum Cultus*, *13*(4), 3-12.

Mavi, K., Ermis, S., & Demir, I. (2006). The effect of priming on tomato rootstock seeds in relation to seedling growth. *Asian Journal of Plant Sciences*, *5*(6), 940-947.

Mavi, K., Matthews, S., 2013. An alternative method of organic priming technique in naturally aged. 30 ISTA seed congress abstract book, Antalya.

Mayer, A. M., & Shain, Y. (1974). Control of seed germination. *Annual Review of Plant Physiology*, *25*(1), 167-193.

Mazor, L. E. A., Perl, M., & Negbi, M. (1984). Changes in some ATP-dependent activities in seeds during treatment with polyethyleneglycol and during the redrying process. *Journal of Experimental Botany*, *35*(8), 1119-1127.

McDonald, M. B. (2000). Seed priming. Seed technology and its biological basis. *Sheffield Academic Press*, Sheffield, 287-325.

Memiş, N., Muhie, S., Şahin, G., & Demir, İ. Effect of ultrasonic treatment on seed germination and seedling emergence in seven vegetable species. *Anadolu Tarım Bilimleri Dergisi*, *37*(1), 57-66.

Nikolaeva, M. G. (1977). Factors controlling the seed dormancy pattern. *The physiology and biochemistry of seed dormancy and germination*, 51-74.

Özden, E., Memiş, N., Ebrima, N. J. I. E., Özdamar, C., Serpil, M. İ. S., & Demir, İ. (2020). Variations in seed quality of primed onion seed lots during storage at-20° C. *Mediterranean Agricultural Sciences*, *33*(2), 175-180.

Özmen, K., & Kenanoğlu, B. Farklı Priming Uygulamalarının Patlıcan (*Solanum melongena* L.) Çeşitlerinin Tohumları Üzerindeki Etkinliği. *International Journal of Life Sciences and Biotechnology*, *3*(3), 342-360.

Pammenter, N. W., & Berjak, P. (2000). Evolutionary and ecological aspects of recalcitrant seed biology. *Seed Science Research*, 10(3), 301-306.

Parera, C. A., & Cantliffe, D. J. (1994). Presowing seed priming. *Horticultural reviews*, *16*(16), 109-141.

Rehman, H., Farooq, M., Basra, S. M. A., & Afzal, I. (2011). Hormonal priming with salicylic acid improves the emergence and early seedling growth in cucumber. *J. Agric. Soc. Sci*, *7*, 109-113.

Roberts, E. H. (1988). Seed aging: the genome and its expression. Academic Press, New York, pp. 465-598.

Schopfer, P., & Plachy, C. (1985). Control of seed germination by abscisic acid: III. Effect on embryo growth potential (minimum turgor pressure) and growth coefficient (cell wall extensibility) in *Brassica napus* L. *Plant Physiology*, *77*(3), 676-686. Martin, A.C. (1946). The comparative internal morphology of seeds. The American Midland Naturalist 36: 513-660.

Senn, T. L. (1987). Seaweed and plant growth. Clemson University edition. Clemson, SC 29634-0345, USA

Shah, A. A., Ahmed, S., Abbas, M., & Yasin, N. A. (2020). Seed priming with 3-epibrassinolide alleviates cadmium stress in *Cucumis sativus* through modulation of antioxidative system and gene expression. *Scientia Horticulturae*, *265*, 109203.

Simon, E. W. (1974). Phospholipids and plant membrane permeability. *New phytologist*, *73*(3), 377-420.

Stirk, W. A., Arthur, G. D., Lourens, A. F., Novak, O., Strnad, M., & Van Staden, J. (2004). Changes in cytokinin and auxin concentrations in seaweed concentrates when stored at an elevated temperature. *Journal of Applied Phycology*, *16*(1), 31-39.

Suhartanto, M. R. (2002). *Chlorophyll in tomato seeds: marker for seed performance?*. Wageningen University and Research.

Tarakhovskaya, E. R., Maslov, Y. I., & Shishova, M. F. (2007). Phytohormones in algae. *Russian Journal of Plant Physiology*, *54*(2), 163-170.

Taylor, A. G. (2020). Seed storage, germination, quality and enhancements. *The Physiology of Vegetable Crops, 2nd ed.; Wien, HC, Stutzel, H., Eds*, 1-30.

Uche, O. J., Adinde, J. O., Omije, T. E., Ager, C. J., & Anieke, U. J. (2016). Influence of Hydropriming on germination and seedling emergence of green bell pepper (*Capsicum annuum* cv. Goliath). *International journal of science and nature*, *7*(1), 70-75.

Van Staden, J., Jager, A. K., Light, M. E., & Burger, B. V. (2004). Isolation of the major germination cue from plant-derived smoke.

Vertucci, C. W. (1993). Towards a unified hypothesis of seed aging. In *Fourth international workshop on seeds. Basic and applied aspects of seed biology. Paris: ASFIS* (pp. 739-746).

Widell, K. O., & Vogelmann, T. C. (1988). Fiber optic studies of light gradients and spectral regime within Lactuca sativa achenes. *Physiologia Plantarum*, *72*(4), 706-712.

Zhang, H., Ma, D., Qiu, R., Tang, Y., & Du, C. (2017). Non-thermal plasma technology for organic contaminated soil remediation: A review. *Chemical Engineering Journal*, *313*, 157-170.

CHAPTER 4

POSSIBILITIES OF USE OF OLIVE TREES AS AN ORNAMENTAL PLANT

PhD. Suna BAŞER[1]

[1] Olive Research Institute, İzmir, Türkiye. ORCID iD: 0000-0003-2468-2643, E-mail: suna.baser@tarimorman.gov.tr

INTRODUCTION

The olive is a plant from the *Oleaceae* family, which can grow up to 10 meters tall, in the form of evergreen shrubs and trees (Sarı and Karaşah, 2019; Özkaya et.al., 2020). Türkiye is very rich in terms of olive genetic resources and the genetic diversity within them. Olive, which grows naturally in areas where the Mediterranean climate prevails, is one of the species with the highest adaptation, can grow in all kinds of soil conditions and is resistant to salt. The olive tree is resistant to biotic and abiotic stress conditions due to its many anatomical (subsoil tuber and stomata and feather structures found only on the lower surfaces of the leaf) and physiological features, and therefore it has a very long life. In Turkey and in the Mediterranean countries, trees of around 1000 years old age and older are encountered (Polat and Tunalıoğlu, 2012; Simkeshzadeh et. al., 2015; Özkaya et.al., 2020), and some of these old olive trees in our country have been registered as monumental trees.

Due to its current geographical location and climatic features, our country is home to many natural species that can be used in urban area arrangements. The preference of exotic ornamental plants instead of natural species in these areas causes the existing diversity to gradually decrease and similar-looking areas to increase. The necessity of meeting the ever-increasing supply of consumers through natural species is quite clear. It is very important to use natural species, to raise awareness on this issue and to contribute to sustainability (Sarı and Karaşah, 2019; Kazaz et al. 2020). Sustainable agriculture is aimed at preserving existing resources and using them in the most efficient way possible, and olives are among the most suitable trees for sustainable agriculture (Tsalikidis et. al., 1999; Özkaya et.al., 2020). At the same time, the olive tree, which is accepted as the symbol of the mediterranean civilization, is a valuable plant with historical and cultural value and natural heritage feature (Arnan et al. 2012; Polat and Tunalıoğlu, 2012; Simkeshzadeh et. al., 2015).

Olive trees have a very large use as traditional medicine, cosmetics and ornamental plant, especially food. Olive is a preferred tree in landscape designs with its dendriological features such as color, texture, shape and size and visual quality value. It can also be used in surfaces that receive sunlight, terraces and roof gardens, building entrances, shopping and business centres, lounges and even as bonsai (Sarı and Karaşah, 2019; Şahin, 2020).

With this study, it is aimed to examine the different uses of olive trees, which are of great economic importance, as ornamental plants and to evaluate their cultural, visual and aesthetic contributions holistically.

1. AESTHETIC VALUE

1.1. Use in Landscape Designs

In landscape, some plant taxa have increased importance in landscape design, having aesthetic, functional and all or many of the ecological tolerance features (Güneroğlu and Pektaş, 2022).

Trees are plants that give meaning to their space through their measurements, textures, shapes and color indicators, integrating with this area to make it attractive to people. In this context, olive is among the rare trees that can be examined with its visual quality value, dendrological characteristics (color, texture, shape, size) and similar parameters (Polat and Tunalıoğlu, 2012). Olive trees are used for different purposes in landscape design projects due to their form (URL-1). Olive trees are grown to produce olives or olive oil, as well as occasionally grown as ornamental trees for landscape designs in many parts of the world (Mehdi et.al., 2011).

The olive tree, which has been primarily assessed economically by people for centuries, is an important natural landscaping element with visual value, creating natural and historical values and original landscaping patterns in urban and rural landscaping (Figure 1), as well as a valuable contribution to healthy living (Tsalikidis et.al., 1999; Polat & Tunalıoğlu, 2012).

Figure 1: Landscape architecture with olive trees (URL-2)

The olive tree has interesting appearances with its trunk, leaf, flower and fruit colors (Polat and Tunalıoğlu, 2012, Güneroğlu and Pektaş, 2022) (Figure 2). The trunk of olive trees native to the Mediterranean climate is usually corrugated and curved in older individuals (Sarı and Karaşah, 2019).

Figure 2: Olive; flower, fruit, leaf and trunk appearances (Original by Başer)

The shape of the trunk as a biological feature of the olive tree changes dynamically according to the development of each branch, and as the tree ages, folds and protrusions appear on the trunk. Over time, these formations take an active role in the living materials used in landscape design projects (URL-1). In young trees, the leaves are smaller and dark green. The leaves are light green and the lower parts are matte and silver green. Ideal for color contrast with gray color leaves. Flowers in the olive bloom from April to May, from under the leaves on the two-year-old branchlets and shoots, small whitish-yellow color, cluster-shaped, fragrant (Mehdi et. al, 2011; Efe et. al., 2013; Kılıç et. al., 2017).

The prominent features of *Olea eurapaea* L. in landscape designs (Güneroğlu and Pektaş, 2022):

- Aesthetic properties: Leaf, fruit, evergreen
- Usage purposes: Alle (plants with remarkable aesthetic properties, single-stemmed and branching from above), border (plants of different sizes and dense structures), background (evergreen, dark green leaves and tall plants), solitary (tall plants used singularly to attract attention in design with features such as form, texture, color), group (plants that are in contact, capable of forming associations with the same or different species), display screen (1.5-2 m or higher, dense and evergreen plants), noise screen (evergreen and deciduous plants with large and feathered leaf tissue), shading (tall plants with a wide canopy),
- Usage areas: Parks and gardens, sloping areas, arid areas (Figure 3).

Figure 3: Use of olive tree in landscape design (Original by Başer)

Today, the drought created by global warming has changed the preferred plants in landscape studies. Thanks to its olive tree durability, it has been among the preferred plants in many landscaping works in recent years and is increasingly used. With its resistance to difficult climatic conditions and its unique natural form, it is suitable for use in medians, parks and gardens (Figure 4) (Simkeshzadeh et. al., 2015; URL-1).

Figure 4: Use of olive tree in different areas (Original by Başer & İsçi)

The olive tree adapts to drought and poor soil conditions to some extent, its dense leaves keep the summer temperature low and provide shade, it is resistant to wind, due to these important properties, it can be preferred as an ornamental plant in hot dry climates. Among its aesthetic qualities, the texture and variation in the size of the trunk and canopy, as well as the form texture and color of the gray-silver leaves, are features that greatly contribute to the creation of contrast in the garden (Tsalikidis et.al., 1999).

Due to the fact that the leaf form is thin and long and the color is dark green and silvery, which is the effect of cold colors; when viewed from a distance, a wideness, spaciousness can be felt in the space. It can be used to show the area wider in areas where landscaping will be applied. Olive trees in the form of shrubs can often be used to delimit a place in the area. The visual impact of the old species used in the form of trees is quite high due to the forms that emphasize naturalness in the area where they are located. (URL-1).

The olive tree can be planted all year round with proper preparation. If landscaping is to be done in an area with olive trees, it should be kept in the plan and included in the design to create an immediate impact and preserve the character of the existing landscape (Figure 5).

Figure 5: Preserving the character of the current landscape (URL-3).

In plans that require uniformity and a large number of olive trees are repeated, a choice between new olive dwarf varieties can be made depending on the type of design and the size of the site. The more twisted and deformed the olive tree is when it is utilized as a specimen tree, also more character it has and the stronger it influences the garden's character (Tsalikidis et.al., 1999; Leva and Petruccelli, 2011).

Amphisis, Manzanilla, Spain olive varieties can be used as screen, group planting and background tree in green areas with its wide oval form and fine-medium coarse texture. Gorgan, Kroneiki, Mishen, Roughani, Sevillana, Valanolia and Zard olive cultivars, with round form and medium texture, which could be used as specimen tree to plant in lawn. Rashid variety is suitable for use as accent, screen and frame plant with its long oval form and coarse texture (Simkeshzadeh et. al., 2015).

1.2. Use in Xeriscape

One of the agricultural areas where water is used intensively today is irrigation in landscape designs. The use of xeric landscape studies, which is an approach of irrigation programs that are compatible with nature, sustainable, adopting the economic use of water, is becoming increasingly important due to the increasing negative effects of climate change (Çöp and Akat, 2021). In xeric landscape designs (Figure 6), olive trees are quite suitable candidates with their aesthetic appearance, adaptation to ecological and morphological conditions, and moderate water demand.

Figure 6: Use of olive trees in xeric landscape (URL-4).

1.3. Use in Edible Landscape

Today, the gradual decrease in green areas has led to a turn to ecological design solutions in order to protect existing resources and support natural processes. In this context, edible gardens contribute with their economic features as well as providing healthy and fresh food. Edible gardens, which encourage their users to learn and socialize, consist of very important plant taxa with their aesthetic properties (leaves, flowers, fruits and color, form, texture in trunks) (Çelik, 2017; Güneroğlu and Pektaş, 2022).

Today, with the inclusion of small-scale agricultural landscape works such as edible gardens, hobby gardens and permaculture in urban landscapes, existing lands have started to be evaluated with innovative approaches. The use of edible plants, which are becoming increasingly important, is increasing in areas such as parks, residential gardens, roof and vertical gardens and school gardens. Woody plants with edible fruit properties, which have a great benefit to the urban landscape compared to other ornamental plants, are important living materials used both visually and functionally (Çelik, 2017; Güneroğlu and Pektaş, 2022).

The use of woody plants with natural edible fruit characteristics should be included in urban landscapes and their dissemination should be ensured (Figure 7). The olive tree is also very suitable for use in edible landscape designs due to its many aesthetic and functional features.

Figure 7: Use of olive trees in edible landscape (URL-5).

1.4. Use in Ecological Living Park

Fruit trees and other ornamental plants can coexist as a beautiful combination of functionality and aesthetics in a well-designed space. Fruit trees make many positive contributions to urban life:

- They provide visual aesthetics to the city with their unique features, pleasant smells and aesthetic beauties (flowers, colors) that they offer to nature,
- They encourage people to connect with nature,
- They improve the quality of life,

- Fruit trees create an ecosystem and habitat for animals and plants in cities and increase urban biodiversity,
- The use of fruit trees provides a wide range of useful environmental benefits from clean air to energy costs and sustainability of green areas (Çelik, 2017; Aykun Dikmen and Yılmaz, 2021).

The rapid growth of cities around the world in recent years has forced the protection of areas that provide interaction between the city and the natural-rural environment and play a vital role in ensuring urban health. The 'OLIVELO Ecological Common Living Area on the City Side of Izmir', which is still under preparation, is a good example of these areas (URL- 6)

Figure 8: OLIVELO Ecological living park (URL-7).

Olive trees form an important part of the vegetation in this area (Figure 8). Wild olives with economic value have been largely grafted and protected due to their involvement in natural agricultural activity. One of the main objectives of the project is to protect the olive presence in the field, to increase their numbers, to carry out agriculture with traditional methods in an ecological context and to ensure its sustainability. While raising awareness about the olive oil that needs to be produced at the highest level due to its extremely rich contents, it is also very important that it is an essential individual of the forest ecosystem near which it is located. In the project, olive was used as a complementary and prime contributor tree species to agricultural production (URL-6).

1.5. Use in Espalier

Espalier is the practice of shaping plants flat on a vertical plane, plants are usually firmly attached to geometric-shaped structures such as walls or wires and take the shape of these structures (Figure 9). With this method, which takes effort and time to apply, aesthetic appearances can be created in small spaces and more plants can be used in the area. When used in front of walls where plant development is difficult, plant leaves add movement to the visual and an interesting appearance is formed with different shapes applied (Erduran Nemutlu, 2012).

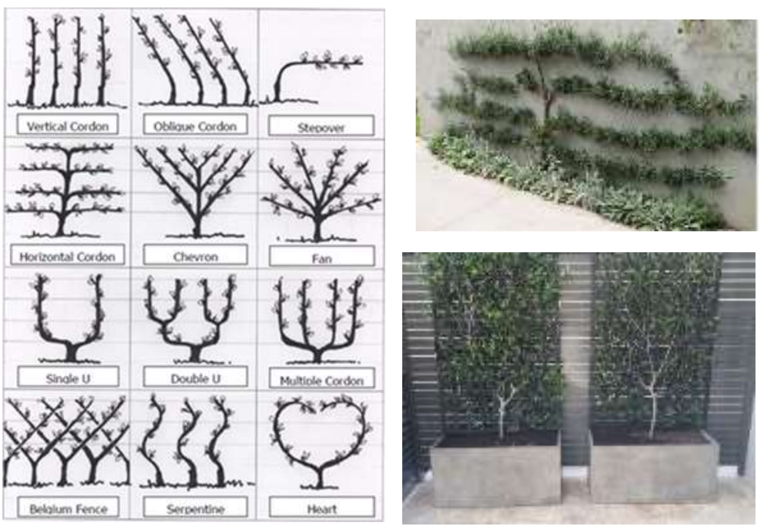


Figure 9: Espalier olive tree (URL-8, URL-9, URL10).

In today's landscape studies, espalier applications are of great importance in terms of enriching the green texture of cities. It is very important that the plants used in the espalier application have very flexible side branches, attractive flower, fruit or trunk shell in terms of the result to be achieved. Many plant species are applied to formal or informal models (Figure 9). The 'Cord system', which is the training of a tree to grow in a single direction, forms the basis of formal shapes. Different shapes can also be formed by creating multiple cords on the same plant. Espalier's regular care is required to be permanent, so it is a costly practice, but regular maintenance is also a desirable feature for urban trees (Erduran Nemutlu, 2012; URL-9).

1.6. Use in Bonsai

The bonsai cultivation (potted tree), defined as the art of growing miniature trees in Japanese culture, has led to the development of a certain art and technique. This tree that is planted in the pot is fragile, so it requires special care, takes a long time to make and allows a person to try new ideas, to create different approaches (URL-11).

Figure 10. Olive bonsai indoor (cascade style) and outdoor uses (URL-12, URL-13).

Bonsai art combines both horticultural and aesthetic techniques to shape the beauty of a plant from its natural state. To create a bonsai tree, it is necessary to apply the correct pruning and potting techniques and to know where to place the tree. The wild olive tree is a hardy plant that is easy to grow and produces exceptional bonsai trees. It can be grown indoors and outdoors as long as it is protected from frost (Figure 10). It is a recommended tree type for those who want to learn the art of bonsai, and its popularity is increasing rapidly. Styles such as sumo, gradual, semi-gradual and informal upright can be applied for olive trees (URL-11).

1.7. Use in Pots

Growing the olive tree in pots has an increasing use both because it facilitates winter care and allows different arrangements for decorative purposes. Due to the fact that they do not receive enough sunlight, the olive tree is not suitable for growing indoors (URL-14). Olive trees are preferred in the arrangement of home gardens (Figure 11), roof gardens, entrances of shopping centers in pots. The use of terracotta and clay pots of different sizes is common.

Figure 11. Olive trees use in pots (URL-14).

2. HISTORICAL AND CULTURAL VALUES

Monumental trees are defined as trees that have a natural life that can build a bridge between past and present, present and future, reaching measures far above the usual measures of their species in terms of age, trunk diameter, canopy diameter and height, or that have a special place in mystical culture and folklore in local history (Sabuncu et al., 2013; URL-15). Monumental trees have remarkable physical features such as forks, candlesticks, curves, horizontals, which have a visually aesthetic appearance or deviate significantly from the natural appearance. It has development qualities that differ from its counterparts in terms of its natural lifestyle, exhibiting strange examples of fusion and coexistence, such as the coexistence of two or more species on the same stem and root. It is the group, rows or single trees that complete the urban texture and have an effect on the image of the city. When olive trees are evaluated in this sense, they are an important tool that gives identity to the areas where they are located (URL-15; URL-16; URL-17).

Figure 12: The 1651-year-old olive monument tree located in the Kırkağaç region of Manisa (URL-16).

It is very important that these trees are not subject to ornamental plant trade, that the necessary precautions are taken, that the areas where they are located are included in the urban landscape and that they are transferred to future generations.

CONCLUSION

The purpose of landscaping work is to provide a beautiful and efficient environment for people in urban and rural areas, in terms of cultural, economic and aesthetics. In this regard, olive trees have a wide range that can be used for almost any landscape work.

Temperature increases due to climate change cause the decrease in natural water resources and therefore wetlands. In the near future, when the growing and care conditions will be increasingly difficult, it will be important to use the species with functional and ecological tolerance characteristics as well as the aesthetic appearance in the species to be used in landscape studies. Olive trees are excellent choices for xeric and edible landscape designs, given their functional features and ability to adapt to ecological and morphological conditions, low water requirements.

As a result, the olive tree, which is notable for its economic importance, assumes its position as a valuable species in the field of ornamental plants due to its aesthetic, functional and cultural characteristics.

REFERENCES

Arnan, X., Lopez, B.C., Martinez-Vilalta, J., Estorach, M., Poyatos, R., (2012). The Age of Monumental Olive Trees (*Olea europae* L.) in Northeastern Spain. Dendrochronologia 20 (2012) 11-14.

Aykun Dikmen, B., Yılmaz, H., (2021). Erzurum Kentsel Açık Yeşil Alanlarında Meyve Ağaçlarının Kullanımı. Atatürk Üniv. Ziraat Fak. Derg., 53 (3): 262-272

Çelik, F., (2017). The Importance of Edible Landscape in the Cities, Turkish Journal of Agriculture - Food Science and Technology, 5(2): 118-124

Çöp, S., Akat, H., (2021). Kurakçıl Peyzaj Çalışmalarında Bitkisel Uygulamalar: Muğla-Sarıgerme Halk Plajı Örneği. Mehmet Akif Ersoy Üni. Fen Bil. Enst. Dergisi 12 (2): 263-277.

Efe, R., Soykan, A., Cürebal, İ., Sönmez, S., (2013). Dünyada, Türkiye'de, Edremit Körfezi Çevresinde Zeytin ve Zeytinyağı, Edremit Belediyesi, Balıkesir, 335s.

Erduran Nemutlu, F., (2012). Bitkisel Tasarımda Espalier Kullanımı ve Çanakkale Örneğinde İrdelenmesi. Atatürk Üniversitesi Ziraat Fakültesi, 43 (1), 89-100.

Güneroğlu, N., Pektaş, S. (2022). Yenilebilir Meyve Özelliği Olan Odunsu Bitki Taksonlarının Peyzaj Mimarlığındaki Önemi: KTÜ Kanuni Kampüsü Örneği. Türkiye Ormancılık Dergisi, 23(1): 79-89.

Kazaz, S., Kılıç, T., Doğan, E., Mendi, Y.Y., Karagüzel Ö., (2020). Süs Bitkileri Üretiminde Mevcut Durum ve Gelecek. Türkiye Ziraat Mühendisliği IX. Teknik Kongresi, Bildiriler Kitabı-1: 673-698.

Kılıç, T., Ergür, E.G., Kazaz, S., Gül, A., (2017). Meyve Özellikli Odunsu Bitki Türlerinin Peyzaj Amaçlı Bitkisel Tasarımda Kullanılabilme Olanakları. VI. Süs Bitkileri Kongresi Bildiriler Kitabı, 347-357.

Leva, A. R., Petruccelli, R. (2011). Dwarf olive trees for ornamental use: A morphological evaluation. The Journal of Horticultural Science and Biotechnology, 86(3): 217-220.

Mehdi, R.M., Raziyeh, S., Mohammad, S.M., (2011). A Study on Traditional Usage of Olives. Journal of Applied Sciences Research, 7 (7): 1186-1187.

Özkaya, M.T., Tunalıoğlu, R., Boz Yılmazer, E., Aktepe Tangu, N., Kumral, N.A., Tezcan, H., Köseoğlu, O., Sevim, D., Irmak, Ş., Durlu Özkaya, F., (2020). Zeytin Üretiminde Mevcut Durum ve Gelecek, Türkiye Ziraat Mühendisliği IX. Teknik Kongresi Bildiriler Kitabı I, 647-671.

Polat, Z., Tunalıoğlu, R., (2012). Zeytin'in (*Olea europaea* L.) Ekolojik, Ekonomik ve Görsel Değerlerini Bir Bütün Olarak Görebilmek. Zeytin Bilimi 3 (2) 2012, 115-122.

Sabuncu, A., Doğru, A., Özener, H., Turgut, B., Halıcıoğlu, K., (2013). Anıt Ağaç Envanterinin Coğrafi Bilgi Sistemleri ile Oluşturulması. TMMOB Coğrafi Bilgi Sistemleri Kongresi, Ankara

Sarı, D., Karaşah, B. (2019). İç ve Dış Mekânlarda Kullanılabilecek Tıbbi-Aromatik Bazı Süs Bitkileri, SETSCI Conference Proceedings 4 (7), 152-156, Samsun, TURKEY.

Simkeshzadeh, N., Etamadi, N., Mobli, M., Baninasab, B., (2015). Use of Olive Cultivars in Landscape Planning Regarding Form and Texture. J. Agr. Sci. Tech., Vol.17: 717-724.

Şahin, M., (2020). Ornafruit: Fruit Species for Ornamental. Ornamental Plants: with Their Features and Usage Purposes Principles, 397-424.

Tsalikidis, I., Voyiatzi, C., Tamoutseli, K., (1999). The Use of the Olive Tree in Ancient and Contemporary Garden Design of the Mediterranean Region. 3nd Int. ISHS Symp. on Olive Growing Eds. LT. Metzidakis and D.G. Voyiatz is Acta Hort. 474.

URL-1. Zeytin Ağaçlarının Peyzaj'da Kullanımı, https://www.academia.edu/10240963/Zeytin_A%C4%9Fac%C4%B1n%C4%B1n_Peyzajda_ki_%C3%B6nemi, Academia (Access date: 01.06.2022)

URL-2. https://landezine.com/uliveto-by-surfacedesign/, Lanzedine Landscape Architecture Platform, (Access date: 01.06.2022)

URL-3. Gardenista, https://www.gardenista.com/posts/simple-landscaping-ideas-10-genius-gardens-with-an-olive-tree/, Terremoto Landscape Architecture, (Access date: 13.06.2022)

URL-4. https://www.pinecrestgardens.org/botanical/the-dry-gardens, Pinecrest Gardens, (Access date: 13.06.2022)

URL-5. https://pinehouseediblegardens.com/#/eastward/, Pine House Edible Gardens (Access date: 06.07.2022).

URL-6. OLIVELO, https://olivelo.izmir.bel.tr (Access date: 06.07.2022)
URL-7. Ekolojik Yaşam Parkı, http://www.izmirhalleri.com/?p=1981, (Access date: 10.07.2022).
URL-.8. https://tr.pinterest.com/pin/183029172325914028/, (Access date: 10.07.2022).
URL-9. Espalier, Stoneman's Gaden Center, https://irp-cdn.multiscreensite.com/cf97b91f/files/uploaded/Espalier.pdf, (Access date: 13.07.2022).
URL-10. Espaliered Olives, https://www.houzz.com.au/photos/gardening-design-alfresco-troughs-with-espaliered-olives-modern-garden-sydney-phvw-vp~126401295, Mosarte Australia (Garden Landscape Supplies) (Access date: 13.07.2022).
URL-11. Growing and Maintaining Your Bonsai (Ebook), Cultivea, https://www.cultivea.com/wp-content/uploads/2022/04/Ebook-Bonsai-UK.pdf, (Access date: 21.07.2022).
URL-12. Bonsai Empire, https://www.bonsaiempire.com/tree-species/olive, (Access date: 21.07.2022).
URL-13. https://www.pinterest.co.uk/pin/832391943635783583/?mt=login, (Access date: 30.07.2022).
URL-14. https://plantura.garden/uk/trees-shrubs/olive-tree/olive-trees-in-pots, (Access date: 30.07.2022).
URL-15. https://www.resmigazete.gov.tr/eskiler/2012/07/20120719-3.htm, (Access date: 03.08.2022)
URL-16. https://www.anitagaclar.gov.tr/detail/zeytin-agaci-oleae-europae-l-/143, Anıt ağaçlar (Access date: 03.08.2022)
URL-17. https://www.anitagaclar.gov.tr/nasil-olusur/tur-bilgileri/8, (Access date: 03.08.2022)

CHAPTER 5

PERMACULTURE AND FOOD FOREST

Agri. Eng. Irmak ESKIAR[1]

Prof. Dr. Hatice DUMANOĞLU[2]

[1] Ankara University, Faculty of Agriculture, Department of Horticulture, Ankara, Türkiye
eskiarirmak@gmail.com, Orcid ID: 0000-0002-9666-5984
[2] Ankara University, Faculty of Agriculture, Department of Horticulture, Ankara, Türkiye
dmanoglu@agri.ankara.edu.tr, Orcid ID: 0000-0002-7099-7630

1. INTRODUCTION

The term permaculture was coined by the Australian Bill Mollison as an abbreviation of "permanent agriculture" (Bell, 1992). While teaching at Tasmania University in 1968, he turned to this field and developed the system he called "permaculture" in 1974 with his student David Holmgren (Mollison, 1991). Permaculture is an approach that relates to different disciplines, strategies, and techniques (Hemenway, 2009). Gökmen (2009) defines permaculture as “system designs that are based on the harmony of human and nature, that observe and imitate natural system, apply the least interference to it, and that can meet their own needs”. Permaculture has been developed based on soil fertility, natural farming philosophy, and different tree and plant systems to increase awareness in the society against the damage caused by human activities to nature (Najafidashtape & Hamamcıoğlu, 2018).

The permaculture design system has many principles. These are ethical and design principles. The ethical principles of the permaculture design system are caring for the world, caring for people, and using excess time, money, and energy to care for the world and other people (Mollison, 1991; Bayar, 2016; Parlak, 2018). To the earth, atmosphere, soil, water, forests, micro-habitats, biodiversity, in short, all living and non-living beings; by paying attention to the need for food, shelter, education, work, and pleasant human relations, people are also taken care of. In permaculture design, every living thing has its own basic life ethic. For example, even if a tree has no commercial value, it does its part in nature, recycles biomass, produces oxygen and carbon dioxide, shelters small animals, and produces soil. Therefore, the main thing in permaculture is cooperation, not competition (Mollison, 1991).

Considering the design principles of permaculture, "observe and interact" is at the forefront of the principles. Nature and human are in a state of interaction and a design suitable for the region with a detailed observation is essential for the continuity of the system without affecting the nature (Yeniçeri, 2018).

"Catch and store energy" and "obtain a yield" are the other two design principles of permaculture. According to Mollison (1991), permaculture systems aim to turn the flow of nutrients and energy into a cycle. So, for example, kitchen scraps are recycled as compost, animal manure is used to produce biogas or transferred to the soil, household wastewater flows into the garden, green manure plants are left in the ground, and leaves are used as mulch around trees. In a good design, the energy collected and stored is used effectively to maintain the system (Francis, 2008).

With the principle of "apply self-regulation and accept feedback," self-regulating systems can be designed in permaculture. The principle of "use and value renewable resources and services" emphasizes the importance of renewable natural resources in permaculture design (Francis, 2008). With the sixth principle of permaculture, "produce no waste", systems are designed to benefit from all pollutants. This principle is the recycling strategy that minimizes pollution and waste. Recycling is the process of actively reducing material to its more essential components with an input of energy (Holmgren, 2020). The symbol that conforms to this principle is the worm. The worm lives by consuming plant wastes. It converts them into humus, which improves the soil environment for soil microorganisms and plants. Thus, the worm, like all living things, is part of a network in which the outputs of one are the inputs of the other (Francis, 2008).

The seventh principle of permaculture is "design from patterns to details". A functional and self-organizing design aims to place each element in a way that serves needs and accepts the products of other elements. This principle focuses on the different relationships that bring elements together in integrated systems and advanced methods of designing communities of plants, animals, and humans to benefit from these relationships. The eighth principle is "integrate rather than segregate." Since, in nature, the connections between the elements, from the inner workings of organisms to entire ecosystems, are important, permaculture strongly emphasizes the construction of mutually beneficial and symbiotic relationships. The ninth principle is "use small and slow solutions." Systems should be designed to perform functions on the smallest scale that is practical and energy efficient. For example, the rapid response of crops to soluble fertilizers is often short-lived; Manures, compost, and natural rock minerals often provide more sustainable and balanced plant nutrition (Holmgren, 2020).

The tenth permaculture design principle determined by David Holmgren is "use and value diversity". Diversity within species and populations, including genetic diversity, is critical to the long-term stability of systems. Permaculture is equally concerned with creating new bioregional diversity from the melting pot of nature and culture it inherited (Holmgren, 2020). Another permaculture design principle by Holmgren is "use edges and value the marginal". This principle operates from the premise that the value and contribution of edges and the marginal and invisible aspects of any system can not only be recognized and protected, but these aspects can be extended can increase system productivity and stability (Francis, 2008). Edges are areas with different ecological structures. At the boundary between two ecological areas (soil/water, forest/grassland, estuary/ocean, field/orchard), productivity increases because the resources of both systems are available. In addition, edges often have their own unique types. Edges define areas and divide them into manageable sections. Edges are valuable to permaculture in implementing and maintaining part of the designed system (Mollison, 1991).

The twelfth principle is "creatively use and respond to change". This principle refers to consciously and collaboratively benefiting from the change. As an example, nitrogen-fixing pioneer plants grow, saturating the soil with nitrogen. After completing their task and spreading seeds, these plants die and are replaced by various fruit trees. Nitrogen-fixing seeds in the soil germinate again and continuity is ensured as the insurance of the system (Yeniçeri, 2018).

Apart from these principles, the principle of "efficient energy planning" is an important permaculture design principle put forward by Bill Mollison. The placement of plants, animals, and structures according to zones and sectors is the key point of this planning (Mollison, 1991; Hemenway, 2009; View, 2020) (Table 1).

Table 1. Changes in factors and strategies in zone planning as distance increases (Mollison, 1991)

Factor or Strategy	Zone I	Zone II	Zone III	Zone IV
Main design for:	House climate Domestic sufficiency	Small domestic stock and orchard	Main crop, forage,	Gathering, forage, forestry, pasture
Establishment of plants:	Complete sheet mulch	Spot mulch and tree guards	Soil condition and green mulch	Soil conditioning only
Pruning of trees:	Intensive cup or espalier, trellis	Pyramid and built trellis	Unpruned and natural trellis	Seedlings, thinned to selected varieties
Selection of trees and plants:	Selected dwarf or multi-graft	Grafted varieties	Selected seedlings for later grafts	Thinned to select varieties, or managed by browse
Water provision:	Rainwater tanks, well, bore, reticulation	Earth tank and fire control	Water storage in soils, dams	Dams, rivers, bores and wind pumps
Structures:	House/glasshouse, storage integration	Greenhouse and barns, poultry sheds	Feed store, Field shelter	Field shelter grown as hedgerow and woodlot

One of Bill Mollison's principles, "using biological resources", aims to use plants and animals in a permaculture system to save energy and do the farm work wherever possible. Biological sources should be used instead of mechanical or agrochemical solutions. Plants and animals are used to obtain fuel and fertilizer, combat pests and weeds, create nutrient cycling, habitat expansion, soil aeration, fire and erosion control, and similar tasks. The development of biological resources in the region requires a long-term investment that requires thought and management at the planning stage, as it is the key strategy to achieve energy recycling and create sustainable systems. Green manure should be preferred instead of nitrogen fertilizer, grass-eating geese and shortgrass instead of lawn mowers, biological control instead of pesticides, chicken or other animals instead of rotary hoes, herbicides, and artificial fertilizers. In the early stages of permaculture, non-biological resources (fossil fuel-powered machinery, artificial fertilizers, technical tools) can be beneficial if used carefully and appropriately to create sustainable, long-term systems and durable physical infrastructures (Mollison, 1991).

Animals: It is important to use animals in the system. Chickens scrape and dig in the ground, looking for worms, insects, and roots. In grassy or thorny areas, chickens or goats destroy all vegetation, aerate the soil and fertilize the area (Mollison, 1991).

Pest control: Umbrella-shaped, multi-part plants such as dill, fennel, daisy, and marigold planted next to the gardens attract predatory insects (insects that feed on insects that harm plants), while a pond to be built in the garden attracts insect-eating frogs. Suitable birdhouses or thorn bushes provide a natural habitat for insectivorous birds. In addition, fungi, beneficial bacteria, or roundworms are also used to combat crop pests and enable pest or insect control for many plants (Mollison, 1991).

Fertilizers: All animals recycle nutrients by eating plants or other animals and depositing nitrogen fertilizers in orchards. For example, duck manure in a large pond or pool becomes a food source for many fish species. Worms aerate the soil, provide humus and plant food, or can be collected as chicken or fish feed. Garden scraps are recycled by worms, thus preventing potential pests and diseases. Many fast-growing and deeply rooted tree species go too deep into the soil and absorb nutrients that are out of reach of more surface-rooted plant species. The leaves of these trees can then be used to make mulch and create humus. Leguminous plants (such as lucerne, bean, leucaena, acacia) contain rhizobium bacteria in their roots and feed the soil by processing the nitrogen they receive from the air in their root tubers. Plant growth can be increased by 80% by inoculating these bacteria on other soils. Other non-legume plants such as alder, autumn olive, and casuarinas also have nitrogen-fixing properties. Legumes such as broad beans and peas are used as a lower plant layer in orchards. If these are mowed or mixed with the soil before flowering, nitrogen is released from the root tubers. Many of these plants, especially legumes, also have different uses; For example, Siberian pea bush and tagasaste not only strengthen the soil, but are also used as a windbreak, chicken feed (seeds), and cattle feed (leaves) (Mollison, 1991). Biological solutions such as compost, animal manure, legumes, green manure, mulch, mushroom compost, vermicompost, and seaweed should be used as fertilizers and soil healers (Pritchard, 2016).

Other biological resources: These are bees (by pollinating flowers and collecting nectar), thorny plants (for making natural hedges), allelopathic plants (plants that inhibit weed growth), and dogs (especially sheepdogs) (Mollison, 1991).

The critical point in the effective use of biological resources is management. If not managed well, these resources get out of control, often causing pollution and becoming harmful, resulting in cattle eating the saplings and goats plunging into the orchard. Most management strategies are based on timing. For example, chickens benefit by dropping their manure and eating insects and weed roots, but should not be brought into a mulched orchard as they can distribute the mulch while digging for foraging insects. If the orchard is not mulched but prepared with a lower plant layer of nitrogen-fixing legumes; chickens can be allowed to enter and eat fallen fruit, insects, and greenery into the garden. Mulch in chicken coops can be covered with stones or a metal mesh (Mollison, 1991).

"Energy cycling" is another principle put forward by Bill Mollison. This principle in permaculture systems aims to stop the flow of nutrients and energy out of the area and turn them into a cycle. For example, kitchen scraps are recycled as compost, animal manure is used to produce biogas or transferred to the soil, household wastewater flows into the garden, green manure plants are released back into the soil, and leaves are used as mulch around trees. Nature itself is a vast and highly complex recycling system that continually transforms matter and energy from one form to another. If these natural cycles can be recreated in permaculture designs, the system will be able to grow through long-term capture and storage of energy in the designed land (Mollison, 1991). Living systems grow when energy goes into the cycle in nature. Permaculture designs seek to capture the energy and create life-sustaining cycles to increase the growth of life systems. For example;

- Wind and solar are captured to generate electricity.
- Fallen leaves are collected to produce mulch or compost.
- Kitchen waste is used in the worm farm to feed the worms.
- Domestic gray water is diverted into the garden to provide water and nutrients to the trees.

- When green manure plants begin to bloom, they are mixed into the soil to provide organic matter.
- Animal feces are fermented and used as fertilizer. This resource is also used to produce biogas as fuel.
- Rainwater is collected and stored in an elevated position so that it is used when needed in a lower position without the need for energy (Jenkins, 2018).

Rainwater harvesting is an umbrella term that encompasses a myriad of techniques used to capture, and spread over the land rainwater, drinking, cooking, washing, watering plants, and in some cases generating hydro-energy. While rainwater tanks are familiar, harvesting methods are much more diverse than that, making rainwater a multifunctional element in the intelligent permaculture design of the land (Jenkins, 2018).

If rainwater, sunlight, kitchen scraps, and animal manure are collected and used in the orchard, energy is stored in fruit trees (Mollison, 1991). Five complementary techniques should be used together to increase water efficiency in the garden. These techniques include producing soil rich in organic matter, shaping the land to capture water and direct it where it is needed, using drought-resistant plants whenever possible, intensive planting to shade the soil, and mulching. Because these techniques are ingeniously combined, they not only save water but also retain water in the soil and protect plants from drought. Also, mulch and rich soil provide high levels of organic matter and speed up plant growth. In a good design, correctly chosen techniques intertwine with each other and create synergy by completing each other (Hemenway, 2009).

Mulching is the process of covering bare soil with different materials and is the most minor intervention that can be made to mimic the natural cycle that nourishes the soil (Bell, 1992). Mulch is the key strategy for retaining moisture and forming humus. Cardboard, newspaper, seaweed, leaves, well-burned manure, old cotton or woolen clothes, nylon, wood chips, old carpets or felt, straw, clover and other seedless straw, wood chips, bark, corncobs, shredded cornstalks, grain stubble and bark, sand, pine needles can be mulch material (Mollison, 1991; Hemenway, 2009).

A 5-10 cm thick (or thicker) layer of mulch further reduces moisture loss by slowing water evaporation from the soil, keeping plant roots cool, and reducing transpiration. In addition, organic mulches absorb rainwater rather than flow it over, and as the organic mulch material rots, it provides humus to the soil; this, too, increases the soil's water-holding capacity. Mulch also prevents erosion, preserves soil structure, and softens temperature fluctuations (Hemenway, 2009). Another benefit of mulch is that it suppresses annual weed seeds in the soil. In addition, a colloidal mass forms on the surface with organic mulch, which protects plants from drought. Colloids are tiny fibrous organic particles that swell with water, forming a gel-like consistency, thereby trapping water (Bell, 1992). Live mulch using ground cover plants is preferred, especially in large areas where it is impossible to carry cover material (Öcal, 2020). Perennials such as red fescue and Dutch white clover, annual grasses that need to be mown in place after one season or lightly mixed with the soil, or short-term green manure plant species such as common vetch can be used as ground cover plants. The roots of cover crops go deep into the soil, loosen it and allow organic matter to reach deep (Hemenway, 2009).

Compost is obtained by decomposing biochemically decomposable wastes by using the oxygen by organisms. After laying it in the soil, it mixes with the soil ecosystem, increases diversity by supporting the biological processes in the soil, and turns into humus over time. Compost is a mixture that improves soil structure. If rich mineral content is provided, then a much richer and more helpful product is obtained from raw animal manure. For this reason, composting the manure increases the yield, taste, and nutritional value of the product, while providing an additive that does not deplete the soil richness. Humus is the last state that compost can get, that is, there are no nitrogen and phosphorus compounds left in it, which continue the decay process. One of the most effective tools of waste management is composting. Compost, formed by gathering some amount of organic matter together and turning it into a heap, can be obtained in many different ways. The components of compost are air (oxygen), water (moisture), heat, and organic matter (nitrogen/carbon balance).

- Air (oxygen): Since air is one of the most important factors for composting, it should be ensured that air enters all parts of the compost pile.
- Water (moisture): The ideal humidity ratio for compost is thought to be 30%.

- Heat: When the composting process is planned correctly, the required temperature will emerge thanks to the metabolism of living things in the compost pile (Eliades, 2020).

In order for composting to start, the materials containing the two basic elements (nitrogen and carbon) must come together in the right ratio. Materials with a high carbon content are "brown" materials that decompose very slowly, such as sawdust, cardboard, dry leaves, straw, branches, and other woody or fibrous materials. Materials with a high nitrogen content are "green" materials that decay very quickly, such as grass clippings, fruit and vegetable scraps, animal manures, and green leafy materials. When composting, materials containing 2/3 carbon materials and 1/3 nitrogen are used. In other words, one bucket of nitrogen-rich material should be added to every two buckets of dry carbon-containing material (Eliades, 2020).

Bill Mollison's principle of "small-scale intensive systems" aspect as efficiently and sustainably as possible in small manageable land areas; it is about using biological resources and designs that imitate nature, reducing human labor and making use of natural ecological processes, and thus obtaining maximum yield. In smaller manageable areas, yield is achieved in the most ecological, healthiest way possible and with the least effort. Such systems use very little energy and can provide a much higher return on investment (Eliades, 2012).

Although permaculture design is considered to be labor intensive, it focuses more on designing a farm (or garden or city) in the best possible way. A certain amount of manpower is used here. These can be friends and neighbors. Efficient perennials are grown in stages. Mulching for weed control, use of biological resources, alternative technologies that produce and store energy, adequate and measured use of machinery are other critical points (Mollison, 1991).

Small-scale dense systems mean that most land can be used efficiently and meticulously, and the area is under control. The starting point for the control of the land is the door of the house. The meticulous management of the existing land and the very careful use of natural resources are the only strategies that will be sustainable in the future (Mollison, 1991).

2. FOOD FOREST IN PERMACULTURE

Trees are the most successful and most efficient natural energy and matter storers. In food forests, trees share space with many species (Hemenway, 2009). Food forests are three-dimensional designs in which life extends in all directions, up, down, and out (Rockman, 2017). It is a sustainable garden system based on forested ecosystems, consisting of seven main layers of vegetation, from tall trees to ground covers. Food forests are organized into mutually advantageous plant communities, also called plant guilds, that perform tasks such as nutrient accumulation, nitrogen fixation, increasing pollination, attracting diverse useful wildlife, reducing the need for weeding and irrigation, and so on. Guilds are consciously designed plant communities in which plants are selected for specific functions. Plant guilds bring the benefits, strength, and durability of the multifunctionality of natural plant communities to food forest design (Buckley, 2018).

By understanding how nature designs forest systems and how these systems are self-sustaining and self-replicating, these systems can be modeled with productive species. Thus, food can be produced most sustainably with the minimum amount of input for maximum output (Lawton, 2019). Food forests produce food and flowers almost all year, as well as intriguing educational places with their varied rhythms and cycles. In food forests, the lifespan of many garden inhabitants is measured in decades, not years. The character of the food forest, therefore, changes constantly throughout its life. Along with the regular annual cycle of flora, trees, shrubs, and perennials have different lifespans and growth speeds and different responses to seasons and each other. All tiers share light and nutrients in case of undulating green layers from the base of the food forest to the canopy of the tree. In the food forest, as in natural forests, the lower layers first leaf out and attract sunlight each spring. Then the shrubs take on their green cover, and after a few weeks, the trees follow them. Many plants reach their peak size at different times of the season, once again better sharing resources. This collaborative aspect of the food forest has some competition but is actually balanced together. By working with nature rather than struggling, a multi-layered food forest design can be created that acts like a natural forest, producing food and habitat. Food forests, like natural forests, have various layers. A simple food forest has a tree layer at the top, a middle layer of shrubs, and herbs, vegetables, and flowers at the ground layer. Each plant has been chosen for its role, with many functions, such as food, wildlife habitat, herbal medicine, insect attraction, and soil production. Large trees and shrubs are placed in such a way that the sun hits between them, and the plants in the lower layers are placed in sunny or shady places, depending on whether they like light. In the food forest, trees whose leaves cover the ground, whose trunks reach towards the sky, and whose branches fill the space determine the character of the design. In the food forest, trees dominate but do not overwhelm other plants. A prerequisite for healthy and sustainable design is that trees live as integrated partners, not as scattered specimens. However, in a typical conventional garden, these elements remain separate and disconnected from each other (Hemenway, 2009).

On sloping lands, on steep slopes, the most ecological option is to establish a food forest because trees and other perennials hold the soil in place and eliminate the need for plowing soil that causes erosion. Three-dimensional flora creates abundant habitats for birds, small animals, and beneficial insects. Pest problems are reduced, and after the food forest matures, it requires minimal care because dense foliage reduces water needs, suppresses weeds, and self-mulches to replenish and enrich the soil. Because the food forest is usually made up of perennial and self-seeding plants, plowing is not required, and seasonal planting is minimized (Hemenway, 2009). Very high yields are possible due to vertical stacking of up to seven tiers of trees and plants in a single area to create a dense planting system. A microclimate is created by the close arrangement of plants, which allows plants to grow in a protected area without exposure to harsh conditions (Furbeck, 2020). Intensive mixed cultivation of various species creates an environment of biodiversity that allows synergy between plants, helps plants grow, protects each other from pests and diseases, and increases productivity (Eliades, 2012).

Biodiversity ensures a continuous supply of food throughout the year. Food forests use natural predators to eliminate pests, attract birds and other large predators as a living ecosystem, and contribute to natural pest control. Growing different types of plants together makes them grow better. It creates a natural synergy that gives advantages to all the plants related. As a result, plants become more resistant to pests and diseases and more productive. When plants die in nature, they stay in place, they are not uprooted. Instead of uprooting dying annuals, the stem should be cut at ground level so that the roots rot, creating thousands of complex air and water channels in the soil and the tops of the cut plants form a natural layered compost system, such as the forest floor (Eliades, 2011).

The design process of the food forest largely follows the order of observation, vision creation, planning, development, and implementation. Shapes, heights, gaps, and overall dimensions can be changed according to land conditions and preferences of designer (Hemenway, 2009).

A large garden may be large enough for full-height trees, while on smaller lands, biodiversity can be achieved by using dwarf or naturally small species. Plant guild gives unity to this multi-layered garden, and this multifunctional vegetation welcomes beneficial insects, birds, and other wildlife as well as humans. It is not a depressing mass of trees that block light but a multi-layered edible food forest with plenty of sunny clearings and edging areas. While northern designers want to place trees less frequently so that less strong sunlight can reach the lower layers, southern designers prefer to plant more frequently to meet their need for shade. In sunny openings are smaller persimmon trees, plums, cherries, pawpaws, and a few ornamentals such as golden-chain trees and pink-flowered silk trees, which happen to fix nitrogen. Catching the sunlight farther down, dancing with birds, are flowering shrubs and berry bushes. Here and there, when honeysuckle and hardy kiwi vines climb tree trunks, leaving footprints of flowers and fruit behind them. Beneath all of these and on the lighted edges are perennial flower, vegetable, and soil-producing mulch plants (Hemenway, 2009).

The distance between plants depends mainly on their water and light requirements. While arid climate plants need more distance between them, they can be planted very close in hot and humid regions. In cold climate designs, it is necessary to establish very open systems in order to allow light to reach the lower layers and compensate for the lack of heat required for the development. Also, most fruit trees in temperate climates, even in hot and humid areas, need air circulation between the plants to reduce the chance of fungal problems when there are out-of-season rains. The designer can create his own food forest by combining tall and short tree species, climbing plants and grasses according to their height, shade tolerance, and water requirements (Mollison, 1991).

The variety of trees, shrubs, and other vegetation to choose from means that food forest has got diversity as a real forest and as unique as a designer. The designer can mix and blend multiple styles to create a garden that generates food, beauty, habitat, nature conservation, and income (Hemenway, 2009).

To have a few spots in the food forest exclusively:

- Wind barriers (fences and hedges) to be created in open areas will significantly accelerate the development of other plants.
- Trees and woody plants should be planted first as they take time to develop. These are the plants that will determine the shape of the garden. It is important to design according to the full adult height of the trees. When the seedlings are planted too close to each other and grow, they are faced with an overcrowded garden and dense shade. Instead of creating a closed layer of tall trees, gaps should be left to allow sunlight to descend through the mature trees to the ground. The farther north the garden is, the weaker the sun and the more space between the trees will need to leave.
- Initially, lots of nitrogen-fixing and other soil-building plants should be planted. The dense vegetation of the food forest will need plenty of nutrients during its youth period. The fertile soil rich in organic matter created by nutrient-gathering plants will accelerate growth and succession.
- Buying all the plants for the food forest at once can be expensive. For this reason, a small area can be allocated as a nursery for plant propagation such as seed germination and cuttings. It is best to place the nursery in Zone 1. Perennials for ground covers can also be grown here from seed. Trees, shrubs, and herbs can propagate by cutting. By dividing the adult plants, a large number of new plants can be obtained, resulting in a large number of new plants and a large plant population for colonization in the new food forest. They can be grown here for a year or two and then taken to their permanent place. Also, different varieties can be grafted. Nurseries are essential for obtaining large numbers of plants at a low price.

- Open spaces between trees and shrubs can initially be filled with annual vegetables, flowers, nitrogen-fixing cover crops such as clover, and seedlings. The openings will get smaller as the top layers grow and the seedlings are ready to be transplanted (Hemenway, 2009).

The garden, shaped as a seven-layered food forest, includes tall trees, short trees, shrubs, herbaceous plants, ground cover plants, climbing plants, and root layer plants whose subsoil parts are consumed (Hemenway, 2009).

1) Tall-Tree Layer: This layer is the upper layer consisting of edible or trees with other benefits planted with spaces between them so that plenty of light can reach the lower layers. Species with a large and dense crown system, namely classic shade trees such as maple, sycamore, and beech, are not well suited for the food forest. When planting tree species, their height at maturity should be considered so that enough sunlight can reach the soil for other plants (Hemenway, 2009).

2) Low-Tree Layer: In this layer, the development force of the crown system is under control by grafting on dwarf, semi-dwarf rootstocks, or some trees do not form large crowns on their own roots. Trees such as apricot, peach, nectarine, almond, medlar, and mulberry, which can naturally form short trees, can be planted here. Fruit trees that can grow in shade conditions, such as persimmon and pawpaw, can also be used. The crown systems of trees can be pruned in open forms to allow the species below them to receive light. Short trees include blooming species such as dogwood, mountain ash, and some nitrogen fixers, including golden-chain trees, silk tree, and mountain mahogany. Nitrogen-fixing trees grow fast and can be pruned frequently for mulch and compost production (Hemenway, 2009).

3) Shrub Layer: In this layer, some shrubs contain shrubs that bloom, bear fruit, are attractive to wildlife, or have other benefits. These include licarpa, rose, hazelnut, butterfly bush, bamboo, serviceberry, nitrogen-fixing *Elaeagnus* species, Siberian pea shrub, and dozens of others. In this case, the personal tendencies of the designer can be highlighted, and the shrubs can be chosen to emphasize food, crafts, ornaments, birds, insects, native plants, exotics or just biodiversity. From dwarf licarpas to almost tree-sized hazelnuts, shrubs can come in a wide variety of sizes and can therefore be used in edges,

openings, and any suitable place. Shade-tolerant species can be placed under trees; sun-loving ones can be placed in sunny clearings in between (Hemenway, 2009).

4) Herb Plant Layer: This layer contains vegetables, flowers, aromatic herbs, cover crops and mulch producers and other soil-enriching plants. These are non-woody plants. Although perennials are emphasized, some annuals are also included in this layer. Her, too, Here, too, shade-loving species will stay under taller plants, while sun-loving species will need open spaces. At the edges of the food forest, traditional garden areas for plants that require full sun can be found (Hemenway, 2009).

5) Ground Cover Plant Layer: Plants in this layer are short, ground-spreading herbaceous or woody plants.These are short, ground-spreading herbaceous or woody plants. These plant species, which provide food or protect wildlife, occupy the edges, spaces between shrubs and herbaceous plants. Strawberry, nasturtium, clover, creeping thyme, ajuga, phlox, and verbena can be counted among the ground cover plants. They also play an important role in suppressing weeds (Hemenway, 2009).

6) Climbing Plant Layer (Vine Layer): This layer is for climbing plants that wrap around the tree, trunk, and branches and fill the unused parts of the third dimension of the garden for food supply and wildlife. There are food plants such as kiwifruit, grapes, hops, passionflower, and wrapper berries (vining berries), as well as plants that are important to wildlife, such as honeysuckle and trumpet flower. These can also include solitary climbers such as squash, cucumbers, and melons. Some perennial climbers can be invasive or suffocating so they should be used with care and sparingly (Hemenway, 2009).

7) Root Layer (Subsoil Consumed Plants Layer): The soil provides another layer for the food forest. The third dimension goes downwards as well as upwards. Most plants in the root layer should be of shallow rooted varieties such as garlic and onions or easy to uproot species such as potatoes and Jerusalem artichokes. Deep-rooted species such as carrots are not suitable; because when removing them, other plants may be damaged. A few Asian radish seeds can be thrown into empty spaces; because their long roots can often be quickly pulled out without digging, and when not harvested, the flowers

attract beneficial insects, while the plump roots produce humus as they rot (Hemenway, 2009).

3. CONCLUSION

Permaculture food forests are a form of regenerative agriculture that integrate agroforestry methods by mimicking a multi-layered forest ecosystem with edible and supporting plant species (Leni-Konig, 2020). A food forest is a way of food production method or strategy used in a permaculture garden. Food forests consist of edible or beneficial plants specific to where they are and the climate. To design a food forest, a plan that shows the types of plants to be planted is needed so that it can produce maximum yields according to the environment and is low care at the same time. Also, the most important thing when designing a food forest is the arrangement of plants and trees. As the water plan is a permanent element of the food forest, creating a water plan is one of the most important parts of food forest gardening. Understanding the properties of the soil is vital for planting. Food forest products are delicious and have a higher value than common commercial food because they are natural (Kamran, 2022). Moreover, the food forest is one of the best solutions to meet the growing need for healthy food of the city people.

REFERENCES

Bayar, M. (2016). Sürdürülebilir yaşam tasarımı permakültür: İstanbul'a ilişkin ön değerlendirme [Sustainable life design permaculture: a preliminary assessment for İstanbul] (Tez No. 449293) [Yüksek lisans tezi, Mimar Sinan Güzel Sanatlar Üniversitesi]. Ulusal Tez Merkezi. https://tez.yok.gov.tr/UlusalTezMerkezi/tezDetay.jsp?id=Vt9ljY9rjAyapRZ3iE4ueQ&no=Xr-6CrZnv4F_IB1Agbjcdw

Bell, G. (1992). The permaculture way: pratical steps to create a self-sustaining world (1st ed.). Permanent Publications.

Buckley, A. (2018). Design and plant your edible forest garden evening workshop course notes. reGenerate design. https://wildsight.ca/wp-content/uploads/2016/09/Food-Forest-Workshop-handout.pdf

Eliades, A. (2011, October 21). Why food forests? https://www.permaculturenews.org/2011/10/21/why-food-forests/

Eliades, A. (2012, December 19). Permaculture design principle 7 – small scale intensive systems. https://deepgreenpermaculture.com/permaculture/permaculture-design-principles/7-small-scale-intensive-systems/

Eliades, A. (2020, May 21). What materials can you put into your compost bin and what not to compost. https://deepgreenpermaculture.com/2020/05/21/what-materials-can-you-put-into-your-compost-bin-and-what-not-to-compost/

Francis, R. (2008). Permaculture design course handbook. Permaculture Education. chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://permateachers.eu/wp-content/uploads/2014/04/Permaculture%20Design%20Course%20Handbook.pdf

Furbeck, A. (2020, December 24). How to build a food forest step by step. https://thehomesteadinghippy.com/how-to-build-a-food-forest/

Gökmen, A. (2009, Eylül 19-27). Penny Livingston Stark ile permakültür. Pastoral Vadi Ekolojik Yaşam Çiftliği, Muğla, Türkiye. https://docplayer.biz.tr/6728783-Penny-livingston-stark-ile-permakultur-calistayi-pastoral-vadi-fethiye-19-27-eylul-2009.html

Hemenway, T. (2009). Gaia's garden: a guide to home-scale permaculture (1st ed.). Chelsea Green Publishing Company.

Holmgren, D. (2020). Essence of permaculture (1st ed.). Melliodora Publishing.

Jenkins, E. (2018, August 23). 7 ways to harvest rainwater for your (permaculture) garden. https://www.newlifeonahomestead.com/harvest-rainwater-for-your-permaculture-garden/

Kamran, S. (2022). Designing food forest (Publication No. 357974909) [Project, TED University]. Researchgate. https://www.researchgate.net/publication/357974909_Designing_Food_Forest

Lawton, G. (2019, April 8). The forested garden: what is a food forest? [Video]. YouTube. https://www.youtube.com/watch?v=hCJfSYZqZ0Y&t=3s

Leni-Konig, K. (2020). Beyond school gardens: permaculture food forests enhance ecosystem services while achieving education for sustainable development goals (Publication No. 37365007) [Master's thesis, Harvard Extension School]. Harvard Library. https://dash.harvard.edu/handle/1/37365007?show=full

Mollison, B. (1991). Introduction to permaculture (1st ed.). Tagari Publications.

Najafidashtape, A. & Hamamcıoğlu, C. (2018). Sorumlu üretim ve tüketim bağlamında permakültür ve kentsel açık ve yeşil alan ilişkisi [Relevance between permaculture and urban open and green spaces in the context of responsible production and consumption]. Süleyman Demirel Üniversitesi Mimarlık Bilimleri ve Uygulamaları Dergisi, 3(1), 1-17. https://www.researchgate.net/publication/325973692_Sorumlu_Uretim_ve_Tuketim_Baglaminda_Permakultur_ve_Kentsel_Acik_ve_Yesil_Alan_Iliskisi

Öcal, Y. (2020). Kentsel yerleşimlerde permakültür tasarım potansiyeli: Burdur Karamanlı örneği [Permaculture design potential in the urban settlement: Burdur Karamanlı example] (Tez No. 626420) [Yüksek lisans tezi, Gazi Üniversitesi]. Ulusal Tez Merkezi. https://tez.yok.gov.tr/UlusalTezMerkezi/tezDetay.jsp?id=FbZZThDb2ixPub8Q0heSIw&no=4OkM2HE5AZqktbhrlNacFw

Parlak, N. N. (2018). Ekolojik peyzaj tasarımı ve permakültür yaklaşımı [Ecological landscape design and permaculture approach] (Tez No. 507495) [Yüksek lisans tezi, İstanbul Üniversitesi]. Ulusal Tez Merkezi. https://tez.yok.gov.tr/UlusalTezMerkezi/tezDetay.jsp?id=YJZZE2MXv3l528KE_7usbQ&no=IdkREeQYWRWhClQwggyQHw

Pritchard, B. (2016, March 14). Principles from nature. https://www.permaculturefundamentals.com/?p=57

Rockman, K. (2017, May 1). What is a food forest? https://projectfoodforest.org/what-is-a-food-forest/

View, D. (2020, May 22). What are the permaculture zones? https://sivanandayogafarm.org/blog/what-are-the-permaculture-zones/

Yeniçeri, G. (2018, Mayıs 18). Permakültürün 12 prensibi. https://www.havatopraksu.org/blog/2018/05/18/permakulturun-12-prensibi/

CHAPTER 6

QUALITY IN ORGANIC PRODUCTS

Assist. Prof. Dr. Canan ÖZTOKAT KUZUCU [1]

Res. Assist. Hatice Nihan ÇİFTCİ [2]

[1] Çanakkale Onsekiz Mart University, Agricultural Faculty, Department of Horticulture, Çanakkale, Türkiye
coztokat@comu.edu.tr, ORCID ID: 0000-0003-2828-4984

[2] Çanakkale Onsekiz Mart University, Agricultural Faculty, Department of Horticulture, Çanakkale, Türkiye
haticenihan.ciftci@comu.edu.tr, ORCID ID: 0000-0002-0619-5633

INTRODUCTION

Although organic farming activities have followed a fluctuating development process from its early years to the present, according to the report based on 2019 data published by Fibl and IFOAM, ithas been carried out by at least 3.1 million farmers worldwide on 72.3 million hectares of agricultural land in 187 countries. Organic food and beverage sales have a material value exceeding 106 billion Euros (Anonymous, 2021). This market shows that consumers interest in organic products are continuously increasing. Previous research revealed that consumers prefer organic products for various reasons such as desire for healthy nutrition, craving for foods rich in taste and aroma and sensitivity to environmental protection (Goetzke et al., 2014; Smith-Spangler et al., 2012; Şahin, 2017). Especially women, families with children and the elderly tend to prefer organic foods (Hughner et al., 2007). This trend has brought together with consumer questioning about not only the organic farming techniques used in production of organic foodstuffs, but also the quality of the resultant products.

There are various definitions that explain the concept of quality. Quality refers to the features that make something "it" according to its ultimate purpose. According to the standard ISO 9000:2000, quality is defined as “the sum of features and characteristics of a product, process or service based on its ability to meet stated or implied needs” (Anonymous, 2004). Food quality is related to the organoleptic properties, appearance, nutritional value and safety of the foodstuffs. Therefore, the quality characteristics include sensory and physical properties such as taste, aroma, texture, size, color, as well as chemical properties, microbial contamination and amount of residue left over the products (Anonymous, 2014).

In general, genotype, climatic factors, environmental conditions, cultural practices (fertilizer, plant protection and irrigation programs), interactions between post-harvest processes and processing techniques are seen as the factors that cause quality differences in agricultural products. These differences in the production of foods are decisive for organic products, just as they make a difference in the quality of conventional products. However, the issues that consumers care about more than conventional products in terms of quality expectations in organic products are health and nutritional factors.

1. Quality Factors of Organic Products

1.1. Food Safety

Food safety is making sure that the food will not cause harm or illness to humans. Food safety covers the conditions and practices necessary to protect food from pathogenic microorganisms, chemical pollutants, naturally occurring toxic substances and toxic compounds formed during processing (Anonymous, 1998) during the production, processing, distribution, storage and preparation of food. The factors that may threaten food safety of organic foods include;

- **Microorganism contamination*:*** Since organic products do not contain preservatives, bacteria, fungi, etc., intense microorganism growth (Mditshwaa et al., 2017; Amarante et al., 2008), soil contamination with Escherichia coli, mycotoxins, coliform group microorganisms and parasites due to the use of livestock manure (Lima and Vianello, 2011) are the possible causes of microbial contamination.

It was reported that various pathogens could survive for about two months during the use of livestock manure and even some viruses, spores and protozoans could survive even during fermentation (Kouba, 2003).

Mycotoxins are also an important source of contamination. Mycotoxins can develop in adverse environmental conditions or can be transported through tools and equipment. Aflatoxin in figs and hazelnuts, ochratoxin-A in wine and grape juice and patulin in apple, peach and the other fruit juices are among the most common mycotoxins (Olsen, 2008). Conventional products treated with various fungicides under conventional agricultural conditions can be protected from mycotoxins. However, there is no such possibility in organic products (Atasever and Adıgüzel, 2006*)*. Therefore, care should be taken in terms of microorganism contamination during the production and consumption of organic foods and necessary precautions should be taken.

- **Food chemicals:** Pesticides used during the production of agricultural foods are among the leading sources of contamination that can leave residues on foods. According to Çakmakçı (2017), around 400 pesticides are used in agriculture and the results of their combined effects are unknown. Cancer, male infertility, chronic fatigue syndrome in children and Parkinson's disease are the main diseases caused by pesticides. With the effect of the use of chemical pesticides, which are prevented in organic foods, the risk of residues in foods has decreased. However, due to various contamination risks such as drifting, organic products may contain fertilizer and pesticide residues (Kouba, 2003). Çakmakçı (2017) stated that conventional products contain 6-9 times more multiple pesticides than organic products.

There may be nitrate residues in some agricultural products, especially green leafy vegetables, due to the nitrogenous fertilizers used in conventional production. Nitrates are easily converted to nitrites. Nitrites are highly reactive molecules that can bind to secondary amines to form nitrosamines, which are among the natural cancer promoters that can compete with oxygen in the bloodstream to bind to hemoglobin, thereby leading to methemoglobinemia and possible anoxia (Lairon, 2010). It was concluded that the total nitrogen concentration was 10% lower in organic products as compared to conventional ones (Baranski et al., 2014). Since chemical fertilizers and chemical plant protection products are not used in organic agricultural products, they are considered healthier.

- **Food additives**: Various food additives are used for preservation of quality during food production, extension of shelf life, etc. According to Çakmakçı (2017), only 30 of the 300 additives used in foodstuffs can be used in organic agriculture. Non-natural additives that pose a risk to human health are not used in organic agriculture and such a case is a sign that organic products are healthier.

1.2. Nutritive Properties of Food

Organic products are just as nutritious as conventional products. There are some studies showing that organically grown agricultural products had higher values in terms of vitamin C (Salandanan et al., 2009; Carbonaro et al., 2002). Many studies showed that the amount of polyphenols was higher in organic products (Carbonaro et al., 2002). It was stated that especially polyphenols and polyphenol-oxidase enzymes were found to be high in organic fruits due to the more active defense mechanism (Lattanzio et al., 1994). The superiority of carbohydrate and protein levels in organic foods is not well-documented. It was observed that some organic vegetables (potatoes, carrots, sugar beet, lettuce, collard greens, leeks, turnips, onions, celery and tomatoes) had higher amounts of iron and magnesium (Lairon, 2010).

1.3. Sensory Properties of Food

Consumers may have different preferences when it comes to sensory evaluations of organic products. While consumers from Germany, France and Italy stated that they evaluated organic products mostly with the effect of taste, Italian consumers gave importance to aroma as much as taste. For French consumers, when evaluating organic products, another criterion as important as taste is the feeling left in the mouth (Anonymous, 2010). In studies where sensory evaluations are made, there are studies in which consumers give high appreciation scores to organic products (Peck et al., 2006; Reganold et al., 2010), as well as studies in which they do not perceive a sensory difference between two cultivation techniques (Weibel et al., 2004; Karabulut, 2017).

In brief, researchers have obtained different results in various studies and no definite judgments can be reached about organic products being more delicious.

1.4. External Appearance Properties of Food

External appearance properties of organic products differ from standard good-looking products. Consumers evaluate some defects in appearance differently. While some consumers in France, Germany and Switzerland find the defects negative, another group of consumers in France and Germany perceive the change in the appearance of organic products as a quality indicator for organic products (Anonymous, 2010). The size and shape of organic fruits are characterized by consumers as smaller and irregularly shaped (Anonymous, 2010).

Color is a property of commercial importance in agricultural food products. There are studies in which organic products have a lighter color (Amodio et al., 2007; Karabulut, 2017). However, in the studies of some researchers, organic products have darker colors (Reganold et al., 2010). It was stated that the color changes between organic and conventional fruits may cause the fruit color to be lighter because nitrogen fertilization reduces the formation of carbohydrates in the fruit structure proportionally (Amarante et al., 2008).

1.5. Chemical Properties of Food

The quality of food is under the influence of properties such as fruit flesh firmness, titratable total acidity and amount of water-soluble substances. These quality characteristics do not reach stable values in comparison of organic and conventional products and different reactions occur according to the products. However, the amount of sugar and mineral substances show similar characteristics (Uçurum Celbiş, 2012; Wang et al., 2008; Peck et al., 2006).

2. Quality Characteristics of Some Organic Products and Quality Comparison with Conventional Products

2.1. Vegetables

Melon: Although there are different results between melon varieties in terms of ascorbic acid content and phenolic compounds, organic products have a higher ascorbic acid and phenolic content as compared to conventional melon varieties. In a study conducted with ten different melons, Sweetie #6, Burpee Hybrid, Edonis, Rayan, Swan Lake, Honey Orange, Early Queen, Arava cultivars had higher ascorbic acid content in samples obtained from organic cultivation technique, while it remained at a lower level only in Haogen melon cultivar and almost the same values were achieved in Savor cultivar. In terms of phenolic compounds, higher values were obtained in conventional products only of Savor cultivar, while organic products had higher phenolic compounds in all the other cultivars (Salandanan et al., 2009). Total soluble solids (TSS) is another important quality parameter. There is no significant difference in TSS of organically and conventionally-grown melons (Salandanan et al., 2009).

Tomatoes: Consumer preferences and laboratory analyzes sometimes do not support each other, which indicates that consumers perceptions may be different because they did not receive sensory analysis training. In a study, although TSS, glucose (1.33%), fructose (1.45%) values and color measurements were higher in conventional tomatoes, consumers gave higher scores to organic tomatoes in sensory analysis. It was determined that organic tomatoes contain higher protein (1.92%). In terms of mineral substances, Na and Mg are higher in conventional tomatoes and P, K, Ca and Cu are higher in organic tomatoes. When the antioxidant contents of tomatoes were evaluated, it was seen that there was no significant difference between organic (21.69) and conventional (22.09) tomatoes in terms of vitamin C (mg/100g). Carotene (ppm) was found to be higher in organic fresh tomatoes (3.66) than in conventional fresh tomatoes (3.36). Lycopene (ppm) was found to be higher in conventional fresh tomatoes (99.97) than in organic fresh tomatoes (81.52) (Uçurum Celbiş, 2012).

Pepper: Responses of antioxidant substances in sweet red bell peppers grown by conventional and organic methods varied widely. Antheraxanthin, Lutein, cis-Zeaxanthin, Capsanthin, Cryptoxanthin and Cryptoflavin were higher in conventional peppers, while Vitamin C, total carotenoids, β-Carotene, α-Carotene, cis-β-Carotene, Capsorubin, β-Cryptoxanthin were higher in organic peppers. However, total phenolic acids, Gallic acid, Chlorogenic acid, Quercetin D-glucoside, Quercetin and Kaempferol were found to be high in organic pepper fruits. Total flavonoids, Quercetin 3-rutinoside, Myricetin and Luteolin reached higher values in conventional peppers (Hallmann and Rembiałkowska, 2012).

Leeks: In some studies, sugar and potassium contents were reported to be higher in organic products. In a previous study, nine different leek varieties were examined and average total sugar (11.7 g/100 g d.w.), ascorbic acid (47.2 mg/100 g f.w.), Polyphenols (375.4 mg GAE/100 g d.w), Selenium (76.3 µg/kg d.w) and potassium contents were found to be high) in organic leeks, while low nitrate accumulation was detected (Golubkina et al., 2012).

2.2. Fruits

Blueberry: Taste and aroma are one of the most preferred reasons for organic products. The components that affect the taste in fruits are the balance between the amount of sugar and the total amount of acidity. There are studies showing that organic products had higher sugar contents. According to a study conducted on blueberry fruit, the amount of fructose and glucose in organic blueberry fruit was 97.06 mg/g and 45.53 mg/g, respectively, while these amounts were 79.26 mg/g and 29.72 mg/g in conventional products, respectively. However, there was no significant difference in citric acid values and total acidity, while organic blueberries reached higher values (0.043 mg/g) for malic acid.

It was reported that resveratrol, which has antioxidant properties, whose health benefits are frequently on the agenda, had higher values in organic blueberry fruit than conventional ones (Wang et al., 2008).

Apples: Although organic apples generally come to the forefront in terms of fruit quality, there are also quality characteristics that do not have great differences. In a two-year study conducted by Peck et al. (2006), fruit firmness was found to be higher in organic apples (Gala) (org: 78.59N/ 82.15N con: 77.77N/72.82N). While TSS values were high in organic apples in the first year, they were higher in conventional apples in the second year of the study. Titratable acidity value was high in organic apples in the first year of the study, but there was no difference between cultivation techniques in the second year. Accordingly, TSS/TA ratio was lower in organic apples in both years (org:24.2/33 con:24.8/34.4). When the values related to volatile concentrations in apples were examined, it was determined that ester compounds, which offer fruity aromas, remained at lower levels in organic apples in both years and aldehyde and alcohol levels differed between the years. For the results of sensory evaluation, there was no difference between the first-year fruits by the panelists, while organic fruits were evaluated as less aromatic, harder and sour in the second year (Peck et al., 2006). In another study on apples, there was no significant sensory difference between two growing techniques (Weibel et al., 2004; Karabulut, 2017).

Strawberry: Kılıç et al. (2021) conducted a fertilization study on 'Albion', 'San Andreas' and 'Monterey' strawberry cultivars and average quality differences between strawberries with chemical fertilization and strawberries with organic fertilization were examined. In terms of color characteristics, it was found that L* value was high in strawberry fruits with chemical fertilization. The a*, b*, C* and h◦ values were higher in strawberry products with organic fertilization. In another study, it was reported that organic strawberries were darker than the conventional ones (Reganold et al., 2010).

Total acidity (% org: 1.31 chem: 1.48), citric acid (% org: 0.809, chem: 0.993), L-ascorbic acid (mg/100 g org: 26.087, chem: 36.444) and fruit firmness (N org: 0.91 chem: 1.24) had lower values in strawberry fruits with organic fertilization, while TSS (% org: 10.20, chem: 10.08) had lower values in strawberry fruits with chemical fertilization. When the sugar ratios in fruit were examined, sucrose was expressed in figures very close to each other in both applications, while glucose (% org: 3.118, chem: 2.965) and fructose (% org: 3.573, chem: 3.412) reached higher rates in strawberry fruits with organic fertilization (Kılıç et al., 2021).

Lemon: Sánchez-Bravo et al., (2022) conducted a study on Fino 49 lemon cultivar and found that conventional fruits had higher L*, C* and hº values in lemon peel, while L* and C* values were found higher in lemon juice of organic fruits. TSS (con: 9.77, org: 8.77), TA (citric acid L^{-1}) (con: 64.39, org: 57.27), Malic (g L^{-1}) (con: 0.48, org: 0.27), Citric (g L^{-1}) (con: 6.04, org: 5.45), Succinic (g L^{-1}) (con: 0.65, org: 0.56) acids, Glucose (g L^{-1}) (con: 10.67, org: 9.49), Fructose (g L^{-1}) (con: 5.50, org: 4.93) were all higher in conventional fruits. While the total volatile components in fruit juice were 2537mg L^{-1} in organic fruits, it was determined as 2406 mg L^{-1} in conventional fruits.

Peach and Pear: The polyphenol composition, ascorbic acid, citric acid, α- and γ-tocopherol contents of peaches and pears grown under organic and conventional farming conditions were found to be higher in organic farming products as compared to conventional fruits (Carbonaro et al., 2002).

Kivi Fruit: It was determined that the L* value was quite high in conventional fruits as compared to organic ones, but the hº and C* values were lower in conventional fruit groups, therefore, they had lighter green-toned fruits (Amodio et al., 2007; Karabulut, 2017).

3. Post-harvest and Storage Quality Changes in Organic and Conventional Agricultural products

Agricultural products experience various quality losses throughout the shelf life and storage stages after harvest. There are many studies on quality losses of conventional products. However, the quality losses that occur during storage of organic products are different from conventional samples.

When the quality evaluation of organic and conventional tomatoes was made after 28 days of storage conditions, it was determined that organic tomatoes had lower weight loss (2.78%) and firmness loss (27.14%) than the conventional tomatoes. During storage, organic tomato samples showed a slower increase in browning and color values. Ascorbic acid was higher in organic tomatoes (23.53 mg/100g) than in conventional ones (13.85 mg/100g). Although harvested with a high lycopene content, lycopene contents increased in conventional tomatoes as compared to organic ones during the storage (Pradhan and Srijaya, 2022). While there was no pesticide residue in organic tomato products stored for 12 months, it was determined that it decreased over time during storage in conventional tomatoes and became undetectable after 6 months (Uçurum Celbiş, 2012).

Decrease in L* value of organically grown '0900 Ziraat' cherries (*Prunus avium* L.) during 35 days of cold storage (4°C and 90-95% relative humidity) in Modified Atmosphere Packages without any post-harvest treatments was less than those traditionally grown ones. While the hue value of the fruits belonging to both cultivation techniques decreased as compared to the beginning, this decrease, which is defined as the darkening of the color, was slower in organic fruits as compared to conventional fruits during the cold storage. Compared to organic cherries, traditionally produced cherries lost less weight during cold storage and shelf life, while changes in the amount of dissolved dry matter and titratable acidity were slower. Higher total phenolic content and total antioxidant activity values were determined in organically produced cherries during the cold storage (Selçuk, 2021).

Amodio et al. (2007) determined the quality changes of organic and conventional 'Hayward' kiwi fruits harvested at the same maturity period at the end of 0, 35, 72, 90 and 120 days of storage at 0 °C. While organic kiwi fruits had higher values for minerals, ascorbic acid, total phenolic content and antioxidant activity during the storage, fruit pulp firmness was higher in conventional kiwi fruits. It was reported that conventional kiwi fruits had a higher brightness value, while organic kiwi fruits had a lighter green color.

While the hardness of organic Galaxy Gala apples stored under controlled atmosphere conditions for 6 weeks after harvest decreased by 10% as compared to the initial value, this loss increased to 36% in conventional apples (Peck et al., 2006; Karabulut, 2017).

4. CONCLUSION

Consumer interest in organic agricultural products is parallel to their interest in health and environmental issues, because organic agricultural products are considered to be healthier, tastier and safer. In addition to the standard quality features of conventional products, quality features of organic products can reach a wide range of results.

In general, vitamin C reaches higher values in organic pears, peaches, melons, tomatoes and leeks, while studies on strawberry indicate the opposite. In the studies conducted in terms of phenolic compounds, it was seen that organic pear, peach, melon, pepper and leek had higher values, while strawberry was more advantageous in terms of phenolic compounds under conventional conditions. Although the superiority of conventional products is generally mentioned in studies on protein amount, it was observed that organic products (tomatoes and leeks) in some studies reach higher values.

It was determined that TSS values were higher in organic melon, apple and strawberry and higher in conventional samples of tomato, lemon and apple. In terms of color values, L* value reached higher values in conventional samples of strawberry, apple and kiwi fruits. While the total amount of titratable acidity, citric acid and malic acid reached high levels in the conventional lemon samples, malic acid came to the forefront in organically grown blueberry fruits. In terms of flesh firmness, organic samples of apples and conventional samples of strawberries were found to have firmer fruits. In terms of glucose and fructose, organic samples reached higher sugar values in blueberry and strawberry fruits and conventional samples in tomato and lemon. In tomato fruit, Na and Mg minerals were found to be high in conventional samples, while P, K, Ca, Cu minerals were found to be higher in organic samples. Carotenoids were generally found in higher amounts in organic tomatoes, while lycopene was found in higher amounts in conventional tomatoes.

In stored products, while the weight loss was less in organic samples, the quality loss was slower than in conventional samples. This suggests that organic products may have a longer storage capability. In addition, while the amount of chemical residues and nitrate levels in organic products remain at low levels, the possibility of microorganism contamination and mycotoxins pose a risk for human health.

REFERENCES

Amarante, C. V. T., Mafra, Á. L., and Albuquerque, J. A. (2008). Yield and fruit quality of apple from conventional and organic production systems. *Pesquisa Agropecuaria Brasileira* 43, 333–340.

Amodio, M. L., Colelli, G.J., Hasey, K. and Kader, A. A. (2007). A comparative study of composition and postharvest performance of organically and conventionally grown kiwifruits. *Journal of the Science of Food and Agriculture* 87, 1228–1236.

Anonymous (1998). WHO Programme of Nutrition. Complementary feeding of young children in developing countries: a review of current scientific knowledge. World Health Organization. https://apps.who.int/iris/handle/10665/65932

Anonymous (2004). FAO 2004, Twenty-fourth FAO regional conference for Europe. ftp://ftp.fao.org/unfao/bodies/erc/erc24/J1875e.doc

Anonymous (2010). Sensory Experiences and Expectations of Organic Food. Research Institute of Organic Agriculture (FiBL), July 2010, 111.

Anonymous (2014). Chalova, V., UFT. https://en.wikipedia.org/wiki/Food_quality#Academic_resources

Anonymous (2021). The World of organıc agrıculture statıstıcs & emergıng trends 2021. FIBL & IFOAM Organıc Internatıonal. 336. https://www.fibl.org/fileadmin/documents/shop/1150-organic-world-2021.pdf

Atasever, M ve Adıgüzel, G. (2006). Organik besinlerin kalitesi. *Atatürk Üniv. Ziraat Fak. Derg.* 37 (1), 117-122.

Baranski, M., Srednicka-Tober, D., Volakakis, N., Seal, C., Sanderson, R., Stewart, G.B., Leifert, C. (2014). Higher ´antioxidant and lower cadmium concentrations and lower incidence of pesticide residues in organically grown crops: A systematic literature review and meta-analyses. *Br. J. Nutr*. 112, 794–811.

Carbonaro, M., Mattera, M., Nicoli, S., Bergamo, P. and Cappelloni, M. (2002). Modulation of Antioxidant Compounds in Organic vs Conventional Fruit (Peach, *Prunus persica* L., and Pear, *Pyrus communis* L.). *Journal of Agricultural and Food Chemistry* 50, 5458- 5462.

Çakmakçı, R. (2017). Organık Tarım Nedır? Ne Değıldır? 17-24. TÜBA-Gıda Güvenliği Sempozyumu Raporu.

Hallmann, E. and Rembiałkowska, E. (2012). Characterisation of antioxidant compounds in sweet bell pepper (*Capsicum annuum* L.) under organic and conventional growing systems. *J Sci Food Agric* 92, 2409–2415.

Goetzke, B., Nitzko, S., Spiller, A. (2014). Consumption of organic and functional food. A matter of well-being and health? *Appetite* 77C, 94-103.

Golubkina, N. A., Seredin, T. M., Antoshkina, M. S., Kosheleva, O.V., Teliban, G.C. and Caruso, G. (2018). Yield, Quality, Antioxidants and Elemental Composition of New Leek Cultivars under Organic or Conventional Systems in a Greenhouse. *Horticulturae* 4, 39.

Hughner, R.S., Mcdonagh, P., Prothero, A., Shultz, C. and Stanton, J. (2007). Who are organic food consumers? A compilation and review of why people purchase organic food. *Journal of Consumer Behaviour*, Vol. 6 Nos 2-3, 94-110.

Karabulut, İ. (2017). Organik Tarım Perspektifinde Kayısı. 79-84. TÜBA-Gıda Güvenliği Sempozyumu Raporu.

Kılıç, N., Burgut, A. Gündesli, M. A., Nogay, G., Ercisli, S., Kafkas, N. E., Ekiert, H., Elansary, H. O., Szopa, A. (2021). The Effect of Organic, Inorganic Fertilizers and Their Combinations on Fruit Quality Parameters in Strawberry. *Horticulturae* 7, 354

Kouba, M. (2003). Quality of organic animal products. Livestock Production *Science* 80: 33-40.

Lattanzio, V., De Cicco, V., Di Venere, D., Lima, G., and Salerno, M. (1994). Antifungal activity of phenolics against fungi commonly encountered during storage. *Italian Journal of Food Science* 1, 23-30.

Lima, G. P. P. and Vianello, F. (2011). Review on the main differences between organic and conventional plant-based foods. *International Journal of Food Science and Technology* 46, 1–13.

Mditshwaa, A., Magwazab, L. S., Tesfaya, S. Z. and Mbilic, N. (2017). Postharvest quality and composition of organically and conventionally produced fruits: A review. *Scientia Horticulturae* 216, 148–159.

Olsen, M. (2008). Mycotoxins in organic and conventional foods and effects of the environment. *CAB International* 145-159.

Peck, G. M., Andrews, P. K., Reganold, J. P. and Fellman, J. K. (2006). Apple orchard productivity and fruit quality under organic, conventional, and integrated management. *HortScience* 41, 99–107.

Reganold, J. P., Andrews, P. K., Reeve, J. R., Carpenter-Boggs, L., Schadt, C. W., Alldredge, J. R., Ross, C. F., Davies, N. M. and Zhou, J. (2010). Fruit and soil quality of organic and conventional strawberry agro ecosystems. *PLoS One* 5, e12346.

Salandanan, K., Bunning, M., Stonaker, F., Külen, O., Kendall, P. and Stushnoff, C. (2009). Comparative Analysis of Antioxidant Properties and Fruit Quality Attributes of Organically and Conventionally Grown Melons (*Cucumis melo* L.). *Hortscience* 44(7),1825–1832.

Sánchez-Bravo, P., Noguera-Artiaga, L., Martínez-Tomé, J., Hernández, F., Sendra, E. (2022). Effect of Organic and Conventional Production on the Quality of Lemon "Fino 49". *Agronomy* 12, 980.

Selçuk, E. G., (2021). Organik ve Geleneksel Olarak Yetiştirilen '0900 Ziraat' Kiraz Çeşidinde Soğukta Depolama Süresince Kalite Özelliklerinde Meydana Gelen Değişimlerin Belirlenmesi. (Yüksek Lisans Tezi). Ulusal Tez Merkezi. https://tez.yok.gov.tr/UlusalTezMerkezi/tezSorguSonucYeni.jsp

Smith-Spangler, C., Brandeau, M. L., Hunter, G. E., Bavinger, J. C., Pearson, M., Eschbach, P. J., … Bravata, D.M. (2012). Are Organic Foods Safer or Healthier Than Conventional Alternatives? A Systematic Review. *Ann Intern Med.* 157, 348-366.

Şahin, H. (2017). Organik Gıdaların Beslenme Açısından Değerlendirilmesi. 91-96. TÜBA-Gıda Güvenliği Sempozyumu Raporu.

Uçurum Celbiş, H. Ö. (2012). Organik Ve Konvansiyonel Yöntemlerle Yetiştirilmiş Taze Ve Dondurulmuş Domateslerde Kalıntı Miktarları Ve Kalite Özelliklerinin Belirlenmesi. (Doktora Tezi). Ulusal Tez Merkezi. https://tez.yok.gov.tr/UlusalTezMerkezi/tezSorguSonucYeni.jsp

Wang, S. Y., Chen, C., Scıarappa, W., Wang, C.Y. and Camp, M.J. (2008). Fruit Quality, Antioxidant Capacity, and Flavonoid Content of Organically and Conventionally Grown Blueberries. *J. Agric. Food Chem.* 56, 5788–5794

Weibel, F. P., Treutter, D., Häseli, A. and Graf, U. (2004). Sensory and health-related fruit quality of organic apples. A comparative field study over three years using conventional and holistic methods to assess fruit quality. In: 11th International Conference on Cultivation Technique and Phyto pathological Problems in Organic Fruit-Growing: Proceedings to the Conference from 3rd February to 5th February 2004, Weinsberg/Germany, pp. 185–195.

Pradhan, A., Srijaya, M. (2022). Postharvest Quality and Storability of Organically Verses Conventionally Grown Tomatoes: A Comparative Approach. 1st International Electronic Conference on Horticulturae session Organic Horticulture. 1, x.

Lairon, D. (2010). Nutritional quality and safety of organic food. A review. *Agron. Sustain. Dev.* 30, 33–41.

CHAPTER 7

CHANGES OF VOLATILE COMPOUNDS DURING MATURITY OF VERDIAL OLIVE VARIETY IN NORTHERN AEGEAN ECOLOGICAL CONDITIONS

Dr. Mehmet Ali GUNDOGDU[1]

[1] Canakkale Onsekiz Mart University, Faculty of Agriculture, Department of Horticulture Çanakkale, Turkiye magundogdu@comu.edu.tr, ORCID ID: 0000-0002-5802-5505

1. INTRODUCTION

Turkey has a very rich plant biodiversity due to its location at the intersection of Asia and Europe for hundreds of years; it is the gene center of many species with wild, crossover and cultured forms (Tan, 2010). One of these species is the olive (*Olea europaea* L.). Throughout history, olive has been the symbol of peace and goodwill for humanity and the source of abundance in the Mediterranean Basin. Today, 95% of this precious fruit, which has added magnificence to the world for 6000 years, production is carried out in the Mediterranean Basin.

Approximately 20 million tons of olives are produced from an area of approximately 10 million hectares in the world (FAO, 2022). Italy, Spain, Greece, Turkey and Tunisia are the leading countries in production. On the other hand, Turkey produced 1 million 400 thousand tons that 400 thousand tons for table and 1 million tons for oil production of olives in 2021.

Analytical characteristics of olive oil vary according to the olive variety, soil and climatic conditions, the region, the nutritional status of the tree, harvest date, the maturity stages of fruits, the processing techniques and the storage conditions of the oils (Colakoglu, 1969).

The volatile compounds in olive oil are formed by the metabolites produced by the fruit inside the cells. While some volatile compounds are synthesis during the development of the fruits, the other volatile compounds are formed by the enzymatic reactions and oxidations that occur when it starts to break down for oil production (Kalua et al., 2007).

Although the concentrations and variations of volatile compounds depend on enzymatic activity, it has been stated in previous studies that external factors such as climate and soil, harvest time and oil extraction methods may also change the sensory profile of the olive oils (Aparicio et al., 1994; Aparicio and Morales, 1998; Morales and Aparicio, 1999; Salas et al., 2005). The aroma of olive oil consists of esters, aldehydes, hydrocarbons, alcohols, furans, ketones and other compounds that have not yet been identified.

This study was carried out to determine the changes in the aroma components of the ‘Verdial’ olive variety in different harvest periods and during maturity under the ecological conditions of the North Aegean.

2. MATERIALS AND METHODS

The fruits of the Verdial olive variety obtained from the Edremit Olive Production Station Directorate Gömeç Collection Orchard (EOPSD-GCO) were used as the plant material of the study. In the orchard where the study was carried out, a total of 6 trees from the Verdial variety were used, with 3 replications and 2 trees in each replication. Fruit samples were harvested in approximately 10-day periods.

The dates determined for the collection of fruit samples within the scope of the research are 15.09.2014, 25.09.2014, 08.10.2014, 20.10.2014, 30.10.2014, 10.11.2014, 20.11.2014, 01.12.2014, 11.12.2014 and 22.12.2014, respectively.

Verdial variety is Spanish origin and is cultivated especially in the Andalucia region. Fruits are large and have high oil content. The oil quality is medium and it is usually blended with Hojiblanca oil. Trees are vigorous and very productive (Seker et al., 2008; Gundogdu and Seker, 2012; Gundogdu et al., 2016).

Maturity indexes of the olive fruits (MI) were determined according to the procedure proposed by IOOC (2007) by evaluating the color of the olive skin and pulp.

In order to extract the aroma compositions of the harvested fruits, liquid-liquid extraction with diethyl solvent was used by modifying the methods reported by Vichi et al (2007) and Ekinci et al. (2021).

The composition of the volatile compounds specified with a GC-MS (Shimadzu® QP-2010) fitted with a DB-WAX polyethylene glycol (PEG) column (30x0.25x0.25). The identification of volatile compounds was determined by using the library of mass spectroscopy (MS) and the standards of volatile compounds (STD) and the retention times (RT) for the column. Wiley 7.0 and NIST libraries were used in MS libraries.

Identification of aroma components that aldehydes, alcohols, hydrocarbons, esters, ketones and terpenes compounds, was carried out by mass spectrometry (MS) that set at 230°C of capillary direct interface temperature; the ion source was set 666 amu s^{-1} scan rates at 250°C. The ionization energy of the MS was programmed for 70 eV. Nist and Wiley libraries were used on MS. One microliter of liquid-liquid extracts was injected in 1:50 split by an auto injector. The injection temperature was set with 280°C.

Data of maturity index of Verdial olive variety were analyzed using ANOVA One-Way by the SAS® statistical software. Differences between harvest periods were determined statistically by Tukey's multiple comparison test ($p<0.01$).

3. RESULTS AND DISCUSSIONS

At the end of the study, the maturity index (MI) values of the fruits taken in 10 periods during the 2014 cultivation season of the Verdial variety are shown in Table 1.

The Verdial olive variety reached different maturity stages during every the harvest periods in this research.

During the study, the Verdial olive variety was harvested at 10-day intervals and the fruit maturity showed a continuous increase. The study, which started with 0.02 MI on 15.09.2014, was completed with 4.00 on 22.12.2014. It can be said that the fruits of Verdial variety ripen slowly in September. It was observed that the fruits were dark green (MI<1) in September (15.09.2014 and 25.09.2014). On October 20, 2014, the fruits of the Verdial variety underwent a dramatic ripening process. The color changes of fruits were started and MI calculated to 2.38. In the following harvest periods, the ripening of the fruits showed a slow development. Although in the following harvest periods, the ripening of the fruits showed a slow development, all skin color of the fruits is almost colored in 01.12.2014 (MI 3.90). All fruits have black skin color with white flesh in the next two harvest periods (11.12.2014 and 22.12.2014). It has been stated that the fruits of the Verdial variety ripen very late in ecological conditions of Spain (Anonymous, 2018). The changes observed in maturity were calculated to be statistically significant ($p<0.01$).

Gundogdu (2011) researched ripening of 16 olive varieties in 30-day periods from August to November in EOPSD-GCO. It was reported that the MI values of Verdial cultivar changed as 1.07, 3.48, 3.98 and 4.76 in August, September, October and November, respectively. Gundogdu reported that MI of the Verdial olive variety that harvested from EOPSD-GCO on 07th October, 21th October, 4th November, 18th November and 2nd December in 2013 were 1.93-2.67-3.28 and 4.21. The findings obtained within the scope of the research are similar to the literature.

Table 1. Maturity Indexes of the Verdial olive variety during harvest periods

Harvest Periods	Harvest Dates	Maturity Index (MI)
1st Harvest	15.09.2014	0.02 c
2nd Harvest	25.09.2014	0.42 c
3rd Harvest	08.10.2014	2.38 b
4th Harvest	20.10.2014	2.92 b
5th Harvest	30.10.2014	2.93 b
6th Harvest	10.11.2014	3.51 a
7th Harvest	20.11.2014	3.59 a
8th Harvest	01.12.2014	3.90 a
9th Harvest	11.12.2014	4.00 a
10th Harvest	22.12.2014	4.00 a
MSD	-	0.5637

The volatile compounds of the Verdial olive variety were determined and the changes of the compounds were detected for each harvest period.

The ratios of volatile compounds (%) in the fruits of Verdial variety during the 10 periods in the 2014 cultivation year are shown in Table 2.

During the research, a total of 39 volatile compounds, including 13 alcohols, 11 aldehydes were major aroma groups. Also, 6 hydrocarbons, 5 esters, 3 ketones and 5 terpene aroma groups, were identified in the Verdial variety in 10 harvest periods (Table 2).

Based on the identified compounds and their ratios in the study, it can be reported that the main aroma components of olive fruit are in the group of aldehydes, terpenes and alcohols. On the other hand, it was observed that the aldehyde ratios of Verdial fruits were much higher in the early stages of the study. When fruits were matured, the ratios of alcohols, esters, ketones, terpenes and hydrocarbons increase, whereas aldehydes ratios decrease.

Kiralan (2010) stated that alcohols, esters and hydrocarbons constitute a significant part of the volatile compounds of olive oils, and that aldehydes, which have 6 carbon open chain unsaturated and saturated systems, are especially positive effects in olive oil quality and sensory demands. 6-carbon aldehydes such as hexanal, trans-2-hexen-1-al (E-2-hexenal) and cis-3-hexen-1-al (Z-3-hexenal) compounds, which are the main aroma components of olive oil, are synthesized from linoleic acid (C18:2) and linolenic acids (C18:3) by the lipoxygenase pathway. These aldehydes are most commonly found in early harvested olives (Yilmaz and Ogutcu, 2012; Seker et al., 2021).

With the progression of maturity, aldehydes are firstly converted into alcohol forms hexane-1-ol (hexanol), trans-2-hexen-1-ol (E-2-hexenol) and cis-3-hexen-1-ol (Z-3-hexenol) with the help of alcohol dehydrogenase enzyme. Then, alcohols are converted to cis-3-hexenyl acetate (Z-3-hexenyl acetate) and hexyl acetate esters by the alcohol acetyl transferase enzyme (Angerosa et al., 2004; Kiralan 2010; Yilmaz and Ogutcu, 2012). Some researchers explained that hexanal, hexanol and hexyl acetate are composed of linoleic acid (C18:2), E-2-hexenal, Z-3-hexenal, Z-3-hexenol, E-2-hexenol and Z-3-hexenyl acetate compounds are composed of linolenic acid (C18:3) (Sabatini, 2010; Ilyasoglu et al., 2011; Yilmaz and Ogutcu, 2012; Seker et al., 2021).

Although 5 aldehydes were identified at the beginning of cultivation season, other aldehyde components were determined as maturity progressed, and 11 aldehydes were identified at the end of the study (Table 2).

When the change of volatile compounds in periodically harvested fruits is examined, aldehydes, especially hexanal and E-2-hexenal compounds, constitute the most important volatile component group in the Verdial variety.

E-2-hexenal (48.51%), hexanal (42.22%) and 2.4- hexadienal (2.67%) compounds and the following total aldehyde ratio (94.25%) decreased as maturity progressed. 22th December 2014 which was the last harvest period (MI 4.0), the ratios of E-2-hexenal, hexanal, 2.4-hexadienal and total aldehydes were 23.68%, 15.75%, 0.39% and 52.76%. Benzaldehyde (0.38-2.38%) and Z-3-hexenal (0.47-2.77%) compounds, which were detected at low ratio in the early harvest period when the maturity was low, increased with ripening. Other aldehydes were identified during maturity in the Verdial olive variety are; Z-2-pentenal (0.0-1.82%), E-2-pentenal (0.0-1.82%), nonanal (0.0-1.76%), 2-methyl butanal (0.0%-0.96%), E-2-decenal (0.0%-0.72%), tetradecanal (0.0%-0.85%) compounds. The ratios of desired volatile compounds such as benzaldehyde, Z-2-pentenal and E-2-pentenal increased during the maturity until 11th December 2014 that reached their highest rates on this date.

Many researchers explained that irrigation on olive orchards increased the hexanal content of olive oil. Besides, E-2-hexenal and hexanal compounds from C18:2 and C18:3 via lipoxygenase pathway and these desired compounds can be found mostly in early harvested olive oils (Baccouri et al., 2008; Kiralan, 2010). Many researchers stated that hexanal ratio in olive oil affects the most part of “green-sweet, cut grass" attributes, contrariwise, E-2-hexenal evokes a "green, apple-like, grass, green apple" feeling. In addition, it has been reported that benzaldehyde, 2.4-hexadienal, Z-3-hexenal and Z-2-pentenal compounds related to the sensation of almond, cut grass, green leaves and green pleasant, respectively (Aparicio and Luna, 2002, Angerosa et al., 2004; Kalua et al., 2007; Yilmaz and Ogutcu, 2012; Seker et al., 2021).

The hexanal, Z-3-hexenal and E-2-hexenal concentrations of the Verdial de Huevar variety harvested at coloration period (MI 2 or 4) in the Seville-Spain region were determined 1520 µg kg^{-1}, 169 µg kg^{-1} and 2795 µg kg^{-1}, respectively. When these concentrations are compared with the other compounds given in the study, they are calculated as 25.62%-2.85% and 47.10%, respectively (Aparicio and Luna; 2002).

Some researchers investigated the effect of pre-treatments (hot water) before oil processing on the volatile compounds of Verdial variety. The researcher stated that although lipoxygenase and hydroperoxide lyase enzyme systems were blocked at temperatures above 60 °C, alcohol dehydrogenase and alcohol acyl transferase enzymes were not affected. At the end of the research, it was reported that the rates of 6-carbon aldehyde compounds (E-2-hexenal, hexanal, Z-3-hexenal, Z-2-hexenal and E-3-hexenal) and 5-carbon aldehyde compounds (E-2-pentenal and Z-2-pentenal) defined in the Verdial variety decreased by 77%-93% compared to the control group as the pre-treatment temperature increased (Perez et al., 2003).

Table 2. Volatile compounds identified during maturity in the fruits of Verdial olive variety in 2014 cultivation season.

VOLATILE COMPOUNDS	HARVEST PERIODS									
ALDEHYDES	**1st***	**2nd**	**3rd**	**4th**	**5th**	**6th**	**7th**	**8th**	**9th**	**10th**
E-2-Hexenal	48.51	45.94	38.83	36.95	36.09	32.94	31.43	28.22	25.42	23.68
Hexanal	42.22	39.39	31.57	27.73	26.46	22.57	21.12	19.02	16.92	15.75
Benzaldehyde	0.38	0.79	1.64	1.89	1.85	2.12	2.18	2.29	2.32	2.38
Z-3-Hexenal	0.47	0.91	1.81	2.12	2.15	2.43	2.50	2.68	2.89	2.77
Z-2-Pentenal	0.0	0.36	0.99	1.17	1.25	1.46	1.58	1.74	1.82	1.79
E-2-Pentenal	0.0	0.37	1.19	1.40	1.42	1.55	1.59	1.67	1.82	1.71
Nonanal	0.0	0.0	0.81	1.05	1.16	1.28	1.33	1.41	1.59	1.76
2.4-Hexadienal	2.67	2.51	1.68	1.47	1.46	1.22	1.15	0.93	0.85	0.39
2 Methyl Butanal	0.0	0.0	0.11	0.26	0.35	0.54	0.60	0.73	0.80	0.96
E-2-Decenal	0.0	0.0	0.0	0.0	0.12	0.28	0.33	0.48	0.60	0.72
Tetradecanal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.24	0.59	0.85
TOTAL ALDEHYDES	**94.25**	**90.27**	**78.63**	**74.04**	**72.31**	**66.39**	**63.81**	**59.41**	**55.62**	**52.76**
ALCOHOLS	**1st**	**2nd**	**3rd**	**4th**	**5th**	**6th**	**7th**	**8th**	**9th**	**10th**
Z-3-Hexenol	0.21	0.46	1.37	1.69	1.78	2.01	2.13	2.33	2.44	2.59
Hexanol	0.11	0.33	0.89	1.11	1.12	1.29	1.40	1.67	1.89	2.01
Phenyl ethanol	0.0	0.18	0.71	0.93	0.92	1.08	1.11	1.20	1.29	1.38
E-2-Hexenol	0.0	0.0	0.26	0.47	0.57	0.76	0.80	0.97	1.03	1.11
E-3-Hexenol	0.0	0.0	0.22	0.40	0.42	0.67	0.72	0.85	1.01	1.09
Z-2-Pentenol	0.0	0.0	0.16	0.32	0.34	0.61	0.70	0.81	0.99	1.07
Pentanol	0.0	0.0	0.31	0.50	0.59	0.70	0.77	0.89	0.98	1.21
1-Penten-3-ol	0.0	0.0	0.39	0.55	0.62	0.77	0.82	0.91	0.98	1.10
Ethanol	0.0	0.0	0.11	0.22	0.29	0.41	0.44	0.52	0.68	0.77
E-2-Pentenol	0.0	0.0	0.0	0.10	0.19	0.36	0.49	0.58	0.66	0.70
3-Methyl-1-Butanol	0.0	0.0	0.0	0.0	0.08	0.27	0.34	0.49	0.55	0.87
2-Methyl-1-Butanol	0.0	0.0	0.0	0.0	0.0	0.11	0.18	0.38	0.50	0.76
Heptanol	0.0	0.0	0.0	0.0	0.0	0.13	0.28	0.36	0.44	0.62
TOTAL ALCOHOLS	**0.32**	**0.97**	**4.42**	**6.29**	**6.92**	**9.17**	**10.18**	**11.96**	**13.44**	**15.28**
ESTERS	**1st**	**2nd**	**3rd**	**4th**	**5th**	**6th**	**7th**	**8th**	**9th**	**10th**
Hexyl acetate	0.0	0.0	0.78	0.99	1.12	1.39	1.51	1.78	1.87	2.00
Z-3-Hexenyl acetate	0.0	0.0	0.31	0.50	0.61	0.80	0.91	1.03	1.10	1.18

Citronellyl acetate	0.0	0.0	0.19	0.30	0.41	0.59	0.66	0.81	0.90	1.02
Ethyl acetate	0.0	0.0	0.0	0.11	0.19	0.40	0.49	0.60	0.71	0.83
Isoamyl acetate	0.0	0.0	0.0	0.0	0.0	0.20	0.27	0.39	0.44	0.53
TOTAL ESTERS	**0.0**	**0.0**	**1.28**	**1.90**	**2.33**	**3.38**	**3.84**	**4.61**	**5.02**	**5.56**
HYDROCARBONS	**1st**	**2nd**	**3rd**	**4th**	**5th**	**6th**	**7th**	**8th**	**9th**	**10th**
3-Ethyl-1.5-Octadiene	0.63	1.02	1.82	2.03	2.04	2.33	2.44	2.51	2.62	2.81
Undecane	0.0	0.11	0.49	0.60	0.68	0.83	0.89	0.94	1.00	1.13
2-Ethyl furan	0.0	0.0	0.0	0.0	0.0	0.12	0.26	0.44	0.75	0.91
2-Butyl furan	0.0	0.0	0.0	0.13	0.21	0.33	0.40	0.42	0.73	0.82
2.4-Dimethyl furan	0.0	0.0	0.0	0.0	0.0	0.10	0.24	0.39	0.62	0.99
Octane	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.13	0.28	0.47
TOTAL HYDROCARBONS	**0.63**	**1.13**	**2.31**	**2.76**	**2.93**	**3.71**	**4.23**	**4.83**	**6.00**	**7.13**
KETONES	**1st**	**2nd**	**3rd**	**4th**	**5th**	**6th**	**7th**	**8th**	**9th**	**10th**
1-Penten-3-one	1.34	1.79	2.36	2.62	2.71	2.92	3.00	3.23	3.30	3.33
2-Butanone	0.0	0.37	0.99	1.11	1.18	1.37	1.43	1.51	1.60	1.65
2-Cyclohexenone	0.0	0.0	0.28	0.39	0.47	0.71	0.79	0.88	0.97	1.01
TOTAL KETONES	**1.34**	**2.16**	**3.63**	**4.12**	**4.36**	**5.00**	**5.22**	**5.62**	**5.87**	**5.99**
TERPENES	**1st**	**2nd**	**3rd**	**4th**	**5th**	**6th**	**7th**	**8th**	**9th**	**10th**
Limonene	1.47	1.85	2.71	2.91	2.94	3.15	3.21	3.33	3.41	3.22
α-Bergamotene	1.30	1.66	2.57	2.82	2.85	3.03	3.15	3.26	3.33	3.17
α-Farnesene	0.39	0.81	1.69	1.96	2.05	2.29	2.33	2.51	2.68	2.50
α-Sinensal	0.30	0.77	1.60	1.81	1.89	2.21	2.30	2.51	2.60	2.48
β-Myrcene	0.0	0.38	1.16	1.39	1.42	1.67	1.73	1.96	2.03	1.91
TOTAL TERPENES	**3.46**	**5.47**	**9.73**	**10.89**	**11.15**	**12.35**	**12.72**	**13.57**	**14.05**	**13.28**
TOTAL RATIOS	**100 %**	**100 %**	**100 %**	**100 %**	**100 %**	**100 %**	**100 %**	**100 %**	**100 %**	**100 %**

* 1st Harvest Period: 15.09.2014; 2nd Harvest Period: 25.09.2014; 3rd Harvest Period: 08.10.2014; 4th Harvest Period: 20.10.2014; 5th Harvest Period: 30.10.2014; 6th Harvest Period: 10.11.2014; 7th Harvest Period: 20.11.2014; 8th Harvest Period: 01.12.2014; 9th Harvest Period: 11.12.2014; 10th Harvest Period: 22.12.2014

Researchers studying with different olive varieties on different ecologies reported that aldehydes are the major group in olive oil aroma components and that E-2-hexenal and hexanal compounds are also active volatile compounds (Kiralan et al., 2012; Yilmaz and Ogutcu, 2012; Sisik Ogras, 2014; Dagdelen et al., 2016; Seker et al., 2021).

The aroma components of the olive fruits harvested during the research were identified. It was determined that alcohol compounds were the second most important aroma component group especially on 3rd harvest period (MI>2.38) and their ratio increased during ripening (Table 2). At the beginning of the study, 2 alcohol components (Z-3-hexenol and hexanol) were detected at very low rates in the early period when the fruits were immature (MI 0.02). It was determined that Z-3-hexenol (0.21-2.59%) and hexanol (0.11-2.01%) compounds identified in all harvest periods were the active alcohol volatile compounds detected in Verdial variety. Other alcohol volatile compounds identified within the scope of the study are phenyl ethanol (0.0-1.38%), E-2-hexenol (0.0-1.11%), E-3-hexenol (0.0-1%). 1.09%), Z-2-pentenol (0.0-1.07%), pentanol (0.0-1.21%), 1-penten-3-ol (0.0-%) 1.10), ethanol (0.0%-0.77%), E-2-pentenol (0.0%-0.70%), heptanol (0.0%-0.62%), 3-methyl-1-butanol (0.0-0.87%) and 2-methyl-1-butanol (0.0-0.76%) compounds. The total alcohol ratio was determined as 0.32% in the first week of the study, when the fruits are immature. It was increased as the maturity progressed and on 22th December 2014, the last period of the study reached a rate of 15.28%.

Although volatile compounds that provide undesirable sensory perception, for example 3-methyl1-butanol, 2-methyl-1-butanol, heptanol etc., were not identified until the 5th harvest period (30th October 2014), the ratios of these compounds increased after November month.

Previous studies have reported that Z-3-hexanol and hexanol compounds impart green leaf and cut grass odor to olive oil, respectively. Controversy, 3-methyl butanol and 2-methyl butanol compounds are undesirable alcohol components and it was stated that they felt the smell of fish oil and yeast (Kritsakis, 1998; Angerosa et al., 2002; Seker et al., 2021).

Kiralan (2010) stated that the alcohol group aroma compounds synthesized in olive oil by lipoxygenase pathway and he reported that these compounds increase with the maturation of the fruits. Also researchers explained that both E-2-hexenol, Z-3-hexenol, E-3-hexenol, hexanol compounds that 6-carbon alcohol compounds and 1-penten-3-ol and pentenol compounds that 5-carbon alcohol compounds synthesized by lipoxygenase pathway in olive oil aroma composition (Benincasa et al. 2003; Gómez-Rico et al. 2009; Yilmaz and Ogutcu, 2012). It has been reported that phenyl ethanol creates a fruity floral, Z-2-pentenol creates green banana and pentanol creates pungent sensory perception in olive oil (Angerosa, 2002; Angerosa et al., 2004, Collin et al., 2008; Seker et al., 2021).

Aparicio and Luna (2002) studied the olive oil volatile composition of the Verdial de Huevar olive variety harvested in the Seville-Spain region at normal maturity. He determined that hexanol, Z-3-hexenol and E-2-hexenol aroma compounds were found at concentrations of 208 µg kg^{-1}, 502 µg kg^{-1} and 462 µg kg^{-1}, respectively. They also stated that these compounds constitute 19.75% of the total aroma component group.

Perez et al. (2003) investigated the effect of hot water applications on the aroma components of the Verdial olive variety before processing the oil. He stated that although lipoxygenase and hydroperoxide lyase enzyme systems were blocked at temperatures above 60°C, alcohol dehydrogenase and alcohol acyl transferase enzymes were not affected. The researcher reported that the ratios of 6-carbon (E-2-hexenol, hexanol, Z-3-hexenol, Z-2-hexenal and E-3-hexenol) and 5-carbon (1-pentene-3- ol, E-2-pentenol and Z-2-pentenol) alcohol compounds defined in the Verdial variety decreased in especially above 64°C temperature in the pre-application, comparison to the control group.

In the study, ester compound group was not defined in the fruits of Verdial olive variety until 08th October (MI 2.38) 2014. Z-3-hexenyl acetate (0.31%), citronellil acetate (0.19%) and hexyl acetate (0.78%) that the major ester compound of Verdial variety, compounds were identified the 3rd harvest period of the study. In addition to these components, ethyl acetate (0.0%-0.83%) and isoamyl acetate (0.0%-0.53%) components were also detected in the later harvest periods of the study. As the maturity of the fruits progressed, the ratios of ester compounds increased, and at the last harvest period of the study, on 22th December 2014, a total of 5.56% ester presence was detected (Table 2).

Alcohol acetyl transferase enzyme can form desired ester compounds on olive oil aroma (hexyl acetate, Z-3-hexenyl acetate) from alcohols via lipoxygenase pathway (Kiralan, 2010; Yilmaz and Ogutcu, 2012; Seker et al., 2021). Researchers reported that the amount of hexyl acetate increased with maturation and hexyl acetate compound gives a sweet-fruity floral sensory perception in olive oil (Vekiari et al., 2010; Angerosa et al., 2004). It has been reported in different sources that isoamyl acetate (acetic acid 3-methyl butyl ester) compound detected in olive oil creates reminiscent of banana and ethyl acetate creates reminiscent of sweet and aromatic notes, while citronellil acetate gives a floral citrus sensory perception (Aparicio and Luna, 2002; Angerosa et al., 2004; Kalue et al., 2007; Anonymous, 2022). On the other hand, the Z-3-hexenyl acetate compound evokes a green banana, green leaf and floral sensory feature (Angerosa et al., 2004).

Aparicio and Luna (2002) reported in Verdial de Huevar olive that hexyl acetate and Z-3- hexenyl acetate aroma compounds were found at concentrations of 144 $\mu g\ kg^{-1}$ and 21 $\mu g\ kg^{-1}$, respectively. Perez et al. (2003) reported that the 6-carbon ester compounds (Z-3-hexenyl acetate and hexyl acetate) synthesized by lipoxygenase pathway in the verdial olive variety were at a concentration of more than 800 $ng\ g^{-1}$, whereas the other identified ester compounds (methyl acetate, ethyl acetate, 3-methyl butyl acetate, methyl hexanoate) were lower than 400 $ng\ g^{-1}$.

During the research, a total of 6 hydrocarbons (0.63%-7.13%) volatile compounds were identified in the fruits of the Verdial variety collected at different harvest periods. Also, it was determined that the proportions of hydrocarbons increased during fruit ripening (Table 2). 3-Ethyl-1.5-octadiene (0.63%-2.81%) compound was identified since the beginning of the study and it was observed to be the major hydrocarbon compound because its ratio increased with fruit maturation. However, after 5th harvest periods (MI>2.93), undecane (0.0%-1.13%), 2-ethyl furan (0.0%-0.91%), 2.4-dimethyl furan (0.0%-0.99%), 2-butyl furan (0.0%-0.82%) and octane (0.0%-0.47%) was started to become effective.

The presence of 2-ethyl furan and 2-pentyl furan formed by lipid oxidation of unsaturated fatty acids in the aroma composition can give an idea about the advanced levels of oxidation (Frankel, 1980; Kiralan et al., 2012). It is stated that these compounds can help in the differences of high quality oils and advanced level oxidized oils (Vichi et al., 2003). Furans are colorless, lipophilic and highly volatile low molecular weight compounds (Sisik Ogras, 2014). Some researchers have reported that compounds such as toluene, xylenes and ethyl benzene may be caused by external contamination and by one of the pathways in aroma formation (Biedermann et al. 1995). In some literature, it has been reported that 3-ethyl-1.5 octadiene is very distinctive with its geranium-like, lemon-green odor and ethyl furan has a sweet and beany sensory perception (Reiners and Grosch 1998; Kritsakis, 1998; Kalua et al., 2007; Anonymous, 2022). Barrio Perez-Cerezal et al. (1981) reported an inverse relationship between octane concentration and taste and sensory quality in olive oil stored for 100 days.

When the aroma compound profile of Verdial olive variety was examined, the proportion of ketone group (1.34%-5.99%) increased to other flavor components with fruit maturation. 1-penten-3-one (1.34%-3.33%) compound, which has a fruity and sweet sensory perception similar to tomato and strawberry odor, was detected in all harvest periods and it was determined to be a major ketone compound. 2-cyclohexonone (0.0-1.01%) and 2-butanone (0.0-1.65%) compounds were also identified in the following harvest periods with maturation.

In terms of ketone ratios and changes during fruit maturity, different researchers stated that they showed different variation in different cultivars. It is also reported that especially 2-butanone compound gives a fruity ethereal sensory perception in olive oil and ketone compounds longer than eight carbon atoms impair the sensory taste (Kesen et al., 2014; Anonymous, 2022).

It was determined that 1-penten-3-one volatile compound in the aroma components of Verdial de Huevar variety harvested in the Seville-Spain region was 113 ug kg-1 (1.90%) at normal maturity (Aparicio and Luna, 2002).

Perez et al. (2003) investigated the effect of hot water applications before oil processing on the aroma of Verdial variety. As a carbonyl component of 5-carbon linolenic acid origin, 1-penten-3-one was defined as the compound in the ketone group that would provide the desired sensory perception in olive oil. The researchers explained that the hot water process before the oil processing of the fruits negatively affected the presence of 1-penten-3-one, which is one of the positive aroma components.

During the research, a total of 5 terpene compounds were found and it can be said that limonene (1.47%-3.22%) and α-bergamoten (1.30%-3.17%) compounds are the major terpenes because they were detected in the highest proportions, in all harvest periods. In addition, α-farnecene (0.39-2.50%), α-sinensal (0.30-2.48%) and β-myrcene (0.0-1.91%) compounds that identified as terpene compounds were detected at increasing rates during maturity.

Terpenes are the second component group with the highest percentage (3.46%) after aldehydes, while the fruits were dark green (MI 0.02) on 15th September 2014, the beginning of the study. Terpene ratios increased during maturity and reached a high rate of 13.28% at the end of the study. The highest terpene ratio is 4.0 MI. The fruits with a value of 14.05% were defined on 9th harvest period (11.12.2014).

It is not certain that terpenes compounds create what kind of aroma in olive oil. However, it is thought that these components may contribute positively to the aroma of olive oil (Baccouri et al. 2008; Seker et al., 2021). Depending on the olive varieties and locations, the type and amount of hydrocarbons and terpenes may vary. It is said that some researchers make it possible to separate olive oils according to olive varieties and locations, through the hydrocarbon and terpene compounds (Guinda et al., 1996; Bortolomeazzi et al., 2001; Vichi et al., 2007).

CONCLUSION

As a result of the research, when the aroma compositions of the Verdial olive variety were evaluated in all harvest periods, it was determined that the aldehydes decreased with the ripening of the fruits, however, it was always found at the highest rate in all harvest periods. When the aroma compounds were examined, it was determined that E-2-hexenal and hexanal compounds were always present at the highest rate in all harvest periods and were found at a higher rate when the fruits were dark green. Other important aroma compounds are Z-3-hexenol and hexanol from alcohols, limonene and α-bergamoten from terpenes, hexyl acetate from esters, 1-pentene-3-one from ketones and 3-ethyl-1.5-octadiene from hydrocarbons were determined in all harvest periods.

As a conclusion, it can be said that the most important aroma components in the fruits of the Verdial olive variety are the aldehyde group, thus, Hexanal and E-2-Hexenal aroma compounds have a very significant effect on the aroma of olive and olive oil. It is observed that terpenes and alcohols, which are the second and the third most important volatile groups after aldehydes, increased during maturity.

REFERENCES

Angerosa F., Servili, M., Selvaggini, R., Taticchi A., Esposto S. and Montedoro G.F. 2004. Volatile Compounds in Virgin Olive Oil: Occurence and Their Relationship With The Quality. Journal of Chromatography A, 1054, 17-31.

Angerosa, F., 2002. Influence of Volatile Compounds on Virgin Olive Oil Quality Evaluated by Analytical Approaches and Sensor Panels. *European Journal of Lipid Science and Technology*, 104(9–10), 639–660.

Anonymous, 2018 (https://www.oliveoilmarket.eu/all-about-olive-oil/spain-olive-oil-varieties) Date of Access: 01.07.2018.

Anonymous, 2022. (http://www.thegoodscentscompany.com) Date of Access: 01.08.2022.

Aparicio R., Ferreiro L., Alonso V., 1994. Effect of Climate on The Chemical Composition of Virgin Olive Oil. Analytica Chimica Acta, 292: 235–241.

Aparicio R., Morales M.T., 1998. Characterization of Olive Ripeness by Green Aroma Compounds of Virgin Olive Oil. Journal of Agriculture and Food Chemistry, 46(3): 1116–1122.

Aparicio, R., Luna G., 2002. Characterisation of monovarietal virgin olive oils. Eur. J. Lipid Sci. Technol. 104 (2002) 614–627.

Baccori O., Bendini A., Cerretani L., Guerfer M., Baccod B., Lercker G., Zarrouck M., Ben Miled D.D., 2008. Comparative Study on Volatile Compounds from Tunisian and Sicilian Monovarietal Virgin olive oils. Food Chem, 111:22-328

Barrio Perez-Cerezal, A., F. Gutierez Rosales, and R. Gutierrez Gonzalez-Quijano, 1981. Gas–Liquid Chromatography Application, A Head-Space Technic to the Olive Oils Atrojado Problem, Grasas Aceites 32:155–161.

Benincasa, C., De Nino, A., Lombardo, N., Perri, E., Sindona, G. and Tagarelli, A. 2003. Assay of Aroma Active Components of Virgin Olive Oils from Southern Italian Regions by SPME-GC/Ion Trap Mass Spectrometry. Journal of Agricultural and Food Chemistry, 51, 733–741.

Biedermann, M., Grob, K., & Morchio, G. (1995). On the origin of benzene, toluene, ethylbenzene and xylene in extra virgin olive oil. *Zeitschrift für Lebensmittel-Untersuchung und Forschung*, *200*(4), 266-272.

Bortolomeazzi, R., Berno, P., Pizzale, L., Conte, L. S. 2001. Sesquiterpene, Alkene, and Alkane Hydrocarbons in Virgin Olive Oils of Different Varieties and Geographical Origins. Journal of Agricultural and Food Chemistry, 49: 3278–3283.

Colakoglu M., l969. 1666–67 Kampanyasında Elde Edilen Türk Zeytinyağlarının Analitik Karakterleri. Ege Üniversitesi Ziraat Fakültesi Yayın No. 138. İzmir. 41 s.

Collin, S., Nizet, S., Muls, S., Iraqi, R., & Bouseta, A. (2008). Characterization of odor-active compounds in extracts obtained by simultaneous extraction/distillation from Moroccan black olives. *Journal of agricultural and food chemistry*, *56*(9), 3273-3278.

Dagdelen A., Ozkan G., Karasu S., Sagdic O., 2016. Differentiation of Olive Oils Based on Rheological and Sensory Characteristics Obtained from Six Olive Cultivars. Quality Assurance and Safety of Crops & Foods: 8 (3): 415 – 425

Ekinci N., Gundogdu MA., Seker M., 2021. Effects of different calcium oxide dipping concentrations in aroma profiles of pink lady apple cultivar during cold-storage. Ege Üniv. Ziraat Fak. Derg., 2021, 58 (3):305-313

FAO, 2022. Agricultural statistical database. (http://www.fao.org/faostat/en/#data/QC) (Date of Access: 01.07.2022)

Frankel, E. N., in: Progress in Lipid Research, Pergamon Press, London, U.K 1980, pp. 1–122.

Gomez-Rico, A., Inarejos-Garcia, A.M., Salvador, D. and Fregapane, G. 2009. Effect of malaxation conditions on phenol and volatile profiles in olive paste and the corresponding virgin olive oils (*Olea europaea* L. Cv. Cornicabra). Journal of Agricultural and Food Chemistry, 57, 3587-3595.

Guinda, A., Lanzón, A. and Albi, T. 1996. Differences in Hydrocarbons of Virgin Olive Oils Obtained from Several Olive Varieties, Journal of Agricultural and Food Chemistry, 44, 1723-1726

Gundogdu M.A., 2011. Investigation of Monthly Changes of Phenological and Pomological Characteristics with Olive Oil Components in Olive Varieties. University of Canakkale Onsekiz Mart, Graduate School of Natural and Applied Sciences, Chair of Horticultural Thesis of Master of Science, pp. 179.

Gundogdu M.A., Kaleci N., Nergis O., Dogan E., 2016. Farklı Zaman Periyotlarında Hasat Edilen Bazı Yabancı Kökenli Zeytin Çeşitlerinin Pomolojik ve Bazı Biyokimyasal Karakterlerindeki Değişimlerin Saptanması. Zeytin Bilimi 6 (2): 61-67.

Gundogdu M.A., Seker M., 2012. Bazı Yabancı Kökenli Zeytin Çeşitlerinden Elde Edilen Zeytinyağlarının Yağ Asidi Bileşiminin Olgunlaşma Süresince Değişimi. Zeytin Bilimi 3 (1): 19-28.

Ilyasoglu H., Ozcelik B., Van Hoed V., Verhe R., 2011. Cultivar Characterization of Aegean Olive Oils with Respect to Their Volatile Compounds. Scientia Horticulturae 129(2):279-282.

IOOC, 2007. Optimal Harvest Time. In: Tombesi A. ve Tombesi S., Eds. Production Techniques in Olive Growing. Artegraf S.A., Madrid. 319-327.

Kalua C.M., Allen M.S., Bedgood D.R., Bishop A.G., Prenzler P.D., Robards K., 2007. Olive oil Volatile Compounds, Flavour Development and Quality: A Critical Review. Food Chem, 100, 273–286.

Kesen S., Selli S., Kelebek H., Cabaroğlu T., Şen K., Ulaş M., 2014. Adana ili Gemlik ve Barnea Zeytinyağlarının Aroma Maddelerinin Kıyaslanması, GIDA 39 (2): 103-110.

Kiralan M., 2010. Determination of Aroma Profiles of Olive Oils from Turkish Olive Cultivars (In Turkish). University of Ankara, Graduate School of Natural and Applied Sciences, Doctoral Dissertation in Food Engineering, pp. 168.

Kiralan M., Ozkan G., Koyluoglu F., Ugurlu H.A., Bayrak A ve Kiritsakis A., 2012. Effect of Cultivation Area and Climatic Conditions on Volatiles of Virgin Olive Oil. Eur. J. Lipid Sci. Technol. 2012, 114, 552–557.

Kiritsakis, A.K. 1998. *Olive Oil* from the Tree to the Table. Food and Nutrition press, 330 p.,Trumbull, Connecticut, USA.

Morales M.T., Aparicio R.J., 1999. Effect of Extraction Conditions on Sensory Quality of Virgin Olive Oil. Amer. Oil Chem. Soc., 76: 295–300. doi: 10.1007/s11746-999-0234-9.

Perez A.G., Luaces P., Rios J.J., Garcia J.M., Sanz C., 2003. Modification of Volatile Compound Profile of Virgin Olive Oil Due to Hot-Water Treatment of Olive Fruit. J. Agric. Food Chem. 51, 6544-6549.

Reiners J., Grosch W., 1998. Odorants of Virgin Olive Oils with Different Flavor Profiles. *J. Agric. Food Chem.* 46 (7) 2754-2763.

Sabatini, N., 2010. Recent patents in olive oil industry: New technologies for the recovery of phenols compounds from olive oil, olive oil industrial by-products and waste waters. Recent Patents on Food, Nutrition, and Agriculture, 2 (2):154-159.

Salas J.J., Sanchez C., Garcia–Gonzalez D. L., Aparicio R., 2005. Impact of the Suppression of Lipoxygenase and Hydroperoxide Lyase on the Quality of the Green Odor in Green Leaves. J. Agric. Food Chem., 53 (5):1648–1655.

Seker M., Gül M.K., İpek M., Kaleci N., Yücel Z., Yılmaz E., Topal U., 2008. Zeytin (*Olea europaea* L.) Çeşitlerinin AFLP ve SSR Markörleri Polimorfizminin Yağ Asitleri ve Tokoferol Düzeyleri ile İlişkilendirilmesi. Tubitak Project Final Report, Project No: TOVAG–3358, pp: 122.

Seker, M., Gundogdu, M.A., Ekinci, N., Gur, E., 2021. Recent Developments on Aroma Biochemistry in Fresh Fruits. International Journal of Innovative Approaches in Science Research, 5(2), 84-103.

Sisik Ogras S., 2014. Identification of volatile compounds and some other qualitative characteristics of olive oils from different geographic regions (In Turkish).

University of Atatürk, Graduate School of Natural and Applied Sciences, Doctoral Dissertation in Food Engineering, pp. 103.

Tan A., 2010. Türkiye Bitki Genetik Kaynakları ve Muhafazası. Anadolu, J. of AARI, 20(1): 9-37.

Vekiari, S.A., Oreopoulou, V., Kourkoutas, Y., Kamoun, N., Msallem, M., Psimouli, V., Arapoglou, D. 2010. Characterization and seasonal variation of the quality of virgin olive oil of the Throumbolia and Koroneiki varieties from Southern Greece. Grasas y Aceites, 61, 221-231.

Vichi S., Guadayol J.M., Caixach J., López-Tamames E., Buxaderas S., 2007. Comparative study of different extraction techniques for the analysis of virgin olive oil aroma. Food Chemistry, 105, 1171-1178.

Vichi S., Pizzale L., Conte L.S., Buxaderas S., Lopez-Tamames E., 2003. Solid-Phase Microextraction in the Analysis of Virgin Olive Oil Volatile Fraction: Modifications Induced by Oxidation and Suitable Markers of Oxidative Status. Journal of 245 Agricultural and Food Chemistry, 51, 6564-6571.

Yilmaz E., Ogutcu M., 2012. Zeytinyağı Aromasının Oluşumunda Lipoksijenaz Yolu Reaksiyonları. Zeytin Bilimi 3 (1): 51-58.

CHAPTER 8

THE ROLE OF POLYAMINES IN HORTICULTURE GROWING

PhD. Selma KURU BERK[1],
Prof. Dr. Müttalip GÜNDOĞDU[2]

[1] Bolu Abant İzzet Baysal University, Mudurnu Süreyya Astarcı Vocational School, Organic Farming Dep., Bolu, Turkiye, selmakuruberk@gmail.com, ORCID ID 0000-0002-4553-7069
[2] Bolu Abant İzzet Baysal University, Faculty of Agriculture, Horticulture Dep., Bolu, Turkiye, gundogdumuttalip@gmail.com , ORCID ID 0000-0002-9375-7365

INTRODUCTION

Polyamines (PA) are organic compounds containing more primary amine groups (cadaverine, putrescine, spermine and spermidine). The discovery of polyamine in higher plants is based on the discovery of diamine in Datura plant (Bachrach, 2010). Spermidine (Spd) and putrescine (Put) are found in the whole of living structures, while spermine (Spm) are found in eukaryotic cells. The most common polyamines in the plant are Spd, Put and Spm. They play an effective role in many activities such as cell growing and reproduction activities, plant growth, flower and fruit development (Hussain et al., 2011a).

The synthesis of polyamines in plants (Figure 1) starts with the amino acids L-arginine and L-methionine, and there are two alternative synthesis routes in plants (Bagni and Tassoni, 2006). Putrescine is synthesized from arginine by arginase and from ornithine by ornithine decarboxylase (ODC). Moreover, putrescine can be synthesized from agmatine by three sequential reactions catalyzed by arginine decarboxylase (ADC), agmatine imino hydrolase (AIH) and N-carbamoyl putrescine amido hydrolase (CPA), respectively (Kusano et al., 2007). With the addition of Sadenosylmethionine (dcSAM), which is an aminopropyl Putrescine, it turns into spermidine and spermidine is converted into spermine with the same aminopropyl (Martin-Tanguy, 1997).

It is stated that the concentration of polyamine released by plants changes significantly during the transition from the vegetative stage to the generative stage, and therefore, polyamines have an important role in the beginning and duration of flowering. Plants with unstable Put metabolism show a delay in flowering with abnormal flowering structures (Kakkar and Sawhney, 2002).

In putrescine biosynthesis, two genes encoding ADC (ADC_1 and ADC_2) are revealed by environmental stresses. ADC_2 expression is more promoted in abiotic stresses such as high salinity, drought and K^+ deficiency (Perez-Amador et al., 2002) and ADC_1 expression is more promoted in cold stress (Hummel et al., 2004).

1-aminocyclopropane-1-carboxylate (ACC) enzyme, which takes part in ethylene synthesis, is inhibited by polyamines and ethylene production is interrupted. For this reason, it is known that it is used to delay post-harvest senescence and extend the storage life of fruits and flowers (Valero et al., 2002). In addition, in another study, it was reported that putrescine reduced the internal browning and signs of chill damage by limiting lipid peroxidation in pomegranates (Barman et al., 2011). In addition to its post-harvest effect, it has been determined in recent researches that fruit quality has increased in plants treated with poliamine (Eshghi and Jamali, 2014).

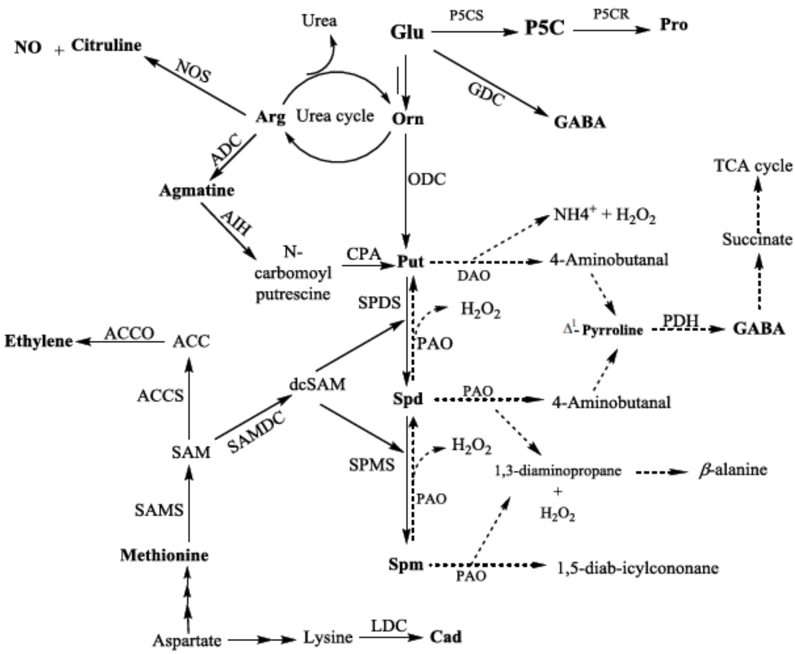


Figure 1: Polyamine biosynthesis pathway in plants (Mustafavi et al., 2018).

1. Growth and development

Polyamines are influence in cell development and cell division, which are important factors for plant growth (Hussain et al., 2011b; Anwar et al., 2019). Studies have shown that properties such as leaf area, plant fresh height and shoot number increase with polyamine (Put, Spm and Spd) applications (Tavallali et al., 2022). In the research conducted on tomatoes, it was stated that this situation varies according to the type of polyamine. It has been stated that Spd and Spm have a more positive effect on cellular development and have similar properties, while putrescine acts in the opposite direction (Handa and Mattoo, 2010). In pistachio, shoot diameter and leaf area increased with Spm application and shoot length increased with Put application (Khezri et al., 2010). Contrary to this situation, in the cucumber plant, it was stated that 0.8

mM put application did not make any difference in plant growth parameters (Yuan et al., 2019). Putrescine increased leaf area fresh and dry weight more than Spm, in rose. Spermidine, on the other hand, had a toxic effect with increasing dose and negatively affected these parameters (Yousefi et al., 2021). Studies show that Spm and Spd promote lateral root formation and primary root growth (Martin-Tanguy and Carre, 1993). As for in eggplant, it has been stated that putrescine applications alone are not sufficient, and together with the yeast applied to the soil, it increases plant height, leaf area and especially yield (Ei-Tohamy et al., 2008).

Breaking bud dormancy and shortening the flowering period in apple trees are associated with a high amount of polyamines, especially with spermine. Therefore, researchers emphasize that polyamines can be used in fruit growing to increase fruit set (El-Yazal and Rady, 2012). It has been emphasized that in pistachio, bud dormancy and PA concentration are in the opposite direction, and dormancy can be prevented by the content of spermine in the leaves (Roussos et al., 2004). Likewise, it has been stated that polyamines break dormancy and accelerate flowering in almonds (Naseri et al., 2019).

2. Fruit Quality

Enzymes that cause fruit softening and break down pectins during fruit ripening are inhibited by polyamines and therefore fruit quality is preserved (Khan et al. 2007). It was stated that better quality cherry fruits were obtained with the pre-harvest Put application. It is reported that putrescine (2.5 mM) provides brighter red colored, firm and heavier fruit (Erbaş et al., 2018). On the contrary, it has been stated that the PAs (put, spm, spd) sprayed during the flowering period negatively affect the firmness and water-soluble dry matter content of the mango fruit, resulting in darker and duller fruits (Malik and Singh, 2006). It has been reported that when the grapes reach the size of a pea, putrescine sprayed on the leaves increases the fruit size and weight and improves the quality of the cluster (Bassiony et al., 2018). In another study, putrescine applied to peaches during fruit development increased fruit quality and yield. It was stated that fruit weight, fruit dimensions, fruit flesh firmness and ascorbic acid amount were measured in the highest amount with 2 mM putrescine dose (Ali et al., 2014). In hot pepper, the amount of capsisin, which is the inevitable factor for pepper quality, was obtained to be higher in pepper treated with putrescine (Sudha and Ravishankar, 2003) and spermine (Koç et al., 2020). The peel thickness, which is one of the important factors for orange, decreased with Spd and Spm application. At the same time, the number of seeds decreased, the amount of titratable acidity (TA) increased and the fruit quality was preserved. Researchers reported that fruit weight and size were higher with putrescine application (Saleem et al., 2008). In the study conducted on Golden Delicious and McIntosh apple varieties, it was found that the fruit firmness increased during the storage period with polyamine applications (Put, Spd and Spm) and this increase was more in the application of spermine (Karamer et al., 1991). In addition to these positive aspects, some researchers stated that putrescine applications in peach put off fruit maturing, prevent coloration and reduce the amount of sugar (Farag et al., 2007).

3. Flowering and fruit setting

The yield and elements affecting yield are among the important factors in terms of horticultural cultivation. One of the important elements in the cultivation of horticultural crops is the yield and the factors affecting yield. Polyamines affect the yield by affecting the flower structures, fertilization and flowering processes, which directly affect the yield. In particular, they affect factors such as the development of the pollen tube and the formation of male gametophytes that affect fertilization (Scaramagli et al., 1999; Falasca et. Al., 2010). Polyamine concentration increases significantly in the transition to the flowering phase, flowering is delayed in plants that do not have enough amount, and even mutant flower structures are formed (Kakkar and Sawhney 2002). However, Arias et al. (2005) stated in their study on tangerine cultivars that the amount of internal polyamine did not affect the amount of flowering, but increased fruit set. In the researches, male fertility in tomato (Song and Tachibana, 2007) and pollen germination were associated with polyamines (Song et al., 2002), and it was stated that fertilization was disrupted in the absence of the plant. The study on male flowers of kiwifruit shows that polyamines are active during the pollen development stage and that in the absence of polyamine, abnormal pollen formation with reduced viability increases (Falasca et. Al., 2010). It was obtained that the treatment of 1 mM Put before pollination in Japanese pear increased pollen germination and fruit set in the stigma (Franco-Mora et al., 2005). Similarly, PAs sprayed during the flowering period increased the fruit retention in mango. While the effect of spermine on this feature is higher, putrescine was found to be more effective in terms of yield (Malik and Singh, 2006).

Spm and Spd treatments in Impatiens flower increase the number of flowers in the plant. In addition, there was an increase in fresh and dry weights, and this effect was greater with spermine (Verdolin et al., 2021). With the application of Put and Spd to gerbera flower, an increase was obtained in the number of flowers, flower diameter width, flower stem length, and it was reported that the most ideal application was 100 ppm of putrescine. However, it has been stated that 100 ppm Spd is more suitable for vegetative growth (Saeed et al., 2019). In roses, it was stated that the flower numbers was not influenced by polyamine applications, but the flowering period was prolonged. It has also been stated that Spm is more effective than other PAs and generally lower doses give more positive results (Yousefi et al., 2019). It is also known that PAs increase flower bud formation and flower number in pistachios (Baninasab and Rahemi, 2008).

4. Stress

Polyamines are released more under stress conditions and thus they create a defense mechanism in plants (Liu et al, 2011). Plants under environmental stress increase the production of γ-aminobutyric acid (GABA), and this amino acid increases the amount of polyamines in the plant by regulating the synthesis pathway, making plant more toleration to abiotic stress (Podlesakova et al., 2019). In addition, external polyamine applications under stress conditions also regulate plant growth and reduce the negative stress effect (Shi et al., 2013; Xu et al., 2011). Protecting macromolecules of polyamines, serving as a membrane stabilizer and free radical scavenger causes the plant to form a defense mechanism and respond positively to stress conditions (Velikova et al., 2000; Cona et al., 2006). It is known that in cucumber plants grown in salt stress, the amount of polyamines, particularly Spd, increases and the amount of chlorophyll in the plant is preserved (Shu et al., 2012). In addition, it was stated that parameters such as stem diameter thickness, leaf area and plant height were not affected by stress conditions (Yuan et al., 2019). However, it is known that polyamine applications (Put, Spd, Spm), especially putrescine, increase seedling growth under drought stress conditions

(Çömlekçioğlu and Arıkan, 2017). It has been reported that putrescine prevents germination in pepper seeds under normal conditions, but increases root and shoot length under salt stress. It has been stated that spermine increase fresh weight under these stress (Koç et al., 2014). As regards Ekinci et al. (2019) obtained similar results with the study in pepper, but found that spermidine increased the developmental parameters more. Similarly, in bean plants under salt stress, putrescine (1 mM) was found to protect development parameters such as chlorophyll content, seedling height, stem thickness and fresh weight from the negative effects of salinity (Kibar et al., 2020). In hypoxia conditions due to excessive water saturation of the soil, the accumulation of PAs together with GABA increased in tea leaves (Liao et al., 2017) and fava beans (Yang et al., 2011), and a positive response to stress was formed. GABA given externally in melon roots increased the accumulation of PA, reducing the anoxia effect for a short time and showing a similar effect (Wang et al., 2014).

5. Conservation

Polyamine applications before or after harvest affect fruit quality, prolong post-harvest storage time and reduce losses, although it varies according to fruit species and varieties (Khosroshahi et al., 2008; Yousef et al., 2014). These important effects are due to the fact that polyamines inhibit ethylene production and slow down the respiratory rate (Perez-Vicente et al., 2002). With the post-harvest teratment of 1 mM putrescine kiwi storage conditions, ethylene production and CO_2 amount are significantly reduced. However, Spd had a moderate effect and Spm had no effect (Petkou et al., 2015). In the same fruit, 2 mM putrescine dose reduced chilling damage and increased the amount of vitamin C and antioxidant amount (Yang et al., 2016). It has been stated that 0900 cherry cultivars can be stored for 30 days without decay and with minimum fruit weight loss with 7.5 mM putrescine application before harvest. However, during this period, the taste, color and amount of water-soluble dry matter were more preserved with the 5 mM dose (Koyuncu et al., 2018). Khosroshahi et al. (2008) stated that with the 4 mM putrescine dose applied to the Suratie Hamedan cherry variety after harvest, the fruits could be stored for 25 days with maximum flesh firmness and minimum weight loss. Bal (2012), on the other hand, reported that cherries can be stored for 35 days with 1 mM dose of putrescine application after harvest. Postharvest application of putrescine (2 mM) to strawberry fruits did not soften the fruits during storage (13 days) and the firmness of the fruit flesh was preserved (Khosroshahi et al., 2007). Chestnut fruits were stored for 7 months and it was observed that there was no internal darkening and green mold decreased with putrescine application (2 mM), while phenolic substance, sugar and starch accumulation in fruits decreased and fruit softening increased (Çalışkan, 2020). It has been determined that polyamines (Put, Spm and Spd) in okra have a positive effect on the storage period. While the effect of putrescine was more pronounced, it provided 12 days of storage with 68% reduction in weight loss and 45% reduction in chilling damage (Phornvillay et al., 2019). It was stated that putrescine and spermine (1 mM) reduced weight loss during storage in marrow compared to spermidine and were stored for 14 days without darkening (Palma et al., 2015).

Polyamines affect fruit quality during storage as well as storage period. In Black Diamond plum cultivar, 2 mM putrescine dose reduced fruit rot and darkening during 100 days of storage (Erbaş and Koyuncu, 2019a). At the same time, acidity (TA) and fruit flesh firmness were preserved, but the amount of water-soluble dry matter was adversely affected (Erbaş and Koyuncu, 2019b). In the Giant plum variety, the amount of vitamin C and the amount of phenolic substances were preserved during storage with putrescine application and could be stored for one month (Dursun and Honey, 2020). It was observed that weight loss and microbial activity decreased during storage, and the amount of phenolic substance increased slightly in bananas dipped in putrescine (Hosseini et al., 2018; Nilprapruck et al., 2017). It is emphasized that the chilling damage of mango fruit during storage is related to polyamines. It is stated that spermine and spermidine reduce cold damage in fruits, whereas putrescine does not stop cold damage in mango fruits (Nair and Singh, 2004). The application of PAs (Put, Spm and Spd) at a dose of 1.5 mM in lemons (Amin and Rahemi, 2007) and the application of 5 mM putrescine in Valencia oranges reduced chilling damage during storage and protected the fruits (Mohammadrezakhani and Pakkish, 2014).

6. Aging

Polyamines ensure that the signaling process is preserved intact in aging tissues (Handa and Mattoo, 2010). They take part in the transmission pathway of senescence (Wimalasekera et al. 2011) and prevent aging by preventing chlorophyll loss and ethylene synthesis (Pandey et al. 2000). In a study on carnations, it was stated that spermine decreased the ACC oxidase activity in the leaves, and accordingly, ethylene production decreased, and aging was delayed in cut flowers (Lee et al., 1997). da S Vierra et al. (2017) stated that polyamines delay petal shedding in flowers and thus prolong vase life. It is stated that with the application of 10 ppm sperm in cut roses, the vase life is extended by 3 days, there is an increase in flower quality and a slower bud opening occurs in the first week (Tatte et al., 2015). Otherwise, it is reported that 100 ppm Spm treatment before harvest extends the vase life by 5 days and at the same time preserves the amount of anthocyanin, which provides coloration in the petal leaves, more (Danaee and Abdossi, 2018). It has been reported that the flower quality in gerberas is preserved more than the putrescine with the 2 mM dose of Spm and the flower life is extended by 11 days (da S Vierra et al., 2017). Upfold and Van Staden (1991) on cloves, Iman Talaat et al. (2005) reported that the vase life of roses was prolonged with polyamine applications. In another study, it was stated that the vase life and the amount of anthocyanin in the petals were more effective in putrescine applications than other PAs (Karımı et al., 2017). It was found that 10 mM spermidine given to vase water was more effective in terms of vase life in carnation and gerbera flowers than sprayed on leaves. It has been reported that petal aging is reduced, stem bending is absent, and the vivid color of the petal is preserved (Bagni and Tassoni, 2006). Similarly, it is stated that pre-harvest Spd treatment increases flower stem and length, while Spm application extends vase life (Farahi and Jahroomi, 2018). Studies show that the effect on the plant varies according to the species and PA dose. It has been reported that the use of low doses of Spm and Spd affects vase life and flower quality more positively than the use of high doses of Put (Farahi and Zadehbagheri, 2017). In irises, putrescine (2 mM) extended the vase life by 5 more days, while spermine extended it by 4 days. Similarly, higher flower diameter and anthocyanin content in the petals were obtained, and it was stated that putrescine was more suitable for cut flower quality (Mortazavi et al., 2021). On the other hand, it was observed that putrescine (200 ppm) did not prolong the vase life when used alone in narcissus flowers, but extended it by 2 days when used with salicylic acid (100 ppm) (Sardoei et al., 2013).

7. Propagation

Polyamines are used in cutting, grafting and generative production, especially in tissue culture. Cell division and development, root and shoot formation properties increase their use in propagation.

It is stated that PAs (Put, Spm and Spd) used in the germination of pepper seeds shorten the germination period and increase the root and shoot length. However, it was observed that putrescine inhibited the germination rate of 50% (Khan et al., 2012). Correlatively, Kibar et al. (2020) reported that putrescine in beans reduces the germination percentage, but promotes shoot and root development, seedling dry and fresh weight at low doses.

In the study conducted in the vineyard, it was found that 10 mM Put application in Cabernet Franc/5BB grafting combination increased callus formation (15%) and shoot length at the grafting point (Kök, 2018). It has been reported that 1600 ppm Put application increases the grafting rate with GN15 rootstock in almond seedling propagation, but this increase is not as much as other effective rooting hormones. Putrescine had little effect on GF677 rootstock (Yerebasmaz, 2019).

It was observed that the amount of callus and rooting rate increased by 40% when IBA was used together with putrescine compared to the use of IBA alone in hazelnut cuttings (Cristofori et al., 2010). Similarly, the use of putrescine in addition to auxin increased the rooting index and root length in leafy and leafy-bud fig cuttings. However, it has been stated that this effect decreases with increasing dose (Ghehsareh and Khosh-Khui, 2019). Again, by treating the cherry rootstock cuttings with putrescine (2 mM), the highest rooting rate and root number were obtained (Karimi and Yadolahi, 2012). Although the studies are similar, the effect of polyamines varies according to the species. Because it has been reported that putrescine in the wild pear is not sufficient for rooting on its own. The maximum rooting rate was obtained in the interaction of 4000 ppm IBA and 150 ppm Put in rooting green cuttings (Dumanoğlu et al., 1999).

In the tissue culture propagation method, the effect of adding putrescine into the medium in plant development has been tried by several searchers in different species. It was determined that putrescine increased the average weight of the cactus plant under in vitro conditions. In addition, it is reported that the use of high doses causes a decrease in weight by having a negative effect. Besides, rooting of acacia showed a positive effect on rooting percentage, weight and length. It was determined that tomato shoot weight increased with the addition of 0.5 mM spermidine and 0.3 mM spermine doses to the tissue culture medium. Despite these conditions, it has been reported that the addition of putrescine has a adverse effect on the micropropagation of the lilac plant (Scholten, 1998). An increase in the amount of callus was determined by annexing Put and Spd into the medium in obtaining haploid plants from marrow and dark green squash (Kara and Sarı, 2019). In addition, it has been reported that the adding of 2 mM spermidine to the medium has a stimulant effect, but putrescine has no effect in the clementine type and haploid plant production with anther culture. Researchers stated that they could not obtain haploid plants while obtaining tri-haploid plants (Chiancone et al., 2006). However, the use of putrescine in the reproduction of banana in tissue culture medium had a negative effect. It was reported that shoot number decreased with the treatment of putrescine during the culture (Choudhary et al., 2013).

The use of polyamines in tissue culture media to obtain haploid plants by gynogenesis varies according to the species and variety. In onions, it has been reported that the addition of Spd and Put together increases the yield of new plants (Ebrahimi and Zamani, 2009), but only the addition of putrescine has no effect (Martinez et al., 2000). The most gynogenic embryos (4.97%) were obtained from the use of Put and Spd together (Ebrahimi and Zamani, 2009). In addition, it was stated that the addition of Spd to the medium in cucumber did not increase gynogenesis, on the contrary, the amount of putrescine in the medium increased during the advancing culture days (Wei et al., 2010). In watermelons, it has been reported that the addition of polyamine to the medium increases callus formation in the ovary and ovule culture, but it is not possible to obtain a complete plant (Yıldız and Solmaz, 2020).

CONCLUSION

Polyamines are used in the field of horticultural crops in the culture stages of many species, post-harvest or propagation conditions. Although there are generally positive aspects according to the conditions of use, negative effects are also seen at high concentrations. It is seen that they have a positive effect on properties such as plant growth and reproduction, postharvest physiology and fruit quality although the effects of these growth regulators vary according to the plant species. For this reason, studies on the dose and time of use of polyamines according to species should be increased and the use of polyamines should be brought to horticulture more.

REFERENCES

Ali, I., Abbasi, N. A. and Hafiz, I. A. (2014). Physiological response and quality attributes of peach fruit cv. Florida king as affected by different treatments of calcium chloride, putrescine and salicylic acid. *Pakistan Journal of Agricultural Sciences*, *51*(1), 33-39.

Amin, H. and Rahemi, M. (2007). Investigation of effect of polyamines on chilling control in lemon. *In Proceedings of the 5th Congress of Iranian for Horticultural Science,* Shiraz, Iran.

Anwar, R., Fatima, S., Mattoo, A. K. and Handa, A. K. (2019). Fruit architecture in polyamine-rich tomato germplasm is determined via a medley of cell cycle, cell expansion, and fruit shape genes. *Plants*, *8*(10), 387.

Arias, M., Carbonell, J., and Agustí, M. (2005). Endogenous free polyamines and their role in fruit set of low and high parthenocarpic ability citrus cultivars. *Journal of plant physiology*, *162*(8), 845-853.

Bachrach, U. (2010). The early history of polyamine research. *Plant Physiology and Biochemistry*, *48*(7), 490-495.

Bagni, N. and Tassoni, A. (2006). The role of polyamines in relation to flower senescence. *Floriculture, Ornamental and Plant Biotechnology*, *1*, 88-95.

Bal, E. (2012). Hasat sonrası putresin ve salisilik asit uygulamalarının kirazın soğukta muhafazası üzerine etkisi. *Süleyman Demirel Üniversitesi Ziraat Fakültesi Dergisi, 7(2),* 23-31.

Baninasab, B. and Rahemi, M. (2008). Effect of exogenous polyamines on flower bud retention in Pistachio (*Pistacia vera* L.) trees. *Hortıculture Envıronment And Bıotechnology, 49(3),* 149-154.

Barman, K., Asrey, R. and Pal, R.K. (2011). Putrescine and carnauba wax pretreatments alleviate chilling injury, enhance shelf life and preserve pomegranate fruit quality during cold storage. *Scientia Horticulturae, 130*(4), 795-800.

Bassiony, S. S., El-Aziz, A., Maha, H., and Fahmy, H. M. (2018). Effect of foliar application of putrescine and salicylic acid on yield, fruit quality and storability of "Flame Seedless" Grape (Vitis vinifera L.). *Journal of Plant Production, 9(12),* 1203-1214.

Chiancone, B., Tassoni, A., Bagni, N. and Germana, M. A. (2006). Effect of polyamines on in vitro anther culture of *Citrus clementina* Hort. ex Tan. *Plant cell, tissue and organ culture*, *87*(2), 145-153.

Choudhary, D., Kajla, S., Duhan, J.S., Poonıa, A. K. and Kharıb, P. (2013). Comparative study of various growth regulators on in vitro multiplication of commercial cultivar of banana Grand naine (G-9). *Annals of Biology*, *29*(3), 288-293.

Cona, A., Rea, G., Angelini, R., Federico, R. and Tavladoraki, P. (2006). Functions of amine oxidases in plant development and defence. *Trends in Plant Science, 11*, 80–88.

Cristofori, V., Rouphael, Y. and Rugini, E. (2010). Collection time, cutting age, IBA and putrescine effects on root formation in *Corylus avellana L*. cuttings. *Scientia Horticulturae*, *124*(2), 189-194.

Çalışkan, B. (2020). *Kestanelerde derim sonrası bazı uygulamaların meyve kalitesi ve depolama süresi üzerine etkileri.* (Master's thesis, Aydın Adnan Menderes Üniversitesi Fen Bilimleri Enstitüsü).Turkish National Thesis Center (650363).

Çömlekcioğlu, N. and Arıkan, S. (2017). Fizyolojik stres ve eksojen poliaminlerin Isatis tinctoria L. yapraklarındaki indigo miktarı ve fide gelişimi üzerine etkisi. *Mediterranean Agricultural Sciences*, *30*(3), 261-267.

da S Vieira, M.R., de Moura, F.B., Simões, A.D.N., de Souza, A.V., Santos, C.M., Paes, R.D.A. and Leal, Y.H. (2017). Application of polyamine and boron improves quality of potted gerbera cv.''Kosak''. *Journal of Applied Horticulture*, *19*(1), 84-88.

Danaee, E. and Abdossi, V. (2018). Effect of different concentration and application methods of polyamines (putrescine, spermine, spermidine) on some morphological, physiological, and enzymatic characteristics and vase life of *Rosa hybrida* cv.'Dolce Vita'cut flower. *Journal of Ornamental Plants*, *8*(3), 171-182.

Dumanoglu, H., Aygün, A., Alay, A., Günes, N.T. and Özkaya, M.T. 1999. Ahlatin (*Pyrus elaeagrifolia* Pall.) yeşil çeliklerinde köklenme ve sürme üzerine çelik alma zamani IBA ve putrescine'in etkileri. *Tr. J. of Agriculture and Forestry, 23,* 559-565.

Dursun, F. N., and Bal, E. (2020). The Effect of Some Postharvest Applications on Storage Performance of Autumn Giant Plum Cultivar. *Turkish Journal of Agriculture-Food Science and Technology*, *8*(2), 504-510.

Ebrahimi, R. and Zamani, Z. (2009). Effect of polyamines on in vitro gynogenesis of onion (*Allium cepa L*.). *Am Eurasian J Sustain Agric*, *3*(1), 71-74.

Ei-Tohamy, W.A., Ei-Abagy, H.M. and Ei-Greadly, N.H.M. (2008). Studies on the effect of putrescine, yeast and vitamin C on growth, yield and physiological responses of eggplant (*Solanum melongena L*.) under sandy soil conditions, *Australıan Journal of Basıc And Applıed Scıences, 2,* 296-300.

Ekinci, M., Yıldırım, E., Dursun, A., and Mohamedsrajaden, N. (2019). Putrescine, spermine and spermidine mitigated the salt stress damage on Pepper (*Capsicum annum L*.) seedling. *Yüzüncü Yıl Üniversitesi Tarım Bilimleri Dergisi*, *29*(2), 290-299.

El-Yazal, M.A.S. and Rady, M.M. (2012). Changes in nitrogen and polyamines during breaking bud dormancy in "Anna" apple trees with foliar application of some compounds. *Scientia Horticulturae, 136*, 75-80.

Erbaş, D. and Koyuncu, M. A. (2019b). Derim sonrası putresin, nitrik oksit, oksalik ve salisilik asit, uygulamalarının Black Diamond erik çeşidinde depolama süresince meyve kalitesi üzerine etkileri. *Journal of the Institute of Science and Technology*, *9*(4), 1830-1840.

Erbaş, D., and Koyuncu, M. A. (2019a). Farklı uygulamaların black diamond erik çeşidinde soğukta depolama boyunca üşüme zararı, iç kararması ve çürüme oranı üzerine etkilerinin incelenmesi. *Uluslararası Tarım ve Yaban Hayatı Bilimleri Dergisi*, *5*(2), 212-222.

Erbaş, D., Koyuncu, M. A., Özüsoy, F., and Onursal, C. E. (2018). Derim öncesi putresin uygulamasının 0900 Ziraat kiraz çeşidinin meyve kalitesi üzerine etkileri. *Akademik Ziraat Dergisi, 7(2)*, 151-156.

Eshghi, S. and Jamali, B. (2014). Usıng plant bioregulators to ımprove production and fruit quality of strawberry. *Acta Horticulture*, *1049*, 395-400.

Falasca, G., Franceschetti, M., Bagni, N., Altamura, M. M. and Biasi, R. (2010). Polyamine biosynthesis and control of the development of functional pollen in kiwifruit. *Plant Physiology and Biochemistry*, *48*(7), 565-573.

Farag, K. M., Ismaıl, A. A., Essa, A. A. and El-Sabagh, A. S. (2007). Effect of putrescıne, gıbberellıc acıd and calcıum on qualıty characterıstıcs and maturıty delay of" desert red" peach fruıt cultıvar. *J. Agric. Environ. Sci. Alex Univ.*, *6*(1), 35-66.

Farahi, M. H. and Zadehbagheri, M. (2017). Effect of foliar application of polyamines on growth properties, vase life and endogenous plant growth regulators contents of cut rose flower (*Rosa hybrida cv*. Dolcvita). *Iranian Journal of Horticultural Science*, *47*(4), 717-729.

Farahi, M.H. and Jahromi, A.A. (2018). Effect of pre-harvest foliar application of polyamines and calcium sulfate on vegetative characteristics and mineral nutrient uptake in Rosa hybrida. *Journal of Ornamental Plants*, *8*(4), 241-253.

Franco-Mora, O., Tanabe, K., Tamura, F. and Itai, A. (2005). Effects of putrescine application on fruit set in 'Housui'Japanese pear (Pyrus pyrifolia Nakai). *Scientia horticulturae*, *104*(3), 265-273.

Ghehsareh, M. G. and Khosh-Khui, M. (2019). The effect of cutting type, leaf area, leaf number, putrescine and indole-3-Butyric acid on the rooting of ficus cuttings (*Ficus elastica* Roxb. ex Hornem.). *Advances in Horticultural Science*, *33*(1), 3-11.

Handa, A.K., and Mattoo, A. K. (2010). Differential and functional interactions emphasize the multiple roles of polyamines in plants. *Plant Physiology and Biochemistry, 48*(7), 540-546.

Hosseini, M. S., Zahedi, S. M., Abadía, J. and Karimi, M. (2018). Effects of postharvest treatments with chitosan and putrescine to maintain quality and extend shelf-life of two banana cultivars. *Food Science and Nutrition, 6*(5), 1328-1337.

Hummel, I., Gouesbet, G., El Amrani, A., Ainouche, A., & Couee, I. (2004). Characterization of the two arginine decarboxylase (polyamine biosynthesis) paralogues of the endemic subantarctic cruciferous species pringlea antiscorbutica and analysis of their differential expression during development and response to environmental stress. *Gene, 342*, 199-209.

Hussain, J., Khan, F.U., Ullah, R., Muhammed, Z., Rehman, N.U., Shinwari, Z.K. …. Hussain, A.M., 2011a. Nutrient evaluation and elemental analysis of four selected medicinal plants of khyber pakhtoon khwa, *Pakistan Journal of Botany, 43(1),* 427-434.

Hussain, S.S., Ali, M., Ahmad, M., Siddique, K.H.M. (2011b). Polyamines: natural and engineered abiotic and biotic stress tolerance in plants. *Biotechnology Advances, 29,* 300-311.

Iman Talaat, M., Bekheta, M.A. and Mahgoub, M.M. (2005). Physiological response of periwinkle plants (*Catharanthus roseus* L.) to tryptophan and putrescine. *International Journal of Agriculture* and *Biolog*y, *7,* 210-213.

Kakkar, R.K. and Sawhney, V.K., 2002. Polyamine research in plants. A changing perspective. *Physiologia Plantarum, 116,* 281–292.

Kara, B. and Sarı, N. (2019). Sakız ve siyah kabak (*Cucurbita pepo L.)*'larda ovül kültüründe spermidine ve putrescine uygulamalarının haploid bitki elde edilmesine etkileri. *Türkiye Tarımsal Araştırmalar Dergisi*, *6*(2), 206-213.

Karımı, M., Akbarı, F., and Heıdarzade, A. (2017). Protective effects of polyamines on regulation of senescence in spray carnation cut flowers (Dianthus caryophyllus' Spotlight'). *Acta Agriculturae Slovenica, 109(3),* 509-515.

Khan, A.S., Singh, Z. and Abbasi, N.A. (2007). Pre-storage putrescine application suppresses ethylene biosynthesis and retards fruit softening during low temperature storage in 'Angelino' plum. *Postharvest Biology and Technology, 46(1),* 36–46.

Khan, H., Ziaf, K., Amjad, M. and Iqbal, Q. (2012). Exogenous application of polyamines improves germination and early seedling growth of hot pepper. Chilean Journal of Agricultural Research, 72(3), 429-433.

Khezri, M., Talaie, A., Javanshah, A. and Hadavi, F. (2010). Effect of exogenous application of free polyamines on physiological disorders and yield of 'Kaleh-

Ghoochi'pistachio shoots (*Pistacia vera L.*). *Scientia horticulturae*, *125*(3), 270-276.

Khosroshahi, M.R.Z., Esna-Ashari, M. and Ershadi, A. (2007). Effect of exogenous putrescine on post-harvest life of strawberry (*Fragaria ananassa* Duch.) fruit, cultivar Selva. *Scientia Horticulturae*, *114*(1), 27-32.

Khosroshahi, M.R.Z., M. Esna-Ashari and M. Fattahi. 2008. Effect of exogenous putrescine on postharvest life of sweet cherry (*Prunus avium*) fruit, cultivar "Surati-e Hamedan". Journal of Applied Horticulture, 10(2): 154-157.

Kibar, B., Şahin, B., and Kıemde, O. (2020). Fasulyede (*Phaseolus vulgaris L.*) Farklı Tuz ve Putresin Uygulamalarının Çimlenme ve Fide Gelişimi Üzerine Etkileri. *Journal of the Institute of Science and Technology*, *10*(4), 2315-2327.

Koç, E., İşlek, C., and Karayiğit, B. (2020). Effects of spermine and putrescine polyamines on capsaicin accumulation in *Capsicum annuum* L. cell suspension cultures. *Acta agriculturae Slovenica*, *115(2)*, 369-375.

Koç, E., Üstün, A., İşlek, C. and Arıcı, Y. K. (2014). Effect of exogenously applied spermine and putrescine on germination and in vitro growth of pepper (*Capsicum annuum* L.) seeds under salt stress. *Anadolu University Journal of Science and Technology C-Life Sciences and Biotechnology*, *3*(2), 63-71.

Koyuncu, M.A., Erbaş, D., Onursal, C.E., And Özüsoy, F. (2018). Hasat öncesi farklı dozlardaki putresin uygulamasının 0900 ziraat kiraz çeşidinin soğukta depolama süre ve kalitesi üzerine etkileri. *Ege Üniversitesi Ziraat Fakültesi Dergisi*, *55*(3), 271-279.

Kök, D. (2018). Farklı dozlarda putresin ve indol–3–bütirik asidin birlikte uygulamalarının Cabernet Franc/5bb aşı kombinasyonunda kallus gelişimi üzerine etkileri. *Bahçe*, *47*(Özel Sayı 1), 169-172.

Kramer, G. F., Wang, C. Y., and Conway, W. S. (1991). Inhibition of softening by polyamine application in Golden Delicious' andMcIntosh'apples. *Journal of the American Society for Horticultural Science*, *116(5)*, 813-817.

Kusano, T., Yamaguchi, K., Berberich, T. and Takahashi, Y. (2007). The polyamine spermine rescues arabidopsis from salinity and drought stresses. *Plant Signaling and Behavior, 2,* 250-251.

Lee, M. M., Lee, S. H. and Park, K. Y. (1997). Effects of spermine on ethylene biosynthesis in cut carnation (*Dianthus caryophyllus* L) flowers during senescence. *Journal of Plant Physiology*, *151*(1), 68-73.

Liao, J., Wu, X., Xing, Z., Li, Q., Duan, Y., Fang, W. and Zhu, X. (2017). γ-Aminobutyric acid (GABA) accumulation in tea (Camellia sinensis L.) through the GABA shunt and polyamine degradation pathways under anoxia. *Journal of agricultural and food chemistry*, *65*(14), 3013-3018.

Liu, J.H., Nakajima, I. and Moriguchi, T. (2011). Effects of salt and osmotic stresses on free polyamine content and expression of polyamine biosynthetic genes in *Vitis vinifera. Biologia Plantarum, 55,* 340–344

Malik, A. U. and Singh, Z. (2006). Improved fruit retention, yield and fruit quality in mango with exogenous application of polyamines. *Scientia Horticulturae, 110*(2), 167-174.

Martinez, L. E., Agüero, C. B., Lopez, M. E. and Galmarini, C. R. (2000). Improvement of in vitro gynogenesis induction in onion (*Allium cepa L.*) using polyamines. *Plant Science, 156*(2), 221-226.

Martin-Tanguy, J. and Carre, M. (1993) Polyamines in gravepine microcuttings cultivated in-vitro – effects of amines and inhibitors of polyamine biosynthesis on polyamine levels and microcutting growth and development. *Plant Growth Regul., 13,* 269–280.

Martin-Tanguy, J. (1997). Conjugated polyamines and reproductive development: biochemical, molecular and physiological approaches. *Physiologia Plantarum, 100*(3), 675-688.

Mohammadrezakhani, S. and Pakkish, Z. (2014). Chilling injury induces lipid peroxidation and alters the hydrogen peroxide content in peel and pulp of Valencia orange fruit under low temperature storage conditions. *Advances in Applied Agricultural Sciences, 2,* 10-26.

Mortazavi, S. H., Arghavani, M., Asil, M. H. and Kheiri, A. (2021). Effect of polyamines on morphophysiological characteristics of Dutch iris (Iris hollandica'Blue Magic') cut flower. *Iranian Journal of Horticultural Science, 52(2),* 269-280.

Mustafavi, S.H., Naghdi Badi, H., Sękara, A., Mehrafarin, A., Janda, T., Ghorbanpour, M. and Rafiee, H. (2018). Polyamines and their possible mechanisms involved in plant physiological processes and elicitation of secondary metabolites. *Acta Physiologiae Plantarum, 40*(6), 1-19.

Nair, S. and Singh, Z. (2004). Chilling injury in mango fruit in relation to biosynthesis of free polyamines. *The Journal of Horticultural Science and Biotechnology, 79*(4), 515-522.

Naseri, S., Gholami, M. And Baninasab, B. (2019). Changes in polyamines during bud dormancy in almond cultivars differing in their flowering date. *Scientia Horticulturae, 258,* 108788.

Nilprapruck, P., Meetum, P.,and Chanthasa, C. (2017). Role of exogenous putrescine and spermine applications for ımproving banana fruit quality of banana cv. hom thong at low temperature storage. *Science, Engineering and Health Studies,* 11 (3), 9-15.

Palma, F., Carvajal, F., Ramos, J. M., Jamilena, M. and Garrido, D. (2015). Effect of putrescine application on maintenance of zucchini fruit quality during cold storage: Contribution of GABA shunt and other related nitrogen metabolites. *Postharvest biology and technology, 99,* 131-140.

Pandey, S., Ranade, S., Nagar, P.K. and Kumar, N. (2000). Role of polyamines and ethylene as modulators of plant senescence. *Journal of Bioscience, 25,* 291–299.

Perez-Amador, M.A., Leon, J., Green, P.J. and Carbonell, J. (2002). Induction of the arginine decarboxylase ADC_2 gene provides evidence for the ınvolvement of polyamines in the wound response in Arabidopsis. *Plant Physiology, 130,* 1454-1463.

Perez-Vicente, A., Martinez-Romero, D., Carbonell, A., Serrano, M., Riquelma, F. Guillen, F. and Valero, D. (2002). Role of polyamines in extending shelf life and the reduction of mechanical damage during plum (*Prunus salicina Lindl.*) storage. *Postharvest Biology and Technology, 25(1),* 25-32.

Petkou, I. T., Pritsa, T. S. and Sfakiotakis, E. M. (2004). Effects of polyamines on ethylene production, respiration and ripening of kiwifruit. *The Journal of Horticultural Science and Biotechnology*, *79*(6), 977-980.

Phornvillay, S., Prongprasert, N., Wongs-Aree, C., Uthairatanakij, A. and Srilaong, V. (2019). Effect of Polyamines Application on Reducing Chilling Injury Incidence in Okra Pod (*Abelmoschus esculentus* (Stored at Low Storage Temperature. *Food and Applied Bioscience Journal*, *7*(3), 45-54.

Podlesakova, K., Ugena, L., Spíchal, L., Doležal, K. and De Diego, N. (2019). Phytohormones and polyamines regulate plant stress responses by altering GABA pathway. *New biotechnology, 48,* 53-65.

Roussos, P. A., Pontikis, C. A. and Zoti, M. A. (2004). The role of free polyamines in the alternate-bearing of pistachio (*Pistacia vera* cv. Pontikis). *Trees, 18(1),* 61-69.

Saeed, A.M., Abdulhadi, M.D., and Salih, S.M. (2019). Response of gerbera (*Gerbera jamesonii*) cv.'Great Smoky Mountains' to foliar application of putrescine, spermidine and salicylic acid. In *IOP Conference Series: Earth and Environmental Science 388,* 1-11.

Saleem, B.A., Malik, A.U., Anwar, R. and Farooq, M. (2008). Exogenous applıcatıon of polyamınes ımproves fruıt set, yıeld and qualıty of sweet oranges. *Acta Horticulture, 774,* 187-194.

Sardoei, A. S., Mohammadi, G. A. and Rahbarian, P. (2013). Interaction effect of salicylic acid and putrescine on vase life of cut narcissus flowers. *International Journal of Advanced Biological and Biomedical Research*, *1*(12), 1569-1576.

Scaramagli, S., Franceschetti, M., Michael, A.J., Torrigiani, P. and Bagni, N. (1999). Polyamines and flowering: spermidine biosynthesis in the different whorls of developing *Nicotiana tabacum* L.. *Plant Biosyst.*, *133,* 229-237.

Scholten, H. J. (1998). Effect of polyamines on the growth and development of some horticultural crops in micropropagation. *Scientia horticulturae*, *77*(1-2), 83-88.

Shi, H., Ye, T. and Chan, Z. (2013). Comparative proteomic and physiological analyses reveal the protective effect of exogenous polyamines in the bermuda grass (*Cynodon dactylon*) response to salt and drought stresses. *Journal of Proteome Research, 12,* 4807–4829

Shu, S., Guo, S. R., Sun, J. and Yuan, L. Y. (2012). Effects of salt stress on the structure and function of the photosynthetic apparatus in *Cucumis sativus* and its protection by exogenous putrescine. *Physiologia Plantarum*, *146*(3), 285-296.

Song, J. and Tachibana, S. (2007). Loss of viability of tomato pollen during long-term dry storage is associated with reduced capacity for translating polyamine biosynthetic enzyme genes after rehydration. *Journal of Experimental Botany*, *58*(15-16), 4235-4244.

Song, J., Nada, K. and Tachibana, S. (2002). Suppression of S-adenosylmethionine decarboxylase activity is a major cause for high-temperature inhibition of pollen germination and tube growth in tomato (*Lycopersicon esculentum* Mill.). *Plant and cell physiology*, *43*(6), 619-627.

Sudha, G. and Ravishankar, G.A. (2003). Putrescine facilitated enhancement of capsaicin production in cell suspension cultures of *Capsicum frutescens*. *Journal of Plant Physiology , 160(4),* 339-346

Tatte, S., Singh, A. and Ahlawat, T.R. (2015). Effect of polyamines on postharvest quality and vaselife of rose var. Samurai. *The Bioscan*, *10*(2), 675-678.

Tavallali, V., Alhavi, N., Gholami, H. and Abarghuei, F.M. (2022). Developmental and phytochemical changes in pot marigold (Calendula officinalis L.) using exogenous application of polyamines. *Plant Physiology and Biochemistry, 183,* 128-137.

Upfold, S.J. and Van Staden, J. (1991). Polyamines and carnation flower senescence: Endogenous levels and the effect of applied polyamines on senescence. *Plant Grow. Regul.*, *10,* 355-362.

Valero, D., Perez-Vicente, A., Martinez-Romero, D., Castillo, S., Guillen, F. and Serrano, M. (2002). plum storability improved after calcium and heat postharvest treatments, role of polyamines. *Jornal of Food Science, 67*(7), 2571-2575.

Velikova, V., Yordanov, I. and Edreva, A. (2000). Oxidative stress and some antioxidant systems in acid raintreated bean plants: protective role of exogenous polyamines. *Plant Science, 151,* 5966.

Verdolin, L.G., Mariz, B.L. and Dias, L.L.C. (2021). Gibberellin and polyamines effects, in growth and flowering of New Guinea impatiens. *Ornamental Horticulture*, *27*, 247-254.

Wang, C., Fan, L., Gao, H., Wu, X., Li, J., Lv, G., and Gong, B. (2014). Polyamine biosynthesis and degradation are modulated by exogenous gamma-aminobutyric acid in root-zone hypoxia-stressed melon roots. *Plant physiology and biochemistry*, *82*, 17-26.

Wei, A., Du, S., Han, Y., Liu, N. and Zhang, G. (2010). A study on the relationship between cucumber gynogenesis and content of ovary hormones and polyamines. *Acta horticulturae*, (871), 625.

Wimalasekera, R., Tebartz, F. and Scherer, G. (2011). Polyamines, polyamine oxidases and nitric oxide inbdevelopment, abiotic and biotic stresses. *Plant Science, 181,* 593–603

Xu, X., Shi, G., Ding, C. and Xu, Y., (2011). Regulation of exogenous spermidine on the reactive oxygen species level and polyamine metabolism in Alternanthera philoxeroides (Mart.) Griseb under copper stress. *Plant Growth Regulation, 63,* 251–258

Yang, Q., Wang, F., and Rao, J. (2016). Effect of putrescine treatment on chilling injury, fatty acid composition and antioxidant system in kiwifruit. *PLoS One*, *11*(9), 1-16

Yang, R., Chen, H., and Gu, Z. (2011). Factors influencing diamine oxidase activity and γ-aminobutyric acid content of fava bean (Vicia faba L.) during germination. *Journal of Agricultural and Food Chemistry*, *59*(21), 11616-11620.

Yerebasmaz, H. (2019). *Aşılı köklü badem fidanı üretiminde farklı uygulamaların köklenme ve aşı başarısı üzerine etkileri* (Yüksek Lisans Tezi, Bursa Uludag University Fen Bilimleri Enstiüsü Bahçe Bitkileri Bölümü. Turkish National Thesis Center. (605182).

Yıldız, Ç. and Solmaz, İ. (2020). Karpuz genetik kaynaklarında ovül-ovaryum kültürü yöntemiyle haploid bitki elde edilmesi. *Çukurova Tarım ve Gıda Bilimleri Dergisi*, *35(1),* 35-42.

Yousef, A.R.M., Abd El-Razek, E., Emam H.S. and Dorria, M.M.A. (2014). Prestorage application of putrescine to improve fruit quality, color parameters and extending shelf life of ‘Hollywood’ plum (*Prunus salicina* L.). *Middle East Journal of Agriculture Research, 3(4),* 1135-1144.

Yousefi, F., Jabbarzadeh, Z., Amiri, J. and Rasouli-Sadaghiani, M. H. (2019). Response of roses (*Rosa hybrida* L.'Herbert Stevens') to foliar application of polyamines on root development, flowering, photosynthetic pigments, antioxidant enzymes activity and NPK. *Scientific Reports*, *9*(1), 1-11.

Yousefi, F., Jabbarzadeh, Z., Amiri, J., Rasouli-Sadaghiani, M. and Shaygan, A. (2021). Foliar application of polyamines improve some morphological and physiological characteristics of rose. *Folia Horticulturae*, *33*(1), 147-156.

Yuan, Y., Zhong, M., Du, N., Shu, S., Sun, J. and Guo, S. (2019). Putrescine enhances salt tolerance of cucumber seedlings by regulating ion homeostasis. *Environmental and Experimental Botany*, *165*, 70-82.

CHAPTER 9

LED LIGHTING AND ITS EFFECTS ON PLANT PRODUCTION

Assoc. Prof. Dr. Hakan BAŞAK[1]
Prof. Dr. Köksal DEMİR[2]

[1] Kırşehir Ahi Evran University Faculty of Agriculture Department of Horticulture, Kırşehir, Turkiye, hbasak@ahievran.edu.tr, ORCID ID 0000-0002-1128-4059
[2] Ankara University, Faculty of Agriculture, Department of Horticulture, Ankara, Turkiye, koksaldem@ankara.edu.tr , ORCID ID 0000-0001-6120-7249

INTRODUCTION

Many environmental factors are effective in the growth and development of plants. Light has a major role in all stages of growth and development. As a light source, sunlight, which is seen as inexhaustible energy, is naturally utilised. In recent years, a different stage has been reached with LED lighting technology and development. With LED technology, the ability to create light and light recipes at the desired wavelength has led to great effects. The fact that the activities of LED light sources and different spectra in the physiology of plants have been revealed with day-to-day researches has rapidly increased the interest in this subject. The data obtained in the use of LED technology as an artificial light source has revealed a high potential for crop production in plant production.

The widespread use of artificial light sources in plant production has created a great potential in greenhouses, climate chambers, tissue culture studies, plant factories and, with the technological developments in recent years, in food production studies under space conditions. The use of light sources in plant production has important effects on many events of plant physiology as well as the benefits of additional illumination. For this reason, light sources have started to be preferred not only for lighting purposes but also in plant production in recent years. With the increase in energy efficiency in LED technology, it has been possible to convert the energy used into light over 90%. Thus, LED light systems have emerged as a great potential for plant cultivation today.

The light required for the growth of plants is defined as small particles called photons or quanta. The energy content of photons varies depending on the wavelength and colour spectrum of light. The spectrum of sunlight consists of three parts: ultraviolet, visible light and invisible infrared. Very little of the spectrum available to plants is utilised by plants in photosynthesis.

The spectrum effective in photosynthesis is located in the range of 400-700 nm. An effective light source for plant growth should convert electrical energy into PAR energy as much as possible. The daily light integral DLI expresses the amount of photons received during the day in the PAR value region in the range of 400-700 nm. DLI corresponds to the amount of photosynthetic light received in an area of 1 m^2 per day. DLI can be very effective on plant quality factors such as root and shoot development in seedlings, rooting and stem diameter in cuttings, branching and number of flowers (Demir, K. and Demir Y., 2021).

Light consists of a periodically changing electric field and magnetic field. The frequency (or wavelength) of these waves determines the physical properties of light and its location in the electromagnetic spectrum. Table 1 shows the wavelengths, frequencies and energies of rays in nanometres.

Table 1: Rays, wavelengths, frequencies and energies

Lights	Wave range	Photon energy
Ultraviolet (UV)	10 nm – 400 nm	124 eV – 3 eV
Visual zone	390 nm – 750 nm	3.2 eV – 1.7 eV
Infrared (IR)	750 nm – 1 mm	1.7 eV – 1.24 meV

The figure below shows the rays and wavelengths that are effective in the growth of plants.

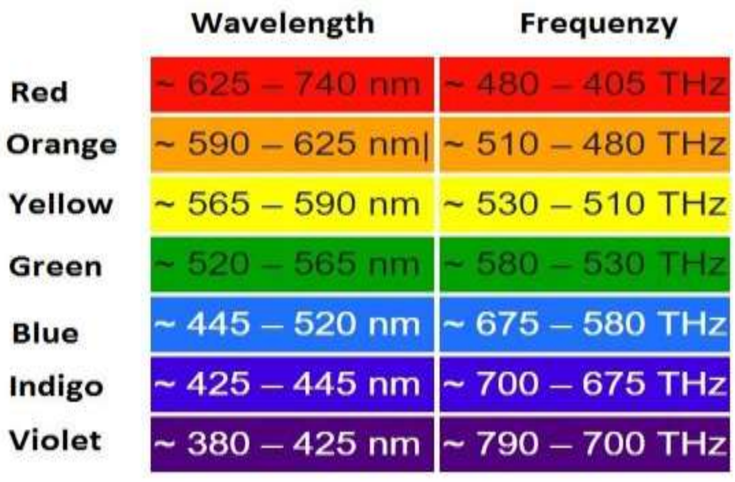


Figure 1: Rays and wavelengths effective in plant growth (Anonymous, 2022. https://www.uib.no/en/hms-portalen/75292/electromagnetic-spectrum)

Led lighting sources have been used significantly in recent years due to their long life, high energy efficiency and the ability to create light prescriptions at desired wavelengths. In the last few years, plant production studies have gained momentum in closed controlled environments due to their effectiveness and properties. In addition, the ability to create light in wide spectrum ranges has created a wide field of study in plant production studies and researches (Figures 2 and 3).

Figure 2: Vegetable production with LED technology in closed environment

Figure 3: Basil production with LED technology in closed environment

Light is one of the main factors of plant growth. In nature, problems are encountered due to the fact that access to sunlight is frequently affected by weather conditions. The necessary light source does not always occur during the development period and insufficiencies occur. By using artificial light sources, it is possible to produce high-yielding crops in a controlled manner and independent of weather conditions. In the recent past, fluorescent and bulb/accordion light sources were used for artificial lighting. Studies and research results have revealed that these light sources have many disadvantages. Lack of lighting efficiency and high power requirement were the main factors that negatively affected their use. As a result of the researches, the high energy efficiency of the LED (Lighting Emitting Diode) light source and the ability to regulate the desired wavelengths have led to a great potential in its use in plant cultivation. The wavelength and frequency of the light that plants generally need and accept for their morphological development are within a certain range. LED light can be obtained in various frequency and wavelength ranges with the properties required by the plant. Since LED light is cold light, it can be used at the desired distance without the danger of burning plants. This provides both design flexibility and space saving.

The use of LED light has been increasingly used for plant production in greenhouses and various laboratory environments. Light is one of the key factors in plant growth. However, access to the light source is not always at the desired level since access to sunlight in nature is affected by weather conditions. With artificial light sources, it is possible to produce high-yielding plants in a controlled manner and independent of weather conditions. Low illumination efficiency and high power usage are among the most undesirable features. The wavelength and frequency of the light that plants generally need and accept for their morphological development are in a certain range. Led light can be obtained in various frequency and wavelength ranges with the properties required by the plant. Due to the cold light status of the LED light source, it can be used at the desired distance without the danger of burning the plants due to proximity. This feature facilitates the design and allows significant utilisation of the production area. The use of LED light has become rapidly widespread for plant production in greenhouses and various laboratory environments (Harman et al., 2021).

The effects of different coloured LED lights on plants vary. The fact that the effect of LED light on plants depends on the colour of the light, the exposure time of the plant to light, the growth period of the plant, the type and morphology of the plant makes it difficult to reach a consensus on the effects of LED light. In this context, although it is obvious that special studies should be carried out for different plants and conditions, in the meta-analysis conducted by Yuanchun Ma et al. in 2021, some general judgements were reached based on data from hundreds of studies. According to data from 139 different experiments, it was observed that plants using red LED light gave 54% and 172% more favourable results in catalase and peroxisone production activities than the control group using white fluorescent light. Again, the stem length was found to be 63% shorter in the use of red LED. According to the data collected from 128 different studies, it was observed that the plants using blue LED light had lower leaf area (78%), dry root weight (69%), dry stem weight (37%) and stem length (64%) than the plants in the control group using white fluorescent light. Total antioxidant content was found to be 68% higher in plants under blue LED light. According to the average of 101 experiments in which red and blue LED light was used in a 1:1 ratio, the dry weight of the plants using LED light was 161% more favourable than the plants in the control group. The effect of red and blue LED light showed different effects on annual and seasonal plant species. For example, compared to the control group, the increase in catalase production in seasonal plants was 77% higher than the increase in annual plants (Yuanchun et al., 2020).

LED lamps contain a semiconductor chip embedded in an epoxy or plastic lens with connecting wires to direct the electric current. The double-row package is the most widely used LED design. Improved high-power LEDs produce higher brightness due to higher light. Thanks to some additives in the construction of LEDs, the LED can emit light at a constant wavelength. The application of red and blue monochromatic LEDs alone or in combination has been reported to be effective for plant morphogenesis both in viva and in vitro. In the construction of red-blue mixed LED panels, the voltage requirements of red and blue LEDs are significantly different. White LEDs can be produced using a red combination. Green, blue LED units can also be found in the same luminaire. These are very important advantages of LED technology (Demir and Demir, 2021).

With the development of LED technologies, properties such as dose, intensity and wavelength of light have started to be adjusted very precisely. In this way, studies have accelerated to provide the appropriate value environment needed for the development of different plants. In the first emergence of LED technologies, red and blue light were generally used for plant production. Today, red, blue light and their combinations as well as green, far red and UV (ultraviolet) light types can be used together. Thanks to this diversity, the wide range of rays offered by the sun can be simulated in a controlled manner. One of the recent developments is the use of UV light, which is generally considered to be harmful to plants, in combination with LED technology. The use of low doses of UV radiation can provide positive morphological and metabolic improvements in plants. Developments in LED technologies have enabled the use of UVA and UVB rays on plants and pioneered brand new studies.

UV rays can be analysed in 3 categories. UVA (320-400nm wavelength), UVB (280-320nm wavelength) and UVC (100-280nm wavelength). While all of the high-energy UVC rays coming from the sun are filtered by the ozone layer, 6% of the sun rays reaching our world consist of UVA and UVB rays. Plants have special photo receptors that detect these UVB rays. UVB rays are detected by the UVR8 receptor. UVA rays are perceived by the plant by stimulating phototropin and cryptochrome proteins when combined with blue light. Phototropins and cryptochromes are proteins that are usually found along the leaves of the plant and regulate the plant's response and growth according to the light environment (Harman et al., 2021).

UVB rays can help the plant to maintain its own balance against the unfavourable conditions developing in its environment. UVB radiation has the potential to reduce changes in plant biochemistry, undesirable changes in DNA, proteins and lipids, and oxidative damage. UVB irradiation at tolerable doses may cause the plant to reduce biomass, develop smaller but thicker leaves, develop shorter stature, modify the photosynthesis process, produce less chlorophyll but more phenolic compounds. Phenolic compounds are components that activate the antioxidant protective system of the plant and are of great importance for the human diet. They are also closely related to the quality of fruit and vegetables. Although the effects of UVA rays are still controversial, results are obtained that they have an effect especially on the leaf area of the plant. It is also effective in plant growth, antioxidant levels and phenolic production. Thanks to their high wavelengths, UVA rays can reach deeper distances below the surface of the plant. The use of UVA rays in plants has high potential, but further studies are needed (Akvilė et al., 2019).

Light is one of the most important environmental factors in crop production. Plants need light not only for photosynthesis but also to regulate their development. The sensitivity of plants to light ranges from UV radiation to far-red radiation. The UV-C part of ultraviolet radiation (100-280 nm) is absorbed by the stratospheric ozone layer and the atmosphere, while only UV-A (315-400 nm) and UV-B (280-315 nm) radiation reach plants. The main wavelengths of the visible light spectrum (400-700 nm) perceived by plant photoreceptors and pigments are blue (400-500 nm) and red (600-700 nm) and to a lesser extent green (500-600 nm) radiation. A small part of the light spectrum close to infrared radiation, such as far-red (730 nm), is also perceived by phytochromes and is important for plant growth (Huché-Thélier et al., 2016).

Plants utilise a large number of photoreceptors to accurately detect and react to changes in the spectral composition according to changes in the direction of light over a wide range of wavelengths and duration (photoperiod). It is rumoured that some plant photoreceptors can also be found in the roots.

Plants have evolved a variety of photoreceptors that regulate different morphological and physiological events according to different wavelengths of light. Kopsell et al. 2015 classifies the photoreceptors in plants as Phytochromes (phy), Cryptochromes (cry), Phototropins (phot), UVR8, ZTL/FKF1/LKP2 (Zeitlupe, Flavin-binding Kelch, LOV Kelch Proteins) (Harman et al., 2021)

The effects of different coloured LED lights on plants vary. The fact that the effect of LED light on plants depends on the colour of the light, the duration of exposure of the plant to light, the growth period of the plant, the type and morphology of the plant makes it difficult to reach a consensus on the effects of LED light. In this context, although it is obvious that special studies should be carried out for different plants and conditions, in the meta-analysis conducted by Yuanchun Ma et al. in 2021, some general judgements were reached based on data from hundreds of studies. According to data from 139 different experiments, it was observed that plants using red LED light gave 54% and 172% more favourable results in catalase and peroxisone production activities than the control group using white fluorescent light. Again, the stem length was found to be 63% shorter in the use of red LED. According to the data collected from 128 different studies, it was observed that the plants using blue LED light had lower leaf area (78%), dry root weight (69%), dry stem weight (37%) and stem length (64%) than the plants in the control group using white fluorescent light. Total antioxidant content was found to be 68% higher in plants under blue LED light. According to the average of 101 experiments in which red and blue LED light was used in a 1:1 ratio, the dry weight of the plants using LED light was 161% more favourable than the plants in the control group. The effect of red and blue LED light showed different effects on annual and seasonal plant species. For example, compared to the control group, the increase in catalase production in seasonal plants was 77% higher than the increase in annual plants (Yuanchum et al., 2021).

The light emitted by LEDs used as artificial light sources is widely used in closed systems such as plant growth chambers, greenhouses, multi-tiered vertical farming, as well as in post-harvest storage and processing (Bantis et al., 2018).

LED lights and provide many unique technical advantages compared to existing artificial light sources. LEDs are characterised by the ability to control the spectral composition of the emitted light, adjustable size and shape, durability and long operating life. LEDs emit much less heat than other light sources, have low energy purity and photon output is linear with the electrical input current (Hernandez et al., 2012).

The selection of the appropriate LED light in crop production is effective in changing yield, photochemical content, nutrient content of the product, flowering control, post-planting performance, pre-harvest and post-harvest product quality and production of regeneration material.

In particular, blue and red LEDs are widely used for plant growth because chlorophyll a and b efficiently absorb blue and red wavelengths; the maximum absorbance for chlorophyll a is 430 and 663 nm, while the maximum absorbance for chlorophyll b is 453 and 642 nm, respectively (Chory, 2010).

Numerous studies have been conducted on the effect of different ratios of red to far-red light, which can modulate shoot elongation in seedlings and plants (Gilbert et al., 1995; Von Wettberg and Schmitt, 2005; Casal, 2013).

The amounts and ratios of blue (B), red (R) and far red (FR) light to each other are more effective than other wavelengths of light in controlling many developmental and physiological responses throughout the life cycle of plants. However, different responses of plants to green (G) light, blue/green and red/green ratios have also been demonstrated (Wang and Folta, 2013). Green light can stimulate photosynthesis, especially in the depths of the canopy where carbon gain occurs in shaded canopies (Smith et al., 2017).

In numerous studies using lettuce, cold white fluorescent lamp (CWF) supplemented with far red (FR) LED for lettuce growth caused a decrease in anthocyanin, carotenoid and chlorophyll content, while increasing fresh and dry weights, stem length and leaf length and width (Li and Kubota, 2009).

The researchers found that R light added to CWF caused an increase in chlorophyll concentration, while supplemental B or ultraviolet (UV) LEDs increased anthocyanin concentration but decreased stem length. Red leaf lettuce grown under R supplemented with FR light also exhibited lower anthocyanin concentration and antioxidant potential, while R supplemented with B light imposed the opposite results (Stutte et al., 2009).

In cucumber, monochromatic R light suppressed plant fresh and dry weight compared to various combinations of RB and RGB, while B light was reported to promote fresh weight (Hernández and Kubota, 2016). In addition, the authors reported that plants receiving more B light in different RB combinations led to increased leaf weight, chlorophyll content per leaf area, leaf net photosynthetic rate and stomatal conductance, but decreased plant height, hypocotyl and epicotyl length, leaf area, plant fresh and dry weight.

Snowden et al. (2016) found that green light positively affected cucumber, tomato stem length, leaf area index (LAI) of petioles.

Samuolienė et al. (2017) reported that mustard, beetroot and parsley microgreens grown under FR+R supplemented with different B light doses (16%, 25% and 33%) increased carotenoid (α- and β-carotene, lutein, zeaxanthin, neoxanthin, violaxanthin) chlorophyll (a and b) and tocopherol contents.

Ouzounis et al. (2016) determined that in nine tomato genotypes, B light added to R light had a positive effect on plant biomass, reduced leaf curling, and also caused an increase in soluble protein concentration, chlorophyll and carotenoid concentration.

Rabara et al. (2017) compared artichoke cultivation under natural light in greenhouse conditions and under R LED in a plant growth chamber and reported that R LED increased shoot dry weight and length compared to natural light.

LEDs can be designed to emit broadband (white) light or narrow spectrum (colour) wave bands specific to desired plant responses (Morrow, 2008).

In roses, several responses have been reported with increasing B:R ratio, such as increased leaf biomass, decreased leaf area and shoot biomass, and the formation of sun-adapted leaves, while no effect on flowering was observed (Terfa et al., 2013).

In a greenhouse trial with two tomato cultivars, the LEDs used (95% R, 5% B) caused an increase in the number of fruits harvested with a longer harvest period, a higher number of internodes and an increase in the number of fruits harvested and the total fresh weight of the fruits compared to natural light (Gómez et al., 2013).

Guo et al. (2016) reported that top and bottom vertical LEDs applied in mini cucumber production increased yield by more than 10%, and also reported that plasma light supplemented with vertical B light placed at the top of the canopy reduced leaf size, plant height and then fruit yield in the first month, while vertical FR at the top of the canopy increased fruit yield compared to the bottom.

Tomato is a vegetable that is usually harvested at an immature stage and the ripening process takes place during storage and distribution of the product. Treatment of ripe green tomato fruit for 7 days in the dark or under R and B LED light, 85.72 and 102.70 μ Einstein m -2 s -1, respectively, had an effect on fruit ripening (Chomchalow et al., 2002).

Tomato fruits exposed to R and a combination of R and UV radiation required five days less time than untreated fruits to reach the same level of ripeness, while R+UV also elevated lycopene, ß-carotene, total flavonoids and phenolic concentrations (Panjai et al., 2017).

Recently, light emitting diodes (LEDs), which can provide any desired broad spectrum with narrow spectra, have been rapidly utilised as artificial light sources. Furthermore, the dramatic performance improvement and cost reduction in the LED industry allows for the extensive application of supplemental LED lights that can efficiently increase plant growth, crop yield and energy efficiency (Gomez and Mitchell, 2013).

The high content of health-beneficial bioactive compounds, including lycopene, vitamin C, phenolic acids and flavonols, contributes to the commercial value of tomato. Most studies have confirmed the role of red and blue lights in promoting secondary metabolites in plants (Taulavuori et al., 2016). However, white LED light including blue light was found to cause higher total phenolic and flavonol content in tomato compared to red and green light

The light source used affects not only morphological parameters but also chlorophyll, carotenoid, anthocyanin, ascorbic acid, sugar contents and metabolite concentrations of plants (Carvalho and Folta, 2014; Li and Kubota, 2009).

Red LED light, which forms the basis of the light spectrum, can be sufficient for plant growth and photosynthesis. Red light with wavelengths of 640 and 660 nm is the most commonly used light in the cultivation of salad lettuce group green vegetables (Lefsrud et al., 2008).

It is reported that red LED light can increase the carbohydrate content and antioxidant capacity of lettuce and suppress the unwanted nitrate content (Samuolien et al., 2009). In fact, it has been determined that green leaf lettuce grown under red light contains higher antioxidants than red leaf lettuce types that naturally contain high antioxidants.

Although red light is effective on photosynthesis, it is generally required to be used together with blue light to ensure regular growth and to prevent excessive grading (Snowden et al., 2016).

Wanlai et al. (2013) found that a combination of red and blue light was more effective in reducing nitrate when applied continuously and 48 hours before harvest compared to red light alone.

The use of infra-red light in combination with red and blue LEDs was found to increase the uptake of nutrients such as potassium, calcium and magnesium in hydroponically grown lettuce (Pinho et al., 2016).

Plant growth generally tends to decrease when the proportion of blue photons exceeds 5-10%. Excessive levels of blue light in the spectrum inhibit cell division, cell expansion and leaf area growth, resulting in reduced photon capture and growth. Species have a wide range of sensitivity to blue light and responses can vary with the developmental stage of the plant (Bugbee, 2016).

Most of the wavelengths of conventional light sources other than LEDs are outside the PAR (Photosynthetically Active Radiation) curve. For this reason, conventional light sources are less efficient in plant growth than LEDs. LED light sources emit almost all of the energy they consume at wavelengths in the PAR region required for photosynthesis (Koç et al. 2009). Especially LED lamps emitting blue, red and infrared light can provide sufficient energy for photosynthesis (Çağlayan and Ertekin 2011).

Studies have shown that different wavelengths of light cause different physiological and morphological changes in plants (Yanagi and Okamoto 1997). For example, while red light (610-720 nm) increases photosynthesis, blue light (400-500 nm) is very important for chlorophyll synthesis and chloroplast development, stomatal opening and photomorphogenesis (Senger 1982).

Different RGB (red-green-blue) combinations (RGB ratios; 1:4:5, 5:0:5, 5:2:3, 7:0:3, 7:1:2) were compared in red and green leaf lettuce (Lactuca sativa L.). As a result of the experiment, it was determined that the RGB ratio was 5:7:0-2:1-3 for growing lettuce in a closed crop production system (Cha et al., 2013).

In addition to the wavelength of light, available light intensity and photoperiodicity are also important for the effect of light on plants. PAR (Photosynthetically Active Radiation) or PPFD (Photosynthetic Photon Flux Density) units are used to express light intensity. The most commonly used PPFD expresses the number of photosynthetically active photons per second falling on a given surface and its unit is $\mu mol/m^2s$.

Kim et al. (2004) reported that lettuce growth under red and blue LEDs was highly enhanced by the addition of 24% green light, while the total photon flux density (PFD) and red-blue light ratio (R/B ratio) remained unchanged.

One solution for the lack of red light in the spectrum of white LEDs is to add red LEDs to white LED lights. The white LED light with additional red light emitted a more promising spectrum to improve photosynthesis and energy efficiency of Chinese cabbage, lettuce, pepper and tomato. The quality of grafted tomato seedlings was significantly improved by supplementing lighting with white plus red plus blue LED lights compared to white LED lights in greenhouses (Avercheva et.al, 2016).

Hernández et al. (2016) compared the physiological responses of tomato seedlings to different R/B ratios using a combination of monochromatic blue LED and red LED and reported that R/B ratios in the range of 1.0-2.3 were best for tomato seedling production under artificial lighting (Hernández et al., 2016).

Wollaeger and Runkle (2014) reported that tomato seedlings grown under blue light alone or in combination with red reduced height compared to those under pure red light and red plus green light.

There was research that high R/FR ratio and blue light can synergistically suppress stem extension; in other words, the full expression of shade avoidance results from both low R/FR and reduced blue light (Bantis et al., 2020; Hernández et al, 2016).

LED technology, which has recently been realised, has become an important source in plant production as well as rapidly taking place in the field of general lighting. Producing LEDs at desired wavelengths and providing light mixtures has enabled different researches to be carried out. Thus, light recipes were created. It has been understood that it has different physiological effects as well as its effects in general. The ability to create light with almost all of the energy used by increasing the efficiency feature has also optimised the use of energy. With the development of the production technique, the amount of production has also increased and has started to take an effective place in plant production. At the point we have reached, LED technology has enabled plant production both in additional lighting and in fully closed environments and has provided an important support to food supply. With the studies to be carried out in this field, revealing the light spectrum and activities in more detail and developing plant-specific light recipes will allow an alternative production model to spread rapidly.

REFERENCES

Akvilė Viršilė, Giedrė Samuolienė, Jurga Miliauskienė, Pavelas Duchovskis, 2019. Chapter 3 - Applications and Advances in LEDs for Horticulture and Crop Production, Ultraviolet LED Technology for Food Applications, Academic Press, 2019, Pages 35-65, ISBN 9780128177945, https://doi.org/10.1016/B978-0-12-817794-5.00003-0.

Anonymous, 2022. https://www.uib.no/en/hms-portalen/75292/electromagnetic-spectrum (access date 29.09.2022)

Bantis, F.; Koukounaras, A.; Siomos, A.S.; Fotelli, M.N.; Kintzonidis, D. 2020. Bichromatic red and blue LEDs during healing enhance the vegetative growth and quality of grafted watermelon seedlings. *Scientia Horticulturae.* 261, 109000.

Bantis, F., Ouzounis, T., Radoglou, K., 2016. Artificial LED lighting enhances growth characteristics and total phenolic content of Ocimum basilicum, but variably affects transplant success. *Scientia Horticulturae.* 198, 277–283. http://dx.doi.org/10. 1016/j.scienta.2015.11.014.

Bugbee, B., 2016. Towards An Optimal Spectral Quality For Plant Growth And Development: The Importance Of Radiation Capture. Acta Hortic 1134:1–12

Carvalho, S.D., Folta, K.M., 2014. Sequential light programs shape kale (Brassica napus) sprout appearance and alter metabolic and nutrient content. *Horticulture Research.* 1, 8. http:// dx.doi.org/10.1038/hortres.2014.8.

Casal, J.J., 2013. Photoreceptor signaling networks in plant responses to shade. *Annual Review of Plant Biology.* 64, 403–427. http://dx.doi.org/10.1146.

Cha, M.K., Cho, J.H., Cho, Y.Y., 2013. Growth of leaf lettuce as affected by light quality of LED in closed-type plant factory system. *Protected Horticulture and Plant Factory*, 22(4):291-297.

Chomchalow, S., El Assi, N.M., Sargent, S.A., Brecht, J.K., 2002. Fruit maturity and timing of ethylene treatment affect storage performance at green tomatoes at chilling and nonchilling temperatures. Water 12, 104–114.

Chory, J., 2010. Light signal transduction: an infinite spectrum of possibilities. *Plant J.* 61, 982–991. http://dx.doi.org/10.1111/j.1365-313X.2009.04105.x.

Çağlayan N ve Ertekin C (2011). Bitkisel Üretim İçin Led Yetiştirme Lambalarının Kullanımı. Uluslararası Katılımlı I. Ali Numan Kıraç Tarım Kongresi ve Fuarı, 27-30 Nisan 2011, Bildiri Kitabı, s.1227-1232, Eskişehir.

Demir, K. Ve Demir Y., 2021. Bitkisel Üretimde Yapay Aydınlatma ve Etkinlikleri. *Tarım Gündem Dergisi*. Yıl 11 Sayı 62, Mayıs-Haziran 2021. S:78-83. ISSN: 2636-8900. Metro Matbaacılık İzmir.

Gilbert, I.R., Shavers, G.P., Jarvis, P.G., Smith, H., 1995. Photomorphogenesis and canopy dynamics. Phytochrome-mediated proximity perception accounts for the growth dynamics of canopies of Populus trichocarpa × deltoides “Beaupré.”. *Plant Cell & Environment.* 18, 475–497. http://dx.doi.org/10.1111/j.1365-3040.1995.tb00549.x.

Gómez, C. and Mitchell, C., 2013. Supplemental lighting for greenhouse-grown tomatoes: Intracanopy LED towers vs. overhead HPS lamps. In Proceedings of the International Symposium on New Technologies for Environment Control, Energy-Saving and Crop Production in Greenhouse and Plant, Beijing, China, 20–24 August 2013.

Guo, X., Hao, X., Zheng, J., Little, C., Kholsa, S., 2016. Response of greenhouse minicucumber to different vertical spectra of LED lighting under overhead high pressure sodium and plasma lighting. *Acta Horticulturae.* 1170, 1003–1010. http://dx.doi.org/10. 17660/ActaHortic.2017.1170.129.

Harman U. U, , Horzum Ö. Demir K., 2021. Led Lıghtıng And Robotıc Arm Technologıes For Plant Productıon, Agricultural and Natural Research & Reviews, Birhan Kunter, Nurhan Keskin, Editör, LIVRE DE LYON, Lyon, ss.79-97,2021.

Hernández, R., Eguchi, T., Deveci, M., & Kubota, C. (2016). Tomato seedling physiological responses under different percentages of blue and red photon flux ratios using LEDs and cool white fluorescent lamps. *Scientia Horticulturae*, *213*, 270-280. https://doi.org/10.1016/j.scienta.2016.11.005

Hernández, R., Kubota, C., 2012. Tomato seedling growth and morphological responses to supplemental LED lighting red:Blue ratios under varied daily solar light integrals. *Acta Horticulturae*. 956, 187–194. http://dx.doi.org/10.17660

Hernández R., Kubota C.,2016. Physiological responses of cucumber seedlings under different blue and red photon flux ratios using LEDs. *Environmental and Experimental Botany*, 121: 66–74.

Huché-Thélier, L., Crespel, L., Le Gourrierec, J., Morel, P., Sakr, S., & Leduc, N. (2016). Light signaling and plant responses to blue and UV radiations—Perspectives for applications in horticulture. *Environmental and Experimental Botany*, *121*, 22-38.

Kim H. H., Goins G. D., Wheeler R. M., Sager J. C. (2004). Green-light supplementation for enhanced lettuce growth under red- and blue-light-emitting diodes. *Hort. Sci.* 39, 1617–1622. 10.21273/HORTSCI.39.7.1617

Koç C, Vatandaş M ve Koç AB (2009). LED Aydınlatma Teknolojisi ve Tarımda Kullanımı. 25. Tarımsal Mekanizasyon Ulusal Kongresi, s.153-158, Isparta.

Lefsrud, M.G., Kopsell, D.A. & Sams C.E. 2008. Irradiance from distinct wavelength light-emitting diodes affect secondary metabo-lites in kale. *HortScience* 43: 2243–2244.

Li, Q., Kubota, C., 2009. Effects of supplemental light quality on growth and phytochemicals of baby leaf lettuce. *Environmental and Experimental. Botany.* 67, 59–64. http://dx.doi.org/10. 1016/j.envexpbot.2009.06.011.

Morrow, R.C., 2008. LED lighting in horticulture. HortScience 43, 1947–1950.

O.V. Avercheva, Yu.A. Berkovich, I.O. Konovalova, S.G. Radchenko, S.N. Lapach, E.M. Bassarskaya, G.V. Kochetova, T.V. Zhigalova, O.S. Yakovleva, I.G. Tarakanov, 2016. Optimizing LED lighting for space plant growth unit: Joint effects of photon flux density, red to white ratios and intermittent light pulses, *Life Sciences in Space Research,* Volume 11, 2016, Pages 29-42,

Ouzounis, T., Heuvelink, E., Ji, Y., Schouten, H.J., Visser, R.G.F., Marcelis, L.F.M., 2016. Blue and red LED lighting effects on plant biomass, stomatal conductance, and metabolite content in nine tomato genotypes. *Acta Hortic.* 1134, 251–258. http://dx. doi.org/10.17660/ActaHortic.2016.1134.34.

Panjai, L., Noga, G., Fiebig, A., Hunsche, M., 2017. Effects of continuous red light and short daily UV exposure during postharvest on carotenoid concentration and antioxidant capacity in stored tomatoes. *Scientia Horticulturae.* 226, 97–103. http:// dx.doi.org/10.1016/j.scienta.2017.08.035.

Pinho P, Jokinen K, Halonen L. 2017.The influence of the LED light spectrum on the growth and nutrient uptake of hydroponically grown lettuce. *Toxicologic Pathology*. 2017;49(7):97-103.

Rabara, R.C., Behrman, G., Timbol, T., Rushton, P.J., 2017. Effect of spectral quality of monochromatic LED lights on the growth of Artichoke seedlings. *Frontiers in Plant Science.* 8, 1–9. http://dx.doi.org/10.3389/fpls.2017.00190.

Samuolienė, G., Urbonavičiūtė, A. Duchovskis, P., Bliznikas, Z., Vitta P. & Žukauskas, A. 2009. Decrease in nitrate concentration in leafy vegetables under a solid-state illuminator. *HortScience*, 44: 1857-1860.

Samuolienė, G., Viršilė, A., Brazaitytė, A., Jankauskienė, J., Sakalauskienė, S., Vaštakaitė, V., Novičkovas, A., Viškelienė, A., Sasnauskas, A., Duchovskis, P., 2017. Blue light dosage affects carotenoids and tocopherols in microgreens. *Food Chemistry.* 228, 50–56. http://dx.doi.org/10.1016/j.foodchem.2017.01.144.

Senger H (1982). The effect of blue light on plants and microorganisms. *Phytochem Photobiol.* 35:911–920.

Smith, H.L., Mcausland, L., Murchie, E.H., 2017. Don't ignore the green light: exploring diverse roles in plant processes. *Journal of Experimental Botany*. 68, 2099–2110. http://dx.doi.org/10. 1093/jxb/erx098.

Snowden, M. C., Cope, K. R. & Bugbee, B.,2016. Sensitivity of seven diverse species to blue and green light: interactions with photon flux. *PLoS One 11*, https://doi.org/10.1371/journal.pone.0163121 (2016).

Stutte, G.W., Edney, S., Skerritt, T., 2009. Photoregulation of bioprotectant content of red leaf lettuce with light-emitting diodes. *HortScience*. 44, 79–82.

Taulavuori, K.; Hyöky, V.; Oksanen, J.; Taulavuori, E.; Julkunen-Tiitto, R. Species-specific differences in synthesis of flavonoids and phenolic acids under increasing periods of enhanced blue light. *Environmental and Experimental Botany*. 2016, 121, 145–150.

Terfa, M.T., Solhaug, K.A., Gislerød, H.R., Olsen, J.E., Torre, S., 2013. A high proportion of blue light increases the photosynthesis capacity and leaf formation rate of Rosa×hybrida but does not affect time to flower opening. *Physiologia Plantarum*. 148, 146–159. http://dx.doi.org/10.1111/j.1399-3054.2012.0169 8.x.

Von Wettberg, E.J., Schmitt, J., 2005. Physiological mechanism of population differentiation in shade-avoidance responses between woodland and clearing genotypes of Impatiens capensis. *American Journal of Botany*. 92, 868–874. http://dx.doi.org/10.3732/Ajb.92.5.868.

Wang, Y., Folta, K.M., 2013. Contributions of green light to plant growth and development. Am. J. Bot. 100, 70–78. http://dx.doi.org/10.3732/ajb.1200354.

Wanlai, Z.; Wenke, L.; Qichang, Y. Reducing Nitrate Content in Lettuce by Pre-Harvest Continuous Light Delivered by Red and Blue Light-Emitting Diodes. *Journal of Plant Nutrition*. 2013, 36, 481–490.

Wollaeger, H.M., & Runkle, E.S. (2014). Growth of Impatiens, Petunia, Salvia, and Tomato Seedlings under Blue, Green, and Red Light-emitting Diodes. *Hortscience*, *49*, 734-740.

Yanagi T ve Okamoto K (1997). Utilization of super-bright light emitting diodes as an artificial light source for plant growth. *Acta Horticulturae*. 418:223-228

Yuanchun Ma , An Xu , Zong-Ming (Max) Cheng., 2021. Effects of Light Emitting Diode Lights on Plant Growth, Development and Traits A Meta-analysis, *Horticultural Plant Journal*, doi: https://doi.org/10.1016/j.hpj.2020.05.007

CHAPTER 10

PRESENT AND FUTURE OF DRYING TECHNIQUES AND BUSINESSES APPLIED IN FRESH FRUITS AND VEGETABLES

Assist. Prof. Dr. Fatih Cem KUZUCU[1]

M. Sc. Koray AKEV[2]

[1]Çanakkale Onsekiz Mart University, Agricultural Faculty, Çanakkale, Turkiye
fatihcem@comu.edu.tr, ORCID ID: 0000-0003-0497-4331
[2]Çanakkale Onsekiz Mart University, Çanakkale, Turkiye
korayakev@gmail.com

INTRODUCTION

Dried fruits are defined as a concentrated form of fresh fruits prepared with different drying techniques. By other definition, dried fruits have a much lower moisture content as most of their original moisture is removed either naturally through sun drying or using special dryers (Anonymous, 2012).

When we look at the commercially important dried fruit production, dates come first on a global basis, followed by raisins, dried apricots, prunes and dried figs. Dried figs, dates, raisins, prunes dried apricots, dried peaches, dried pears and dried apples are referred to as "conventional" or "traditional" dried fruits. Moreover, some fruits such as blueberries, cranberries, strawberries, cherries and mangoes are inoculated with sugar solutions (for example, sucrose syrup) or juice concentrates before drying. Some products sold as dried fruit, such as papaya and pineapple, are actually candied fruit (Barta, J., 2006).

Epidemiological studies have found a relationship between diet quality and dried fruit consumption. Of all the dried fruits that show health benefits, raisins may be among the most researched. This is followed by figs, apples, dates, prunes, apricots, peaches, pears and the other fruits and together they account for about half of all dried fruits produced in each year worldwide (Willimason, G. and Carughi, A. 2010).

Dried fruits are almost as diverse as fresh fruits. While raisins, prunes, figs, dates and apricots are the most common dried fruits in the markets, healthy food stores and local markets offer many more options such as dried apples, mangoes, pineapple, papayas, strawberries and even exotic dragon fruit. They are rich sources of health-promoting bioactive and essential nutrients compounds. Dried fruits rich in carbohydrates (61.33 – 79.18 g/100 g) and free of fat (0.32 – 0.93 g/100 g). The highest calorie is encountered in raisins (299 kcal/100 g), followed by dates (282 kcal/100 g). Dried fruits are excellent sources of sugar, ranging from 38.13 g/100 g in prunes to 63.35 g/100 g in dates. Fructose and glucose are the main sugars found in all dried fruits, followed by sucrose. Very small amounts of galactose and maltose contains some dried fruits. Sugar levels may vary depending on drying methods and regional and various factors (Anonymous, 2010a).

It is important to note that the high dietary fiber content (3.7-9.8 g/100 g) found in dried fruits is an important source for meeting dietary recommendations (14 g fiber per 1000 calories of food consumed each day). That would be 25-38 g of fiber per day depending on age and gender. On a serving basis (40 g), dried fruits provide more than 9% of the daily value of fiber based on the fruit. Dried fruits (40 g/portion) have been reported to compare favorably with common fresh fruit options (one cup or one serving of fruit) in terms of fiber content (Anonymous, 2010a).

Regarding nutritional aspects, the percentage of recommended dietary allowances (RDA) or adequate mineral intake (AI) for adult men and women (ages 15-50) was also determined. In general, dried fruits are a reasonable source of potassium, phosphorus, magnesium, copper, iron, manganese and magnesium. Among the eight dried fruits, peach has the highest mineral content, while apple has the lowest mineral content. Consuming 40 g (on a serving basis) dried fruit supplies 0.6 – 6.5% calcium, 8.4 – 16.4% copper, 2.1 – 20.3% iron, 1.6 – 8.6 magnesium, 2.2 – 6.8% phosphorus and 3.8 – 9.9% potassium (Anonymous, 2011).

Dried fruits contain both water-soluble (folate, niacin, betaine, choline, pantothenic acid, pyridoxine, thiamine, riboflavin and vitamin C) and fat-soluble vitamins (A, K and E). Among the eight dried fruits listed, plum is the richest source of vitamin K (59.5 g/100 g) and apricot is the richest source of vitamin A (180 g/100 g) and vitamin E (4.33 mg/100 g). Vitamin C is contain small amounts of dried fruits generally. Prunes are particularly rich in vitamin K. Of these eight dried fruits, apricots, plums and peaches contain more vitamins than the other dried fruits (Anonymous, 2010a).

Although dried fruits contain all essential amino acids (except for tryptophan in pears), they are not a good source of amino acids in general due to their low protein content (Anonymous, 2010).

In summary, some nutritional facts about dried fruits could be listed as follows (Anonymous, 2022d):

- Dried fruits have low fat and sodium contents and do not contain trans-fat and cholesterol as expected (Anonymous, 2010).

- Dried fruits are a good source of potassium and dietary fiber. Among all fruits, it is among the top five contributors of potassium and fiber (Anonymous, 2005).
- Dried fruits provide essential nutrients normally low in today's diet, such as vitamin A (apricots and peaches), calcium (figs), vitamin K (prunes), boron (raisins and prunes), copper and iron (Anonymous, 2010, Rainey, C.J., et al., 1999).
- There is no added sugar in traditional dried fruits. Mosttraditional dried fruits contain low amounts of sucrose; sugar contents are in the form of glucose and fructose (Anonymous, 2010a).

With its unique combination of taste and aroma, essential nutrients, fiber and phytochemicals or bioactive compounds, dried fruits are a viable step towards a healthier diet and a way to bridge the gap between recommended actual consumption and fruit intake. They should be included with the worldwide recommendations for fresh fruit, as they help in meeting dietary guidelines for a daily serving of fruit (five servings per day recommended) and address barriers to fruit intake (Steinmetz, K.A. and Potter, J.D., 1996).

In different countries, smaller serving sizes ranging from 30 to 43 g, depending on the fruit, are considered nutritionally equivalent to fresh fruit in current dietary recommended (Anonymous, 2010b).

A wealth of scientific evidence shows that individuals who regularly consume large amounts of dried fruit have lower obesity, cardiovascular disease, type 2 diabetes, various types of cancer and the other chronic diseases (Block, G., et al., 1992).

Therefore, dried fruits should be consumed daily to take full advantage of these nutrients. Among many other specialty foods, dried fruits are widely used as ingredients in the packaged snacks, confectionery, baked goods, cereals, energy and nutrition bars, ready-to-eat salads and dessert industries (Anonyous, 2022c).

Fruits can be dried as whole (e.g. apricots, grapes and plums), halves, cubes or slices (ex. mango, papaya and kiwi). Alternatively, after drying (e.g. dates), dried fruits can also be chopped, converted into concentrated juices or pastes. The fruits can also be dried in puree, skin or powder by spray drying. Some fruits can be freeze dried (e.g. strawberries, raspberries, cherries, apples and mangoes). Freeze-dried fruits become very light and crunchy and retain most of their original flavor (taste and aroma) and phytochemicals (Anonymous, 2022d).

As numerous epidemiological studies have shown, consumption of vegetables and fruits reduces the risk of many chronic diseases such as heart disease, obesity, cancer, stroke and type-2 diabetes (Vayalil, P.K., 2012).

Additionally, there is an inverse relationship between fruit and vegetable intake and blood pressure. The US National Cancer Institute (NCI) and the National Research Council (NRC) recommend at least five servings of fruits and vegetables a day. Similarly, the World Health Organization (WHO) recommends 400g of fruit and vegetables per day or the equivalent of five 80g servings of fruit (Anonymous, 2003).

As part of a dietary study with 13,292 participants, dried fruit consumers were defined as those who consumed the equivalent of at least one-eighth cup of fruit per day. Consumption of dried fruit is associated with improved adiposity measures, lower body weight, higher overall diet quality and higher dietary intake of vitamins K, A and E, magnesium, potassium and phosphorus. These benefits are attributed to the higher fiber content, reduced intake of fats, alcohol and added sugars (Keast, D.R., et al. 2011).

Besides, only 7% of participants in the study consumed significant amounts of dried fruit in their diet, which calls into question the effectiveness of ongoing worldwide public health campaigns promoting fruit consumption (Keast, D.R. at al. 2011).

In the most basic sense to be done for drying, it is defined as the process of removing moisture from the product to be dried. From past to present, drying processes have been developed to meet industrial needs and have found a wide application area. Today, there is almost no area where drying is not used in industrial applications. Drying process is widely applied in industries such as food, chemistry, textile, leather and timber industry (Keast, D.R., et al. 2011).

Drying is the process of reducing 80-95% water in the fruit and vegetables to 10-20% and ensuring that they last for a long time. However, quality characteristics such as appearance, color, taste and nutritional values should change as little as possible and when water is added for cooking, it should be able to absorb water close to the amount they contain while fresh (Anonymous, 2022a).

Several different drying methods are used for drying agricultural products. Open sun drying is the oldest known method of drying agricultural products. Although this method is simple, it also brings with many negative effects such as the fact that the products are exposed to dust, rain, insects, birds and the effect of wind. Open-sun drying method also requires a long drying time and large drying area. Therefore, it is extremely important that the drying process is carried out using controlled methods (Anonymous, 2022a).

The processes applied to keep fruits and vegetables for a long time by drying are as follows.

- Pre-treatments
- Drying process
- Post-treatments
- Packaging
- Storage

DRYING METHODS

Sun Drying

It is the drying process performed in the open air by solar energy used. It is also called as natural drying. While the fruits are dried in the open-air by using solar energy, they are damaged by dust, soil, rain and various insects and animals circulating in the drying areas and the product quality is adversely affected (Anonymous, 2022a).

Following issues should be taken into consideration to minimize such damages:

- Fruits to be dried should be harvested at drying maturity.
- Harvest should be performed properly.
- Foreign materials such as straw, litter, leaves, stones, etc. and those with bruises should be separated.
- Products to be dried should be washed both to clean and to get rid of pesticide residues.
- Sorting should be done.

- Whole pieces and slices of fruit should be processed separately.
- Sulfurization should be done in accordance with the procedure.
- Sulfurization rooms should be duly.
- Fruits should be placed on the slabs in the sulfurization chambers.
- Drying should be done not on the soil, but on bedsteads or high benches depending on the type of fruit.
- Drying areas should be covered with awnings to protect them from rain or the bedsteads should have shelves and be placed on top of each other.
- Dried fruits should be subjected to cleaning, selection and sorting processes.
- Moisture balance should be provided by sweating the fruits.
- Non-sulfurized fruits should be fumigated against pests.
- It should be packaged in accordance with the characteristics of the fruit.
- Warehouses should be cool, airy, dim, dry and protected.
- Before the start of the season, information and assistance should be sought by applying to the nearest Provincial Directorates of Agriculture, Research Institutes, Province Control Laboratory Directorates (Anonymous, 2022a).

Artificial Drying:

It is the drying process made by contacting the food to be dried with the heated air of a dryer taken from outside in the drying facilities (Arun S. Mujumdar, 2006).

Combined Drying:

It is a drying process by using solar energy and various fuels. Hot air is obtained from solar energy in sunny seasons and from solid, liquid or gaseous fuel on days when solar energy is not sufficient. These dryers are also called village-type dryers when they have small capacity (Arun S. Mujumdar, 2006).

It is especially recommended instead of sun drying as it does not require much investment and has the opportunity to obtain quality products (Arun S. Mujumdar, 2006).

Freeze Drying:

In this method, the material to be dried is first frozen. The ice formed is then vacuum sucked in vapor form and the water vapor is removed by freezing in ice condensers (Arun S. Mujumdar, 2006).

The product dried by this method is superior in terms of sensory properties and nutritional values. However, the investment cost is high. It is mostly used in the production of instant soups prepared with the addition of water (Sadikoglu, H. et al., 1999).

Fruit Drying

The fruits to be dried should be mature, sturdy, and free of wounds, bruises and insect bites. The basic processes applied in drying different fruits are similar with each other and are as follows.

- Washing, - Separating from foreign materials, - Sorting, - Peeling according to the type of fruit, - Dividing, slicing, chopping, - Seed removal.

In addition to these, pre-treatments such as blanching, dipping in alkaline solutions, sulfuring are applied when necessary (Arun S. Mujumdar, 2006).

Sulfurization

Sulfurization is the application of SO_2 (sulfur dioxide) to the fruits to be dried. It is usually done to prevent color and vitamin loss in all fruits. With sulphuration, cracks occur in the shell, water evaporates faster and the fruit dries faster. In addition, it kills the eggs and maggots of harmful insects and ensures that the fruits last longer (Anonymous, 2022a).

Sulphuration is performed in two ways.

- Fruits are contacted with SO_2 gas obtained by burning powdered sulfur in sulphuration chambers.
- Fruits are dipped into solutions containing sodium bisulfite, sodium sulfite, etc. at certain concentrations or these solutions are sprayed onto the fruits.

Sulfurization by burning is more commonly used.

The minimum and maximum amount of SO_2 required in dried fruits is limited by regulations. It is not allowed to exceed these amounts.

For example, the amount of SO_2 is limited to 2/kg in order not to damage the color of apricot and peach.

Grape Drying

Grape is the leading product that is preserved by drying. The grapes to be dried must be of a certain maturity. When the amount of dry matter dissolved in water is 22-23%, it means that the grapes reached to harvest maturity (Anonymous, 2022a).

When the grapes were brought to the drying area, they are dried directly or by dipping into solutions under the sun. The most common practice is dipping and drying in the sun.

- The dipped grapes are transported to the drying slabs. Slabs are of two types.

Floor slabs: Earthen slabs, concrete slabs, paper slabs; propylene cross-stitch slabs are among the floor slabs. There are also awning and protected ones.

High racks: Also called string system. The string system is arranged as single row, double row and hammock.

- In Turkey, grapes dry in about 10 days. Drying of grapes without dipping takes more than 20 days.
- Dried grapes are collected in the morning or evening coolness. It is granulated by hand and separated from its clusters. Grained grapes are cleaned by sieving or by passing them through grape tossing machines. They are sent to grape processing facilities in 50 kg cross-stitch sacks.
- In grape processing plants, raisins are washed, sulphurated, dried, classified according to their size and color and then packaged.

The moisture ratio of raisins should be 12-15%. Accordingly, 1 kg raisin is obtained from 3.5-4 kg fresh grapes.

In addition, 1 kg dry sulfur is used for 1.5 tons of raisins. Sulfuring time is around 10 minutes (Anonymous, 2022a).

Dip

The dipping process is applied to remove the naturally occurring wax layer on the outside of the grape and accelerate drying. It also has a positive effect on the color of the grapes (Anonymous, 2022a).

Dipping solutions contain potassium carbonate and are prepared in various ways. Dipping solution called "Potasa" is commonly used in Turkey (Anonymous, 2022a).

Fig Drying

Figs dried on the tree and on the ground are collected and packed into chests and sacks and sent to the processing area (Anonymous, 2022a).

Figs are packed after fumigation, selection, classification and washing processes. However, before packaging, they are kept in steam or heated sea water for 3-4 minutes in order to shape the figs.

- Sulfurization is applied to some varieties. The sulphation time is 4 hours or more.
- Dipping is done to remove the hairs in the drying of hairy fig varieties. Dipping is recommended for color and softness (Anonymous, 2022a).

Apricot Drying

Dried varieties must have certain characteristics (Anonymous, 2022a).

- All sides of the fruit should ripen at the same time,
- Easily separated from the stone,
- The stone should be small and the flesh should be sweet,
- It should keep its color for a long time after sulfurization,
- It should have high yields.

The main dried apricot varieties are Çöloğlu, Hasanbey, Hacıhaliloğlu, Karakubuk, Hacıkız, Çataloğlu.

When the amount of water-soluble dry matter in apricots reaches 26%, it means that it has reached the drying maturity.

- Washing and grading processes are applied to the apricots arriving at the drying area.
- Apricots are dried as whole, seedless whole and half.
- Apricots are kept in sulphuration rooms for 2-6 hours depending on the variety and maturity, whole and half formation and the amount of sulfur burned.

- Later, the bedsteads are transported to the drying areas and left to dry. Drying is terminated when the moisture content of the apricots drops below 20%.
- Dried apricots pass through selection, sorting, sulphuration and moisture balancing processes before packaging (Anonymous, 2022a).

Plum Drying

Generally, dark colored, large, small-seeded, high flesh thickness, high dry matter, bright colored varieties are used for drying. After dipping the plums, they are left to dry in the sun. Drying is completed in 7 days in good weather and to understand this practically, the seed should not slip and the peel should not be hard when squeezed between two fingers (Anonymous, 2022a).

Apple Drying

Apples are not suitable for drying in the sun. Therefore, they are dried in drying facilities. After the apples are peeled and sliced, they are sulfurized. About 3-4 kg of sulfur is used for 1 ton of apples (Anonymous, 2022a).

Some data on dried fruits are provided in the below table.

Table 1: Some properties of dry fruits

Fruits	Efficiency (%)	Moisture ratio of final product(%)	Drying duration (days)
Seedless grape	25-28	12-15	8-10
Apricot	20-30	15-20	5-6
Plum	25-30	16-19	7
Apple	11-12	3-5	15-18

Moisture Balancing:

The amount of moisture in dried fruits is different in each batch, in separate parts of the same batch and even in different parts. Moisture needs to be balanced in terms of product quality and further processing (Anonymous, 2022a). Dried fruits are kept in large crates or boxes, with the lid closed, in warehouses for 2-3 weeks. Thus, the moisture content of the fruits is equalized (Anonymous, 2022a).

Vegetable Drying

Since the quality losses are high when the vegetables are dried in the sun, drying facilities are absolutely needed for commercial vegetable drying, except for red peppers and mushrooms (Anonymous, 2022a).

Belt, tunnel and cabin-type driers are available for vegetable drying. According to the characteristics of the vegetables to be dried, sorting, washing, peeling, chopping, boiling, cooling, sulphuration etc. pre-treatments are applied.

Boiling and sulphuration are important so that the color does not turn into brown (Arun S. Mujumdar, 2006).

Boiling

It is made in hot water or steam for certain durations depending on the type of vegetable. However, it is not applied to some vegetables such as red pepper, onion, garlic (Anonymous, 2022a).

Sulfurization:

It is made in the same way as with fruits. With sulphuration, the color of the vegetables is preserved and the loss of vitamin C and carotene is prevented. Dried vegetables are fumigated, packaged and stored (Anonymous, 2022a).

Fumigation

To protect fruits and vegetables against pests, methyl bromide etc. substances are burned in closed facilities. About 2-3 kg of methyl bromide is used for 100 m^3 volume. Fumigation time is 24 hours. Fumigation can be repeated according to warehouse conditions. Sulfurized fruits are not fumigated, but the amount of SO_2 is controlled and repeated if necessary (Anonymous, 2022a).

Packaging

Dried fruits are packed in wooden crates, polyethylene, propylene, cellophane bags, cardboard and metal boxes. Paper is spread inside the boxes or creates when requested. Dried vegetables are packed in moisture-proof polyethylene, aluminum foil combination boxes, waxed paper or cardboard boxes. Small packages are placed in big packages of 10-20 kg (Anonymous, 2022a).

Data on some vegetables dried in drying facilities are provided in Table 2.

Table 2. Some properties of dry vegetables

Vegetables	Boling duration (min)	Pre-drying (temp. ˚C)	Final drying (temp., ˚C)	Final product (Moisture,%)	Efficiency (%)
Beans	2-3	60-65	50-55	7-9	7
Carrot	6-8	65-70	55-60	7	5-7
Cabbages					
Green	1	60-65	55-60	7	6-8
White	1.5-2	60-65	55-60	5	4-6
Red	1.5-2	60-65	55-60	5	6-7
Cauliflower	-	60-65	-	5	4-5
Peas	3-4	65-70	60-65	7	9-14
Spinach		70	60-65	6	6-8
Root celery	2	60-65	55	5-6	5-6
Onion	NB	60-65	55-60	4-5	8-10
Leeks		60-65	55	5	7-10
Mushroom	NB	60-65	55-65	12	10
Pepper	NB	60-65	60	7-8	15

*NB : Not Boiled.

NUTRITIONAL VALUES OF DRY FRUIT AND VEGETABLES

Although the nutritional values of dried fruits and vegetables are lost in terms of vitamin C and carotene as compared to fresh ones, and loss of vitamin B is encountered in sulphurated products, dried fruits and vegetables are good sources of carbohydrates and vitamin (Anonymous, 2011).

Dried fruits, which are prepared by blowing the moisture of the fruits that have been collected on time and when the product is abundant, are also a source of healing. Colorful dried fruits such as kiwi, papaya and pineapple were added to dried fruits such as apricots, plums and grapes prepared for the winter months. One of the oldest methods used, the drying process is to preserve food and it will preserve its durability for a long time and since the amount of water it contains is low, microorganisms that will spoil the food cannot grow and reproduce. It is obtained by reducing the 90 percent water content of fresh fruits to 10-20 percent in dry fruits. With this process, the sugar content of vegetables and fruits whose water content decreases, increases and their durability increases.

After drying, all minerals, except for vitamin C, dried fruits with their high antioxidant potential primarily protect the body against free radicals. Among the fruits, the most suitable ones for drying are grape, pear, plum apple, cherry, apricot, banana, mulberry, kiwi, pineapple strawberry and mango. These dried fruits also have various benefits (Anonymous, 2011).

Benefits of dry fruits could be listed as fallows;

Dried Pear

Dried pear is highly rich in vitamins. It ensures the regular functioning of the kidneys. It makes the urine abundant. It helps to shed sand and stones in the kidney. It lowers high blood pressure. It cleans the blood and ensures the normal functioning of all glands. It cures anemia and prevents constipation. It calms the nerves. It relieves mental fatigue. It quenches thirst. Increases saliva secretion. It reduces vomiting of pregnant women. It cures indigestion. Diabetics can also eat it. Those with a weak stomach should drink its compote. If it is eaten before meals, it increases even more than its benefit (Anonymous, 2011).

Prunes

It is necessary to consume fruits that are low in sugar, especially in the evening. It is beneficial for women to consume dried black plum since it contains plenty of calcium and vitamin D. Therefore, its consumption means a serious protection of bone health. Apart from that, due to the rich potassium and magnesium minerals contained in prunes; it has benefits for blood pressure, liver, heart and kidneys. With its strong antioxidants, it has the effect of reducing the risk of heart diseases and crisis. It lowers blood sugar. Protects against cancer and prevents skin aging (Anonymous, 2011).

Dried Kiwi

It is rich in potassium, calcium, vitamins A and C, iron and magnesium. It’s also very high in nutritional value. High fiber content facilitates digestion by creating a positive effect on intestinal work. In this case, it prevents constipation. It balances blood pressure, lowers blood pressure and cholesterol.

It strengthens the immune system, it is also good for coughs, colds, stomach ailments and anemia. It also beautifies the skin (Anonymous, 2011).

Dried Mulberry

Mulberry, which is rich in B1, B2 and vitamin C, iron and calcium, is known to cure many diseases. White mulberry has antipyretic and diuretic (diuretic) effects. It is known that the syrup obtained from black mulberry has a positive effect on mouth and throat diseases (Anonymous, 2011).

Dried Mango

Mango, which has a high content of vitamins A, C and E, is one of the foods that is very beneficial for nerves, skin beauty and hair, and also cleans the blood, accelerates digestion and is a strong antioxidant (Anonymous, 2011).

Dried Apricot

It is nutritious and rich in potassium. It is good for digestive problems; It prevents stress and anemia. The vitamin A it contains prevents the formation of skin disorders such as acne. It helps growth, strengthens vision functions, prevents the development of diabetes, protects the immune system. Potassium ensures good functioning of all muscles and nerves, especially heart muscles. Apricot is a fibrous fruit. It has been determined that fibrous foods provide a balanced increase in blood sugar and are beneficial in protecting against cancer as they shorten the residence time of harmful substances in the intestine (Anonymous, 2011).

Dried Strawberry

There is also a large amount of phosphorus and iron in dried strawberries. It is also rich in vitamins K, C and B. Strawberry prevents atherosclerosis and gives strength to the body, lowers cholesterol. In addition, strawberry, which is a very good antioxidant, and strengthens the immune system. It is very beneficial for the regular functioning of the digestive system. It expels intestinal worms, diuretics and removes harmful substances from the body, cleans the blood, strengthens the gums and removes lowers blood pressure, bad breath and reduces stress with its calming effect, lowers fever, is good for rheumatism and liver disorders, and moisturizes the skin (Anonymous, 2011).

COMMERCIAL VALUE OF DRY FRUITS

Considering the total of Turkey's Considering the General Exports in 2021 on a value basis, it is seen that there is an increase of 32.9% as compared to the previous year. A 22.2% increase was observed in agricultural products and an increase of 34% in industrial products. Agriculture and Industrial sector constitute approximately 95% of the total of General Exports of Turkey. Exports of Dried Fruits and Products, on the other hand, increased by 12.6% and had a share of 0.7% in total overall exports (Anonymous, 2022b).

Table 3. Sector-based exports of Turkey

SECTORS	2019(1000 dollars)	2020 (1000 dollars)	2021 (1000 dollars)	Change ('21/'20)	Share (21) (%)
I. AGRICULTURE	23.394.512	24.369.143	29.737.575	22,2	13,2
Dry fruit and products	1.418.873	1.399.574	1.574.287	12,6	0,7
II. INDUSTRY	138.253.659	127.645.230	170.880.410	34,0	75,8
III. MINING	4.311.584	4.272.391	5.930.165	38,9	2,6
TOTAL (TİM*)	165.959.755	156.286.764	206.548.150	32,3	91,6
Export exempted from the records of Exporters'' Associations	5.619.092	13.227.403	18.819.527	39,5	8,4
GENERAL TOTAL	180.468.488	169.514.167	225.367.676	32,9	100,0

REFERENCES

Anonymous, 2003. WHO/FAO, Diet, Nutrition and the Prevention of Chronic Disease. Report of a Joint FAO/WHO Expert Consultation. WHO, Geneva, Switzerland.

Anonymous, 2005. USDA, Carbohydrates. Dietary Guidelines for Americans. US Department of Agriculture and US Department of Health and Human Services. Government Printing Office, Washington, DC.

Anonymous, 2010a. USDA, National Nutrient Database for Standard Reference, Release 23. Published online at: http://www.nal.usda.gov/fnic/foodcomp /search/, last accessed March 7, 2011.

Anonymous, 2010b. USDA, Dietary Guidelines for Americans. Published online at: https://www.nal.usda.gov/legacy/fnic/dietary-guidelines, last accessed June 14, 2022.

Anonymous, 2011. INC., Traditional dried fruits: valuable tools to meet dietary recommendations for fruit intake. Paper given at the XXX World Nut and Dried Fruit Congress, Budapest, Hungary, May 20–22, 2011 (Dried Fruit Round Table).

Anonymous, 2012. INC., World Dried Fruits Production. International Nut and Dried Fruit Council Foundation, Reus, Spain.

Anonymous, 2022a. What is the drying process and the details. Published online at: https://www.academia.edu/36010674/KURUTMA_NED%C4%B0R last accessed June 14, 2022.

Anonymous, 2022b. Aegean Exporters' Associations. Dried Fruits Report. Published online at: https://www.eib.org.tr/tr/Sayfa.Asp?SI_Id=720D93419C last accessed June 14, 2022.

Anonyous, 2022c. Meduri Farm Inc. Specialty Dried Fruits. Published online at: http://www.medurifarms.com, last accessed July 14, 2022.

Anonymous 2022d. Dried Fruit. Published online at: http://en.wikipedia.org/wiki /Dried_fruit, last accessed July 16, 2022.

Arun S. Mujumdar, 2006. Handbook of Industrial Drying. CRC Press LLC. E book Published online at: https://ebookcentral.proquest.com/lib/canakkale/detail. action?docID=283238 last accessed June 14,2022.

Barta, J., 2006. Fruit drying principles. In: Handbook of Fruits and Fruit Processing (ed. Y.H. Hui). Blackwell Publishing, Oxford, UK, pp. 81–94.

Block, G., Patterson, B., Subar, A., 1992. Fruit, vegetables, and cancer prevention: a review of the epidemiological evidence. Nutrition and Cancer, 18, 1–29.

Keast, D.R., O'Neil, C.E., Jones, J.M., 2011. Dried fruit consumption is associated with improved diet quality and reduced obesity in US adults: National Health and Nutrition Examination Survey, 1999–2004. Nutrition Research, 31, 460–467.

Rainey, C.J., Nyquist, L.A., Christensen, R.E., Strong, P.L., Culver, B.D. & Coughlin, R. (1999) Daily boron intake from the American diet. Journal of the American Dietetic Associations, 99, 335–340.

Sadikoglu H., Liapis, AI,, Crosser OK., Bruttini, R. 1999. Drying Technology 17:2013–2035, 1999.

Steinmetz, K.A., Potter, J.D.,1996. Vegetables, fruits and cancer prevention: a review. Journal of the American Dietetic Association, 10, 1027–1039.

Vayalil, P.K.,2012). Date fruits (Phoenix dactylifera Linn): an emerging medicinal food. Critical Reviews in Food Science and Nutrition, 52, 249–271.

Willimason, G., Carughi, A., 2010. Polyphenol content and health benefits of raisins. Nutrition Research, 30, 511–519.

CHAPTER 11

THE EFFECT OF BLOOMING AND FERTILIZATION BIOLOGY ON PRODUCTIVITY OF FRUIT SPECIES

Assoc. Prof. Dr. Nihal ACARSOY BİLGİN[1]
Prof. Dr. Adalet MISIRLI[2]

1. Department of Horticulture, Faculty of Agriculture, Ege University, İzmir, Türkiye nihal.acarsoy@ege.edu.tr, Orcid ID: 0000-0002-5018-6347
2. Department of Horticulture, Faculty of Agriculture, Ege University, İzmir, Türkiye adalet.misirli@ege.edu.tr, Orcid ID: 0000-0002-6128-9974

INTRODUCTION

Fruit production is a process that starts with flower induction and continues with pollination, fertilization and fruit development. Considering these processes in fruit growing is of great importance in terms of regulating flower production.

Yield in fruit species; it is a feature that depends on many factors such as flower bud formation, fruit set, ecological factors and cultural practices. In this section, there are factors affecting productivity in terms of blooming and fertilization biology of fruit species. These are differentiation, quantity, drop and chilling requirement of flower bud, gamete formation, flower anomalies, pollination, fertilization and fruit set.

1.1. Blooming Biology

1.1.1. Flower Bud Differentiation

Flower bud formation is an important indicator for determining yield potential. Flower bud differentiation includes two stages (Özbek, 1977). In the physiological differentiation stage; the cells forming the growth cone divide rapidly and differentiate into leaf or flower bud as a result of physiological events. This period is considered to be the time when the growth stops and the morphological differentiation occurs 2-7 weeks ago.

In the morphological differentiation stage, leaf and flower buds can be distinguished according to the shape of the growth cone. A bud has a growth cone in the middle and scales around it. In this process, the growth cone expands, elongates and becomes cylindrical by flattening the top. From the outside to the inside, sepal, petal, male organ and female organ begin to form, respectively.

Factors Affecting Flower Bud Formation: In order to determine the precautions to be taken and application times for flower bud management in modern fruit growing, it is necessary to know the formation time of the flower bud and the effective factors.

For flower bud formation and flower quality; tree age and tree vigor, leaf area, crop load, nutrient elements, carbon assimilation, irrigation, fertilization, lighting, thinning, ringing, strangulation, pruning, rootstock-scion relationship, chilling reguirement are effective (Fabbri and Benelli, 2000; Kaşka and Kargı, 2007).

Attention is drawn to the importance of carbon/nitrogen balance in flower bud formation. It is mentioned that there is a positive correlation between the amount of carbon and the photosynthesis capacity and the formation of flower buds (Şahin, 2004). In this context, the increase in lighting, thanks to directional selection, regular pruning and leaf plucking, leads to an increase in the amount of carbohydrates and therefore the amount of flower buds.

It has been shown that flower bud differentiation is not fully realized when the light level is lower than 10-30% of full illumination in fruit trees. (Kaşka and Paydaş Kargı, 2007). It has been reported that the number of seeds per pod in hazelnut cultivars is higher under lighting conditions (Bak et al., 2014).

On the other hand, while ABA and GA3 applications have a direct effect on flower bud formation, IAA and IAA-like substances have an indirect effect by promoting annual shoot formation (Ülger, 1997). In addition, it has been revealed that the reducing sugar content may be effective in the formation of flower buds in hazelnut.

Excessive irrigation and abundant nitrogen administration in young trees cause vegetative growth and prevent flower bud formation. Nitrogen has a positive effect on the formation of flower buds in trees that have been productive. On the other hand, stem cutting during the bud differentiation stage increases flower bud formation. This is due to the fact that water cannot be taken from the root and the nutrients formed in the upper parts of the tree cannot be transported to the root. However, it is not a widely applied practical method. İn ringing practice, vegetative development stops and carbohydrates are spent on bud differentiation. This application is done in winter or spring. This method is used in many fruit species. The strangulation application is a reliable application to obtain products from trees in arid regions (Ülkümen, 1973). It is recommended to be preferred in trees that grow vigorously and do not form flower buds. Twisting is important in fruit trees during the juvenile period. In this process, the lower branch must be connected parallel to the ground, while the upper branch must be connected to the lower one. At this method, carbohydrates cannot be transported to the lower parts and water to the upper parts, and the formation of flower buds is encouraged, and the juvenile period is shortened. These procedures must be performed prior to flower bud physiological differentiation. Considering the effect of rootstocks in terms of this feature; When cultivars are grafted on weak rootstocks, they develop poorly and bloom early. However, since the vegetative development of the seedlings is strong, they cause late blooming.

The time of flower bud differentiation may differ depending on the species/variety and growing regions and climatic conditions. Flower buds begin to differentiate in deciduous fruit types in the summer of the previous year. Polat and Askin (2008) reported that the period of flower bud differentiation in pome fruit species occurs earlier than in stone fruit species.

In Eğirdir ecology, it was determined that the morphological differentiation period in flower buds of Jerseymac and Jonagold apple cultivars occurs approximately 50-60 days after full blooming (Kaçal, 2009).

It has been reported that flower indiction in cherry and apricot starts after harvest, so tree growth should be considered after harvest in order to ensure adequate flower development for the next year (Westwood, 1995).

It is stated that the differentiation and development of flower buds in apricot cultivars begin in July, the formation and development of flower organs occur in a short time, and different stages are seen together at the same date. There are differences between the flower bud development stages of the same cultivar in locations where there is a great difference between the chilling times. Because, in the location with a high chilling time, flower bud development stages take place earlier (Acarsoy, 2013).

Morphological differentiation in female flowers in hazelnut varieties takes place during the period when shoot elongation stops (Beyhan, 1993). This happens in citrus fruits and olives, about two months before blooming (Eriş and Barut, 2000).

In cold-resistant varieties, the differentiation of flower buds occurs later (Nemeth et al., 2010). In case of water and nutrient deficiencies, flower buds do not form on apricot trees or there are few and defective flower buds. In the next year, such trees either give no or very little product (Karlıdağ and Güleryüz, 2007).

On the other hand, climatic factors also have a significant effect on bud and crop productivity. Rainfall, air and soil moisture directly affect plant growth. Temperature, light, day length and wind have an indirect effect on productivity as they affect photosynthesis. The most influential climatic factor on the physiological life of plants is temperature. A certain temperature sum is needed for the formation of flower buds. Differentiation of flower infloresences begins the previous year. Optimal temperatures and sunny conditions during this period encourage the formation of flower inflorescences, while cool and cloudy weather encourages shoot formation. Knowing the time of flower bud formation and development processes is necessary for the regulation of product load, such as stimulating or inhibiting flower formation. In addition, this situation is important in terms of determining the suitability of the varieties to the ecological conditions of the region. It is possible to carry out cultural practices in the appropriate period thanks to the knowledge of these processes (Polat and Aşkın, 2008).

1.1.2. Flower Bud Density and Drop

Differences in flower bud density may be due to the genetic characteristics of the cultivars, as well as to ecological and growing conditions (Milatovic et al., 2010). It is reported that the heritability of this trait is moderate (h2=0.41-0.48) in peach (Okie and Werner, 1996; Topp et al., 2008). Again in the same species, there is a positive correlation between flower bud density and fruit set (Özdemir Eroğlu, 2018).

It has been determined that there is a difference between varieties in terms of the number of generative buds in apricots (Muradoğlu et al., 2007). Flower density varies from year to year. This may be due to late spring frosts. For this reason, it is recommended to grow varieties with high flower bud density in regions with late spring frosts. In addition, in regions where late spring frosts are not a problem, there is no need for fruit thinning when cultivars with low flower bud density are grown (Milatovic et al., 2010).

Genetic characteristics are significantly effective in flower bud drop (Muradoğlu et al., 2007). Low flower bud drop but high flower density is accepted as an indicator of high quality fruit production. It is stated that the rate of flower bud drop is higher in late blooming genotypes with high chilling requirement than in early blooming ones (Ruiz and Egea, 2008). It is noted that the Guillermo apricot cultivar, which is grown in cold and warm ecologies, has a large amount of bud casting (Alburquerque et al., 2003). Although the Precoce de Tyrinthe variety met the chilling requirement, bud drop rates were found to be very high. However, the desired efficiency can be achieved. This is due to the high density of flower buds, especially due to the presence of many May bouquets on the trees. The difference in bud density may be directly related to the selection of the appropriate ecology and growing conditions, as well as the genetic characteristics of the varieties (Acarsoy, 2013).

When the shoot age and flower and fruit drop of apricot cultivars were compared; It was determined that the highest drop occurred in shoots of 1 year old, and the least in 3-year-old shoots. The highest fruit set rate was found in 3-year-old shoots (Bolat and Şahin, 1995). The majority of flower buds on long shoots develop abortively and drop before blooming (Alburquerque et al., 2003; Julian et al., 2010). Accordingly, branch groups of different ages should be present in terms of productivity, since the age of the shoot is effective in flower and fruit drop.

1.1.3. Flower Anomalies

The probability of occurrence of flower anomalies in fruit species varies according to years depending on genetic factors as well as climatic conditions. Arid conditions in the summer and autumn of the previous year, high temperatures in the winter and their changes during the day, insufficient chilling requirement and frost events cause flower anomalies (Stanica et al., 2010). It has been reported that cytokinin and gibberellin that are effective in cell division and growth (Engin and Ünal 2007) and phytoplasmas affect flower anomalies (MyCoy et al., 1989).

Flower anomalies are listed as, for example, browning in flower organs, tissue necrosis, abortive pistil formation, absence of female organ, double pistil formation, transformation of male organs into pistil and petal, formation of multiple petals and reduction in flower size. Tissue necrosis, called flower abortion, is observed in the female organ during the dormant or flowering stage.

Short pistil in flowers is considered an anomaly. Abortive pistil is more common in apricots than in other Prunus species. Insufficient cold accumulation can cause this situation (Ruiz and Egea, 2008). Variation in abnormal female organ ratio was detected among apricot cultivars in the same ecology. The rate of abortive female organs varies depending on the years. It is reported that this situation may occur depending on climatic conditions. The hermaphrodite flower of the Gemlik olive variety has a normal female organ. On the other hand, in the male flower, it was determined that the female organ was aborted at various stages in differentiation. The male flower is smaller than the hermaphrodite flower (Uysal, 2012).

In cherry, high temperatures observed during flower bud differentiation lead to double pistil formation. Water deficiency also increases the number of female organs. In case of excessive amount of female organs in the flower, some of the fruits form drops and some of them form non-germinated seeds. Double fruit formation in stone fruit species was associated with postharvest water stress. When post-harvest water stress was alleviated, it was determined that there was a significant decrease in double fruit formation in peaches (Naor, 2010). The cause of abnormal flower formation (phyllody) in cherry cultivars is the inhibition of flower inflorescence development after the formation of the sepals. The rate of abnormal flower formations in which leaf-like formations were formed instead of flower organs was determined as 41-47% (Engin, 2011).

1.1.4. Chilling Requirement

Blooming is a physiological event that expresses the need for chilling requirement. For a sustainable fruit production, meeting the chilling requirement of species or varieties has become increasingly important in terms of global climate changes (Fadon et al., 2020).

Depending on the variety, the buds swell by meeting the need for chilling requirement, and thus, seasonal synchronization is ensured with the continuation of growth in the spring. The standard method, which is the sum of the hours below 7.2ºC during the winter months, is accepted for determining the chilling requirement. It is used in different methods other than this method. In additional, the termination of endodormancy in apricot buds can be determined by the weight gain of the flower bud, which is a classical approach. It is reported that the stage in which an increase of 25-30% in flower bud dry weight occurs can be considered as the end of dormancy (Acarsoy, 2013).

With the effect of global warming, the number of cold days tends to decrease remarkably. This situation adversely affects the production, especially in Mediterranean climate conditions, and even in some varieties, it is shown as the reason for the variation between years. Due to climatic factors, irregularities in flower bud development and inability to meet the chilling requirement cause fluctuations in production due to inefficiency or irregular product (Acarsoy, 2013). For this reason, it is important to evaluate the climatic data of the locations and to determine the resting period of the cultivars under controlled conditions and the sum of the effective temperature of the cultivars. There is a wide variation among fruit species and varieties in terms of meeting chilling requirements. Considering this issue, it is necessary to plan the production.

It is known that fruit trees that do not meet the chilling requirement have delayed flowering, irregular flowering and growth. In stone fruit species, uncomplete flowers occur, the number of flower buds decreases and the buds burst irregularly. In pome fruit species, blooming is irregular and leaf buds do not burst. Therefore, cultivars with long dormancy period are not economical to grow in warm places. Fruits such as almonds, peaches, quinces, figs, plums and cherries, which require less dormancy period, can be grown in warm coastal areas. Fruits such as pears, apples and apricots, which have a long dormancy period, should also be grown in cold areas.

1.2. Fertilization Biology

1.2.1. Gamete Formation

Formation of andrecaeum, pistil and gametes is necessary to obtain fruit. Pollen is formed as a result of meiosis in pollen mother cells in pollen sacs in anthers. These occur at different times from winter to spring, depending on ecological conditions. This event takes place in November for almonds, January for apricots, and March for walnuts.

Ovul occurs in the flower bud and carpel. There are generally two ovules in each carpel. The ovule begins to form from the nucellus tissue of the pistil. In the nucellus, the megaspore mother cell forms the eight-nucleated embryo sac as a result of meiosis. The egg cell is important for fruit formation.

Pollination, fertilization and ovule development are required for seed fruit formation. In addition, parthenocarpic and apomictic fruits are formed. Therefore, knowing the development of the ovule is important in terms of production technique. Ovul occurs in stone fruit types in the autumn of the previous year, and in pome seeds in the same year and in February-March. In stone cores, more than one female organ is formed in abnormal climatic conditions. In the ovary, the number of ovules differs according to the fruit species. For example, there are 2 pieces in cherry and 10 pieces in pear.

The ovul begins to age after 4-5 days of blooming and maintains its vitality for about a week. The pollen tube reaches the ovule in 4 - 8 days. In case of delayed pollination, fruit set decreases as the number of viable ovules will be less. In this respect, an important factor is the viability period of the ovule. Blank nuts formation in hazelnut can result from defective embryo sacs, nonviable egg cells, fertilization failure, or embryo abortions at various developmental stages. Temperature has a very important effect on the vitality of the ovule. While high temperatures shorten the vitality process of the ovum, low temperatures prolong this process. The rapid increase in temperatures from 15^0C to 25^0C within two days after anthesis in cherries increases the amount of embryo sacs degenerated ovules (Beppu et al., 2001). Almost all of the secondary ovule have lost their vitality in the antesis. Viability period of primary ovule in cherry genotypes was determined as 4-6 days (Aşkın and Sarısu, 2020)

1.2.2. Pollination, Fertilization and Fruit Set

In fruit species, the product can be obtained as a result of pollination and fertilization, except for parthenocarpy. The ovary and other flower parts form the fruit. Fruit production begins with flower induction, continues with pollination, fertilization, and eventually fruit set occurs.

Pollination is the transport of pollen formed in anthers to stigma by wind or insects according to flower biology. The stigma is usually 1-2 mm in insect-pollinated species, sticky and hairy (apple and pear). In the wind-pollinated species it is much larger, multi-part and broad (walnut, chestnut, and hazelnut). Pollination should be in a certain period of time. In the effective pollination period, the time between pollination and fertilization is important as well as the vitality period of the ovule. Since the viability period of the ovule is long, their effective pollination period is long.

The stigma must be receptive for fertilization. The stigma in the receptive state secretes a sugary liquid, and the pollen germinates. They report that stigma receptivity shortens with increasing temperatures. The stigma dries up due to hot winds such as the "sam wind". This situation prevents fertilization especially in dioecious fruit species. Blank nuts formation occurs. In addition, the stigma, which is very sensitive to cold, may freeze with the effect of low temperature and prevent fertilization. Heavy and continuous rains at the time of fertilization can prevent fertilization by washing the pollen on the stigma.

During the pollination period, when the weather is foggy and cloudy, the pollen remains suspended in the air. Thus, pollination is prevented. It is seen in hazelnut, walnut and chestnut. Blank nuts formation occurs.

For fertilization, pollen germinates at the stigma, forming pollen tube. Thanks to the cutylase enzyme secreted by the pollen tube, it dissolves the style and moves towards the ovary. In this process, it is important that the ovary is alive.

The pollen tube contains one vegetative and two generative nuclei. The pollen tube enters the embryo sac generally from micropylar, chalaza (pistachio) and integuments (aporogamy) and leaves the generative nuclei it carries into the embryo sac. One generative nucleus combines with the egg cell to form the zygote (2n), and the other generative nucleus combines with two polar nuclei to form the endosperm (3n) nucleus. The zygote divides and forms an embryo. If there is more than one ovule in the carpel, many pollen tubes reach the ovule. This is seen in apples and pears. In pomegranate, the pollen in the stigma usually germinates within 6 hours after pollination. It completely passes the style in 48 hours and then reaches the ovule in 72 hours (Gözlekçi, 1997).

Even if pollination occurs, fruit set sometimes decreases. It is thought that this may be due to three reasons.

- The papilla cells on the stigma are wrinkled and shrunken, and if there is no secretion of the stigma, this prevents the germination of pollen.
- Damage to the style tissue prevents the pollen tube from developing towards the ovule.
- Loss of vitality of the ovul in a short time

Fruit set is the most important factor limiting the yield of fruit trees and is mostly dependent on successful pollination and constitutes the most important stage of production. The low fruit set observed in fruit species is generally the result of high temperatures before flowering and low temperatures during the flowering period, temperature requirement and nutrient deficiencies. Self incompatibility, pollination failure, pollen pistil incompatibility, pollen viability, germination rate and production amounts, short duration of egg cell viability and effective pollination period are effective on fruit set.

Cross pollination is observed in fruit species depending on morphological (monoic, dioic), physiological (protandry, protogeny) and genetic (sterility, self-incompatibility) factors. This is the case in species such as hazelnut, chestnut, walnut, pistachio. In order to obtain the product, it is necessary to use pollinator varieties that bloom at the same time as the main variety.

The characteristics of pollinator varieties are as follows:

- The pollen must be of high quality and abundant, and its germination ability should be more than 30%, but it should not produce abortive pollen.
- Pollinator variety should be diploid genotype.
- There should be no incompatibility between the pollinator and the main variety.
- Pollinator variety should not show periodicity.
- The juvenile period of the main and pollinator variety must end at the same time.
- Pollinator variety should be high in economic value, efficient and preferred in the market.

If the market value of the pollinator and the main variety is high, the main variety / pollinator variety ratio will be 1/1 or 2/1. If the main variety is triploid and the pollinator variety is self-infertile, a third variety will certainly be needed as pollinator. It is necessary to use pollinator varieties at a higher rate in the orchard, taking into account the low insect activity and the effects of ecological factors and altitude in rainy and foggy regions.

1.2.3. Pollen Quality

Pollen quality is very important in determining pollinator varieties. Environmental conditions such as temperature and humidity, compatibility and pollen quality are the factors affecting pollination and fertilization. For this reason, the most suitable pollinator is determined with the fertilization biology applications in the orchard. However, since these studies require a long time, tests on pollen quality are important in the laboratory.

Pollen viability, germination and quantity express quality. In the determination of pollen viability; Tests such as IKI, FDA and TTC are widely used. These tests may give different results according to the varieties. Therefore, germination tests should also be done. Hanging drop or petri-agar methods are used. The germination medium contains water, sucrose, agar, boric acid etc. Germination rate of pollen; It varies according to species and variety, nutrient content, pH and ecology (Eti, 1991). In addition, the amount of pollen is important in terms of productivity.

Low temperatures cause both the amount of pollen produced and the vitality to decrease. High temperatures have negative effects on pollen viability, homogeneity, germination and pollen tube length.

Pollen performance has a significant effect on both the fruit set rate and the increase of the quantitative and qualitative characteristics of the fruit. For this reason, knowing the pollen characteristics of species and varieties is of great importance for growers and breeders.

Self and cross compatibility in fruit species can be determined by microscopic investigation of the development of the pollen tube in style. The development of the style is prevented due to the formation of pollen tube swelling, bursting, callose plates. This situation expresses incompatibility. In the case of compatibility, it was determined that the pollen tube reached the egg cell in 4 – 8 days. At low and high temperatures, pollen tube development is slow (Uysal, 2012)

1.2.4. Fertilization Problems in Fruit Species

Morphological sterility: Morphological sterility is abnormal formation of andreceum and pistil or gametes. Male and female forms appear. In raspberry, there are hermaphrodite, male flower, female flower and neutral flower forms. Hermaphrodite flowers bear fruit by pollinating them with their own pollen. The female flowers are pollinated with the pollen of other varieties and bear fruit. Male flowers cannot form fruit and have only pollen.

Cytological sterility: This sterility is caused by the abnormal amount of chromosomes. Pollen or egg cells do not contain the specific haploid chromosome number of the variety. Pollen viability are very low. Pollen tube does not develop well and they do not have the ability to fertilize. The triploid variety is not self-fertile. Diploid varieties should be used as pollinators.

Cytological sterility is also observed in some apple cultivars but is rarely seen in stone fruit species This condition is an inherited trait (Ülkümen, 1973).

Physiological sterility: This is due to nutritional deficiencies. The pollen of the tree, which is old and has poor nutritional conditions, is wrinkled and large-small, and the germination rate is as low as 10-20%. It is encountered in stone fruit species. Physiological infertility can be cured by cultural practices. Orchard where adequate cultural practices are not made; there is no pollen that is viable and has a high germination rate (Karlıdağ and Güleryüz, 2007).

Abortive pollen formation: In some cultivars, viable pollen is not formed, although there is no problem in chromosome numbers and nutritional conditions. In the "J.H. Hale" peach, degeneration occurs at the tetrad stage and no pollen is formed. In Washington orange, the layer forming the pollen does not occur in the anther, therefore no pollen is formed (Ülkümen, 1973).

Male sterility: This type of sterility does not produce viable pollen as a result of the male organs not forming normally. It is of great importance in plant breeding and especially in the production of hybrid varieties. Male sterility can be seen in different fruit species and varieties.

Female organ sterility: This sterility occurs throughout the flower and during gamete formation. It is seen during the formation of embryo sacs in apricots. Female organ sterility is rare in fruit species (Gerçekcioğlu et al., 2012).

Incompatibility: Although the male, female organs and gametes are formed normally, the interaction between pollen and stigma or style prevents the germination of pollen or development of pollen tube in style. It occurs as self and cross incompatibility.

Self incompatibility; It is the event that the variety does not set fruit or form seeds when pollinated with pollen of its own or other plants of the same variety. It occurs at any stage between pollination and fertilization and is controlled by incompatibility genes (S genes). Some fruit species and varieties are self-fertile (peach, cherry, some apricot and quince varieties). In important fruit species such as cherry, chestnut, almond, plum, apple, pear and hazelnut, there is self-incompatibility in most of the varieties (Mısırlı, 2000).

Cross incompatibility; Some cultivars do not form fruit when pollinated with different cultivars. This situation is called cross incompatibility. This is particularly common with cherries. Some cherry varieties are both self-fertile and can be pollinators for other varieties.

Homomorphic self-incompatibility occurs as gametophytic and sporophytic.

Gametophytic incompatibility occurs when the same S gene is present in the style after pollen germination. Pollen is in S1 or S2 character. In order for the pollen tube to develop, it must have a different character such as S3, S4. The genotype of pollen is important in fertilization (Tosun and Sağsöz, 1998). Enzymes (RNAses) that degrade RNA are effective in the developing gametophyte. The pollen tube proteins die and the grass tube cannot develop.

In sporophytic incompatibility, pollen germination is inhibited in the stigma. This is controlled by the genotype of the pollinator.

Incompatibility is determined by examining the development of the pollen tube in style under fluorescent microscope, determining the fruit set ratios in selfing and molecular methods.

A self-compatible variety is compatible with other varieties of the same species. Self-incompatibility promotes cross fertilization. The pollinator should be included in the orchard plant with self-incompatible varieties.

Sporophytic incompatibility was observed in hazelnut (Yılmaz, 2009), while gametophytic incompatibility was detected in citrus fruits (Boncuk, 2011) and apple (Akkurt et al., 2020). Today, production with self-incompatible varieties causes serious problems arising from fertilization biology. Because self-incompatibility in fruit species is one of the most important factors limiting cultivation.

REFERENCES

Alburquerque, N., Burgos, L. and Egea, J. (2003). Apricot flower bud development and abscission related to chilling, irrigation and type of shoots, Scientia Horticulturae 98: 265-276.

Acarsoy, N. (2013). Bazı Kayısı Çeşitlerinde Kış Dinlenmesinin Tomurcuk Gelişimi ve Verimliliğe Etkisi Üzerine Araştırmalar. Ege Üniversitesi Fen Bilimleri Enstitüsü

Aşkın, M.A. and Sarısu, H.C. (2020). Tohum Taslağı Yaşlanma Süreci ve Kiraz Verimsizliği Üzerine Biyolojik Çalışmalar. Meyve Bilimi. 7(2): 42-47

Bolat, İ. ve Şahin, M. (1995). Hacıhaliloğlu ve Kabaaşı Kayısı Çeşitlerinde Meyve Dökümü ve Dal Yaşları Arasındaki İlişkinin İncelenmesi, Türkiye IV. Ulusal Bahçe Bitkileri Kongresi, Antalya, 220 – 222s.

Boncuk, M. (2011). Klemantin Mandarininde Eşeysel Uyuşmazlık Mekanizmasının cDNA AFLP Yöntemiyle Araştırılması. Yüksek Lisans Tezi, Çukurova Üniversitesi, Fen Bilimleri Enstitüsü, Adana, Türkiye.

Beyhan, N. (1993). Bazı Önemli Fındık Çeşitlerinin Çiçek Gelişim Safhaları ve Çiçek Biyolojileri Üzerine Bir Araştırma, Doktora Tezi, Ondokuz Mayıs Üniversitesi Fen Bilimleri Enstitüsü, 175s, Samsun.

Beppu, K., Ikeda, T. and Kataoka, I. (2001). Effect of High Temperature Exposure Time During Flower Bud Formation on The Occurrence of Double Pistils in 'Satohnishiki' Sweet Cherry. Scientia Hort. 87: 77-84.

Bak, T., Karadeniz, T., Şenyurt, M., Kırca, L. and Kırca., S. (2014). Formation of Çotanak Groups According to Direction of Branches in The Ocaks Tombul and Palaz in Hazelnut Varieties, Turkish Journal of Agricultural and Natural Sciences Special Issue: 1.831-834

Eriş, A., Barut, E. (2000). Ilıman İklim Meyveleri-1. Uludağ Üniversitesi Ziraat Fakültesi Ders Kitabi No:6, 226 s.

Engin, H. and Ünal, A. (2007). Examination of Flower Bud İnitiation and Differentiation in Sweet Cherry and Peach by Scanning Electron Microscope. Turk. J. Agric. For., 31: 373-379.

Engin, H. (2011). Kiraz Ağaçlarında Çiçek Anormalliği (Phyllody) Üzerine Araştırmalar. Süleyman Demirel Üniversitesi Ziraat Fakültesi Dergisi 6 (2):48-52.

Eti, S. (1991). Bazı Meyve Tür ve Çeşitlerinde Değişik in vitro Testler Yardımıyla Çiçek Tozu Canlılık ve Çimlenme Yeteneklerinin Belirlenmesi, Ç.Ü. Ziraat Fakültesi Dergisi, 6(1):69-80s.

Fadon, E., Herrera, S., Guerrero, B. I., Guerra, E. and Rodrigo, J. (2020). Chilling and Heat Requirements of Temperate Stone Fruit Trees (*Prunus* Sp.). Agronomy, 10, 409. doi:10.3390/agronomy10030409

Fabbri, A, and Benelli, C. (2000). Flower Bud Induction and Differentiation In Olive, Journal Horticulture Science,75(2), 1313-141.

Gözlekçi, Ş. (1997). Hicaznar Çeşidinin Döllenme, Meyve Gelişimi ve Olgunlaşması Üzerine Araştırmalar (Doktora Tezi). Akdeniz Üniv. FBE. Bah. Bit. ABD, Antalya, 155 S.

Gerçekçioğlu, R., Bilgener, Ş. ve Soylu, A. (2012). Genel Meyvecilik. Nobel Akademik Yayıncılık Eğitim Danışmanlık Tic. Ltd. Şti., ISBN: 978- 605-133-253-6, Ankara.

Julian, C., Herrero, M. and Rodrigo, J. (2010). Flower Bud Differentiation and Development in Fruiting and non-Fruiting Shoots in Relation to Fruit Set in Apricot (*Prunus armeniaca* L.), Trees (Berl.) 24:833–841pp.

Kaşka, N. ve Paydaş Kargı, S. (2007). Meyve Ağaçları Fizyolojisi Büyüme ve Gelişme. Washington Eyalet Üniversitesi Kurs Notları. Çeviri ISBN:9944-73-017-3. S.142

Karlıdağ, H. ve Güleryüz, M. (2007). Hacıhaliloğlu Kayısı Çeşidinde Farklı Yetiştirme Şartları ile Bazı Ağaç Özellikleri Arasındaki İlişkiler, Türkiye V. Ulusal Bahçe Bitkileri Kongresi, Cilt 1: 788 – 791s.

Kaçal, E. (2009). Elmalarda (Malus x Bomestica Borkh) Meyve Tutumu, Meyve Kalitesi ve Çiçek Tomurcuğu Farklılaşması Üzerine Yeni Çiçek Seyrelticilerinin Etkileri. SDU Fen Bilimleri Enstitüsü, Doktora Tezi, Isparta.

Mısırlı, A. (2000). Bazı Sert Çekirdekli Meyve Türlerinde Eşeysel Uyuşmazlık ile Fenolojik Madde İçeriği Arasındaki İlişkiler. Ege Üniversitesi Ziraat Fakültesi Dergisi, 37(1), 161-168.

MyCoy, R.E., Coudwell, A., Chen, M.T., Chiykowski, M. Cousin, J.L., Dale, G.T., DeLeew, D.A., Golino, K.J., Hackett, R., and Seemille, E. (1989). Plant Diseases Associated With Mycoplasma. Academic Press. New York. 546-640.

Milatovic, D., Nikolic, D. and Durovic, D. (2010). Variability, Heritability And Correlations of Some Factors Affecting Productivity in Peach, Hort.Sci. (Prague) 37(3): 79-87pp.

Muradoğlu, F., Balta, M.F. and Çelik, F. (2007). An Investigation on Fruit Sets in Tyrinte, Colomer, Bebeco and Paviot Apricot (*Prunus armeniaca* L.) varieties. Research Journal of Agriculture and Biological Sciences 3: 62-66.

Naor, A. (2010). Irrigation Schedulingand Evaluation of Tree Water Status in Deciduous Orchards. Horticultural Reiews. Ed Julies Janic, 32: 111- 165

Nemeth, S., M. L. Remenyi. and L. Szalay. (2010). Flower Bud Development of Apricot Varieties During Paradormancy. Acta Hort. 862: 279-281.

Özbek, S. (1977). Genel Meyvecilik, Çukurova Üniversitesi. Ziraat. Fakültesi. Yayınları Ankara Üniversitesi Basımevi:111 Ders Kitabı 6, 386s, Ankara.

Okie, W.R. and Werner, D.J. (1996). Genetic Influence on Flower Bud Density in Peach And Nectarine Exceeds That of Environment, HortScience 31(6): 1010-1012pp.

Özdemir Eroğlu, Z. (2012). Melezleme Yoluyla Şeftali Çeşit Islahı. Ege Üniversitesi Fen Bilimleri Enstitüsü

Polat, M. ve Aşkın, M.A. (2008). Meyve ağaçlarında çiçek tomurcuğu oluşumu. Genel Meyvecilik (Meyve Yetiştiriciliğinin Esasları), Gerçekçioğlu, R., Bilgener, Ş., Soylu, A. (eds.). Nobel Yayın Dağıtım, s. 53-83.

Akkurt, E., Mertoğlu, K. ve Evrenosoğlu, Y. (2020). Vista Bella Elma Çeşidinde Farklı Tozlayıcı Çeşitlerin Meyve Tutumu ve Bazı Meyve Kalite Özellikleri Üzerine Etkisi. ANADOLU, 30 (2): 284-294 DOI: 10.18615/anadolu.835053

Ruiz, D. and Egea, J. (2008). Analysis of the Variability and Correlations of Floral Biology Factors Affecting Fruit Set in Apricot in a Mediterranean Climate, Scientia Horticulturae 115, 154–163pp

Stanica, F., Armeanu, I., Dumitraşcu, M. and Peticila, G.A. (2010). Influence of the climate conditions on apricot floral biology in Bucuresti area. Acta Hortic 862: 283-291.

Şahin, A. (2004). Antalya Bölgesinde Yetiştirilen Hicaznar (*Punica granatum* c.v. Hicaznar) Üzerindeki Biyolojik Araştırmalar, Yüksek Lisans Tezi, SÜ Fen Bilimleri Enstitüsü Bahçe Bitkileri ABD,54s, Isparta.

Tosun, F. ve Sağsöz, S. (1998). Bitki Islahı. Atatürk Üniversitesi Ziraat Fakültesi Ofset Tesisi, s51- 53, Erzurum.

Topp, B.L., Sherman, W.B. and Raseira, M.C.B. (2008). Low-Chill Cultivar Development, 106-139, The Peach: Botany, Production and Uses, D.R. Layne and D. Bassi (eds.), CAB International, Wallingford, UK, 615p.

Ustuntas, T. (2015). Narda Dişicik Tepesi Sıvısının Çiçek Tozu Çimlenmesine Etkisi Ve Melezleme Çalışmaları. Adnan Menderes Üniversitesi Fen Bilimleri Enstitüsü Bahçe Bitkileri Anabilim Dalı

Uysal, T. (2012). Gemlik Zeytin Çeşidinde Çiçek Yapısının Sitolojik Olarak İncelenmesi. Uludağ Üniversitesi Fen Bilimleri Enstitüsü. Yüksek Lisans Tezi Bahçe Bitkileri Anabilim Dalı

Ülger, S. (1997). Zeytinlerde Periyodisite ve Çiçek Tomurcuğu Oluşumu Üzerine İçsel Büyüme Hormonlarının Etkilerinin Saptanması, Doktora Tezi, Akdeniz Üniversitesi Fen Bilimleri Enstitüsü, 237s, Antalya.

Ülkümen, L. (1973). Bağ-Bahçe Ziraatı. Atatürk Üniversitesi Ziraat Fakültesi. Yayın No: 275

Yılmaz, M. (2009). Bazı Fındık Çeşit ve Genotiplerinin Pomolojik, Morfolojik ve Moleküler Karakterizasyonu. Doktora Tezi, Çukurova Üniversitesi, Fen Bilimleri Enstitüsü, Adana.

Westwood, M.N. (1995). Temperate-Zone Pomology, Physiology and Culture, Third Edition. Timber Press, ISBN-0-8819-2253-6, 523 p. Portland, Oregon.

CHAPTER 12

ABIOTIC STRESS FACTORS IN ORNAMENTAL PLANTS

Assist. Prof. Dr. Arda AKÇAL[1]

[1] Çanakkale Onsekiz Mart University, Agriculture Faculty, Department of Horticulture Çanakkale, Turkiye. aakcal@comu.edu.tr, ORCID ID: 0000-0002-0426-0745

INTRODUCTION

While the decrease in the amount of usable water in many places in the world poses a danger primarily to the agricultural sector, this situation combined with other environmental factors has led to the formation of stress factors on plant species. All of the factors that negatively affect growth and development events by activating important physiological mechanisms in plants, initiating metabolic changes, causing loss of quality and quantity to the products, and causing death in the plant or plant organs are explained as 'stress'.

As a reason of global climate change, the fact that one or more factors play a role in the habitats of plants accelerates the formation of stress, on the other hand, the slowdown and stopping of plant metabolism delays the adaptation of plants to ecological conditions. As a result, stress decreases the biosynthetic capacity of plants, changes their normal functions and can cause irreversible damages.

Many researchers have stated that stress factors in plants may be of biotic or abiotic origin (Levitt, 1980; Linchtenthaler, 1996; Kaçar et al., 2006). In terms of agricultural production, stress can control by abiotic (radiation, saline conditions, drought, temperature differences, light etc.) and biotic (human, wild, etc., pests such as plants, animals, insects and disease-causing fungi, bacteria, viruses, etc. microorganisms) factors.

The most common abiotic stress factors are affecting all agricultural activities in the world are drought and salinity. These environmental stress factors trigger many events as like as physiological and accordingly some mechanisms developed by plants to adapt environmental conditions.

According to Hsiao (1973), drought stress, also known as water stress, is expressed as a decrease in usable water to the plant in the soil, and the continuation of water loss as a result of transpiration and evapotranspiration under the influence of atmospheric conditions.

Water stress; occurs when water is bound in high temperature, radiation, evaporation, frozen soil, soil dryness or salty soils. This stress on the plant can be short-term or long-term. Prolonged water stress and insufficient water intake can lead to irreversible reactions and lead to death of the plant (Larcher, 2003). Drought is the most important stress factor for usable agricultural areas, which has the largest rate (26%) (Erdoğan, 2018). For most herbaceous plants, water comprises nearly 90% of the fresh mass. In higher plants, roots absorbed water from the soil and transferred to the plant shoots. This movement is caused by transpiration and root pressure. Also, osmotic and turgor potential plays a key role. While drought causes a turgor loss that affects the cell expansion and size of the plant cell. As a reason, plant growth, yield and quality was affected by drought.

Another important factor among abiotic stress factors is salinity. Salinity has become an important problem in today, especially as it threatens arid regions. The increase in salinity in agricultural areas, soil and irrigation waters deteriorates the structure of the soil and significantly limits the product quality and productivity of plants. The number of areas that are adversely affected by salinity is constantly increasing in the world. Szabolics (1985) reported that approximately 1/5 of cultivated areas, and almost 1/2 of irrigable areas are affected by salinity. In addition to soil salinity, the fact that while growers using too much chemicals in fertigation systems which contain different salts, is an issue that should be emphasized in terms of plant growth. When the salinity level increases in the soil and the water and osmotic potential affected in plant cells and the plant enters salt stress in this way. Salt stress causes a series of changes at the macro, cellular and molecular levels of plants. Salinity changes the water and ion content of plant cells, photosynthetic pigment, protein and carbohydrate content, disrupts the chloroplast structure and affects many similar structures at the cellular level.

The value of water, which is considered as the source of life for many living things, has increased a little more as a result of the drought caused by global warming, which clearly reveals the importance of water saving in terms of landscape studies. In recent years, in landscape purposes where outdoor ornamental plants are used, species that are contented in terms of water demand or have high drought resistance have started to be preferred.

In connection with the concept of sustainability, natural species and genotypes are more resistant to diseases and pests and abiotic stress factors. In the creation of landscape areas, first of all, natural plant species should be included. Because natural plants are more resistant than foreign plants and if they are grown properly, they are less affected by regional extreme climatic conditions. According to Barış (2007), natural plants adapt to local environmental conditions in the best way, contribute to soil fertility, reduce erosion and generally require less water, fertilizer and pesticides compared to other plant species. In this respect, working with natural species with high tolerance to different temperatures, drought and salinity in landscape applications, besides reducing the maintenance costs of plants, accelerates the adaptation to growing conditions and provides convenience in terms of fighting against diseases and pests.

The main factors taken into consideration for plants during the development process are temperature, sunlight, some plant nutrients and water source. Although the research results obtained in line with these parameters can be used for many plants, the same is not the case for ornamental plants. Today, although the physiological characteristics of many ornamental species are known, information on agriculture and irrigation management under stress conditions and studies on this subject have not reached a sufficient level yet.

1. RESEARCHES ON ABIOTIC STRESS FACTORS IN PLANTS

Most of the studies on abiotic stress on plants in the last 30 years focused on drought and salinity stress. Also, these studies focused on the physiological changes that occur as a reason of this situation in plants. It was really known that, water stress caused by drought or lack of water is a serious danger that negatively affects the normal vital functions of the plant and can limit the growth of plants more than other factors. The lack of water in the plant always occurs when transpiration exceeds the water uptake by the roots, if the usable water from the soil is low in severe transpiration conditions or if the metabolism stops, ratio of available water decreases. Levitt (1980) defined this situation, as “Water Shortage Stress” or “Drought Stress”.

According to Eriş (1990), it is possible to divide the drought into three as severe droughts, continuous drought and physiological drought. The first signs of water deficiency in the plant show themselves as mechanical effects, when plant cells begin to lose water, they lose their turgority. Volume of the plant cell decreases due to water loss. The plasma membrane is separated from the cell wall; this is characterized as a state of plasmolysis. As a result of the tension, the rupture of the plasma membrane occurs. Autolysis occurs in the cytoplasm as a result of the activation of hydrolytic enzymes (Salisbury and Ross, 1992; McKersie ve Lehsem, 1994).

Schwanz and Polle (2001) reported that while plants continue their lives, they benefit from the water in the soil and can absorb the nutritive elements necessary for them from the soil again through their roots. It has been reported that the plant is affected by drought.

In some studies, on stress in plants, it was previously thought that the reduction of water potential and cell turgor in the leaf was effective in closing stomata; upon the observation of samples where stomatal conductivity decreased without a decrease in potential of leaf water; It was concluded that stomatal closure is more dependent on the soil than the leaflets (Asamaa et al., 2002; Comstock, 2002). On the other hand, according to Nadeau and Sack (2002), the increase in photosynthesis under drought stress is achieved with minimal water loss, while the number and position of stomata are as important as the opening and closing of stomata in optimal gas exchange. Stomatal density regulates the transpiration rate, while stomata open and close. The decrease in stomatal density and size also increases resistance to water stress.

Kocaçalışkan (2003) thought that, the most important factor that stresses the plant is; movement of water inside the soil. Because water loss by transpiration can be compensated if there is enough water in the soil. However, if there is not enough water in the soil and the plant does not work its tolerance mechanisms against it and loses water, water stress is seen in the plant.

Çırak and Esendal (2003) stated that when plants were under drought stress stomata are closed and the absorption of carbon dioxide (CO_2) was decreased, so this situation was also affected and when the plant closes its stomata in order to prevent water loss, the intake of CO_2 necessary for photosynthesis is prevented.

In some researches it is thought to be that, oxidative stress can be overcome by activating some or all of the antioxidant mechanism of plants initiated to water stress has gained weight (Srivalli et al., 2003; Pinheiro et al., 2004; Ramachandra et al., 2004; Jung, 2004).

Özcan et al. (2004) says that water makes up most of the cell contents in plants. It was used as a solvent in cellular reactions. When plant cells loose water, the functioning of the metabolism is disrupted. In this case, ion accumulation due to water loss can damage the cell by causing deterioration of the membrane integrity and the structure of proteins.

Jenks and Hasegawa (2005) stated that action of drought on plants started by decrease in usable water over time is the real limiting factors affecting the spread and productivity of plants, and product loss of 50% or more occurs in agricultural areas exposed to drought.

According to Mahajan and Tuteja (2005), if the leaf surface has a larger width in plants, the water loss will be greater. Reducing transpiration helps conserve available water. In plants, it is observed that leaf growth is inhibited and new leaf formation is limited against drought stress. These structures lower the temperature of the underlying cells by 1-2°C, reducing the rate of transpiration. In addition, the thick waxy cuticle layer formed on the leaf epidermal surface reduces the effect of heat by reflecting the sun's rays, thus reducing the transpiration rate.

An increase in temperature, a rapid decrease in humidity or a dry air mass can cause rapid and acute water losses in plants. Such atmospheric changes cause an increased transpiration rate. As a result of acute drought, response of leaves like wilting due to lack of assimilation, drying of shoot tips, decrease in yield and slowdown in growth are observed. The earliest sign of drought is wilting. As long as the wilting point is not exceeded, wilting subsides as water is given to the plant (Çırak and Esendal, 2003). Also the same researchers reported that, in order to maintain the appropriate water content in their tissues, plants take necessary functional measures to avoid drought such as water uptake from the soil, an early and effective increase in diffusion resistance, reduction of water loss that may occur as a result of reduced transpiration surface, a high water transmission capacity or water storage. These measures are also reflected in plant morphology.

Reduction of leaf area, deep root development towards moist soil layers and closure of stomata are the changes seen in the plant as the first steps of defense against drought. The morphological changes that occur in the leaves in dry conditions are generally aimed at reducing the amount of water lost by transpiration, and the morphological changes in the roots are aimed at absorbing the water in the soil with a higher force.

How about the salinity? What kind of changes occur in plants under salt stress? There were several studies on the effects of salinity on plants. According to Szabolics (1985), soil alkalinity caused by sodium is a different form of salinity. When the ratio of exchangeable sodium on the clay surface to the total cation exchange capacity exceeds 6%, the soil is considered alkaline. About half of the irrigated areas in the world are under the influence of ground water, salinity and alkalinity.

Rhoades (1992) and Grattan (1993) explain salinity as the presence of different salts in soil or water at a level that can inhibit plant growth. Usually these salts include some sulfates, chlorides, carbonates, nitrates and borates. Jacoby (1994) stated that water is strongly bound osmotically in saline soils, which causes physiological drought. He stated that in the case of physiological drought, even if the amount of water in the soil is sufficient for the plant, some problems may be experienced in the uptake of water by the plant, which is strongly bound osmotically in the soil solution. In another study, Shannon and Grieve (1999) stated that in the presence of salt, when there was a decrease on water holding capacity of the soil, and there is an interaction between salinity level and sodium absorption rate, hydraulic conductivity and infiltration rate. According to Sevgican (2002), the transport of soluble salts accumulated in the ground water to the soil surface through evapotranspiration and capillary water movement in arid and semi-arid region conditions and the inability to provide adequate drainage in the areas where agricultural production is carried out creates a salinity problem. In addition, monoculture applications in greenhouses, especially the effects of fertilizers and chemicals used to support cultivation, as well as unconscious irrigation applications can cause significant salt accumulation in the soil after a certain period of time.

As a result of the studies carried out by Irshad et al. (2002), since there was a significant decrease in the water uptake ability of the roots in plants under salt stress, a decline was observed in activities such as root development and stem elongation. The stem diameters of the plants under stress decrease, and their height remains smaller than the control. Similarly, leaf area and flowering and fruit yield are adversely affected in the transition to the generative stage. The above-mentioned consequences of salt stress are long-term symptoms. Significant reductions in dry matter and wet weights of shoots and roots of plants under stress have also been reported in many plants. According to Yaşar (2003), plants under salt stress try to prevent water loss by closing their stomata and reducing transpiration by shrinking leaf areas. However, as the leaf area decreases, the CO_2 fixation per unit area also decreases. Respiration increases during this time, resulting in a decrease in daily net CO_2 assimilation per unit leaf surface area. The plant, which consumes intense energy to live, performs less photosynthesis than it needs and cannot provide the necessary energy. As a result, growth and development decline. The same researcher also reported that, due to the accumulation of ions and irregularities in the opening and closing of stomata at high salt concentrations, a decrease in the total amount of chlorophyll occurs.

Borsani et al., (2003) stated that the first sign of damage caused by salinity is due to lack of water. Researchers have reported that high salt concentrations limited plant growth due to lack of water, and this may be due to the damage caused by Na^+ and Cl^- ions on the leaves and the problems that occur during the transport of nutrients.

Some researchers thought that, visible effects of salinity, which affect plant physiology and yield, occur at high salinity levels. The sensitivity to the mentioned salinity levels varies according to the plants. It has been determined that proportional decreases in yield occur due to the increase in salinity in most of the cultivated plants (Chinnusamy et al., 2005).

Munns (2005) stated that plants under salt stress developed various mechanisms against osmotic and ionic stress caused by salinity, while Hong-Bo et al. (2006) reported that adaptation to salt stress is generally provided by osmoregulators such as potassium, soluble sugar, proline and betaine.

According to Asraf and Ali (2007), plants are produced Reactive Oxygen Species (ROS) in response to environmental stresses such as salinity, drought, herbicide applications and nutritional deficiencies damage the membranes and necessary macromolecules such as oils, DNA, proteins, photosynthetic pigments. The stress tolerance of plants is directly related to the antioxidant enzymes and antioxidants they have in their bodies, which neutralize ROS.

2. HOW ORNAMENTAL PLANTS RESPOND TO ABIOTIC STRESS?

The effects of environmental stresses can be seen in ornamental plants as well as in many plant groups. The fact that the design features are at the forefront in ornamental plants, they are more compact and functional compared to other plant species, increase the tolerance level to mostly abiotic stresses.

While most of the studies on stress issues in ornamental plants focus on the physical and physiological changes that occur in ornamental plants under environmental stress conditions, the reactions of plants to the effects of stress and their resistance mechanisms are also discussed.

In generally, the effects of abiotic stress on ornamental plants were caused this kind of situations; reduction in root, stem and shoot length, reduction in leaf area, which is especially important for leafy species and a decrease in the number of leaves. In addition, it can cause decreases in plant fresh and dry biomass and plant height, chlorophyll content, yield losses, also flower quality, flowering characteristics and color deterioration.

It has been stated that leaf development is limited and the plant habitus is small in plants that are exposed to drought stress and can be reproduced by bulbs, rhizomes and tubers, so even in geophytes that can exceed a certain number in terms of leaves and flowers, a better development can be achieved with surface planting and large pot selection (Drury, 1974).

In a study conducted by Sonneveld and Voogt (1983) in a greenhouse, it was determined that the sodium chloride (NaCl) salt content of the irrigation water used, in particular, caused a decrease in the yield and quality of carnation and gerbera plants which are grown as a cut flower, by affecting the osmotic pressure of the soil.

A classification has been made by Kanber et al. (1992), in terms of sensitivity to salinity on some ornamental plant species that have economic importance as well as important cultivated plants (Table 1). According to Asada (1994), as in other stress factors, plants close their stomata and try to provide water use activity in order to minimize water loss in salt and drought stress. However, adequate CO_2 fixation cannot be achieved with the closure of stomata. Electrons that are not used in the reduction of CO_2 play a role in the reduction of O_2 and cause the formation of free oxygen radicals.

Table 1: Sensitivity to Salinity on Some Ornamental Plant Species

Sensitive	Moderately sensitive	Tolerant
ECe<2.0 dSm^{-1}	ECe=2.0-3.0 dSm^{-1}	ECe=3.0-4.0 dSm^{-1}
Geranium	Carnation	Rose
Lilium	Chrysanthemum	
Gardenia		

Wolf et al. (1991) reported that the distribution of Na+ and Cl- ions on the green parts is important in salt-tolerant ornamental plant species, and they stated that salt-tolerant ornamental plants keep Na+ and Cl- ions in the old leaves and limit their transmission to the young leaves.

According to Cowling and Holmes (1992), deficit irrigation applications in a nutrient-rich and well-drained growing medium gave positive results for yield and quality in some geophytes.

Francois and Maas (1994) stated that flower species such as chrysanthemum, carnation and wallflower can be considered moderately sensitive to salt, while aster (star flower), poinsettia, gladiolus, azalea, gardenia, gerbera, daffodil and african violet can be described as a little more sensitive, are compared to others. Zurayk et al. (1993) reported that all salt applications made for *Mesembryanthemum* did not affect plant height, fresh and dry weight, and that it was the most resistant to salt, supporting the results found by other researchers.

In a study, the effects of irrigation frequency on plant yield and quality of gerberas were determined at different substrates. The results obtained from the study showed that when the irrigation frequency increased, the leaf area and number got the highest value. In a mixture of perlite and pumice, an increase in the number of flowers was determined when the irrigation frequency was low, while the quality of flowers (stem length and flower diameter) was found to be better when the irrigation frequency was increased (Papadopoulou et al., 1996).

In an another study Kotuby et al. (1997) reported that high salinity caused leaf blight and deformity in woody ornamental plant species. Erwin (1999), in a study on impatiens populations, determined that the stomatal opening of the plant was affected by water stress, increased photosynthesis, but limited total flowering. A study of chrysanthemum cultivation carried out by Prabucki et al. (1999) in hydroponic system under salinity conditions, salt treatment was applied to plants at different concentrations of 2, 4 and 6 g/l for 7 days. The research results showed that root growth of the plant was inhibited due to salinity, reductions of 45% in root number, 70% in root length and up to 52% in root weight.

In a study conducted as open system cultivation in greenhouse regarding the effects of salt stress on yield and quality in two lily genotypes, NaCl application was made to the nutrient solution from the outside to determine the response of plants to salinity. The plants were irrigated with nutrient solution with four different salt concentrations, with electrical conductivity ranging from 1 dSm^{-1} to 2.5 dSm^{-1}, in the spring. In the autumn period, nutrient solutions with three different concentrations ranging from 1.5 dSm^{-1} to 4.5 dSm^{-1} were applied to the plants. In this process, at certain intervals; The entire root system and bulb stem, stem length until budding, and inflorescence formation until harvest were observed. In both growing seasons, no yield loss was observed and it was determined that the cut flowers were marketable. The results have been reported that nutrient solutions with an EC of 2.5 dSm^{-1} do not have any negative effects on plant growth, therefore it is possible to use this concentration for lily. It has been reported that in the autumn period, it may be better to change the EC of the nutrient solution for different developmental stages. It has been stated that using good quality water in the first stage, increasing the solution concentration in the second stage and increasing it to a maximum of 3 dSm^{-1} and increasing it to a maximum of 4.5 dSm^{-1} in the third stage can improve flower quality (De Lucia et al., 2003).

In a study examining the effects of salinity and water stress on the relationship between plant growth and leaf-water in *Asteriscus maritimus* plants, some of the plants were exposed to water stress during the growing season, while others were grown at three different salinity levels. It has been stated that low biomass is seen in plants under salt and water stress, and the proportional water content of leaves decreases, resulting in early senescence and wilting (Rodríguez, 2004).

The effects of different alcohol types on plant water use and plant height in daffodils were investigated by Miller (2006). It was determined that the plants did not survive at the dose and above, while the amount of ethanol below 6% shortened the plant height. In an another study focusing on planting depth and limited water applications in *Salvia nemarosa*, it was determined that the best growth in terms of height, diameter and number of shoots was achieved in under 50% water deficit and 4 cm depth planting application (Miller, 2007).

In an another study on the stress tolerance mechanisms of ornamental plants, it has been stated that calcium chlorite ($CaCl_2$) applied to *Catharantus roseus* under drought stress reduces the effect of stress, water stress on the plant is mostly under the control of osmoregulation and secondary metabolites, and this can only be changed by $CaCl_2$ applications (Jaleel et al., 2007).

In a drought study carried out on *Poa bulbosa* ecotypes, one of the typical plants of the Mediterranean climate, it was determined that water stress occurs in the plants in the face of long days and changing temperatures, as well as the amount of abscisic acid (ABA) increased as a result of water deficit applications, and the bulbs cannot survive for a long time (Ofir and Kıgel, 2007).

In a study conducted by Zolinger (2007), on the drought resistance of *Filipendula purpurea*, irrigated at five different irrigation levels, both water deficit applications below 50% caused significant reductions in leaf area of plants, and water stress was more effective in terms of flower bud and leaf number compared to the control plants.

Akat (2008), was conducted some studies on salinity stress on Gerbera plants. It was thought that, vegetative plant development and flowering characteristics were affected by the levels of salinity treatments.

In an abiotic stress study conducted by Akçal (2012) on the effects of drought stress on three different natural cyclamen species, it was stated that the least number of flowers in *Cylamen coum* was obtained from 25% irrigation, with an average of 2.3 pieces. According to different water deficit practices on plants, as it can be seen in Figure 1, the total number of flowers decreased as the quantity of irrigation water increased in different *Cyclamen* species compared to the control.

Figure 1: Variations in the number of flowers of *Cyclamen coum* and *Cyclamen cilicium* at different irrigation levels.

On the other hand, a research was carried out by Yıldırım et al. (2009), on the effects of water stress on *Cyclamen hederifolium* Aiton. In this study it was stated that, deficit irrigation treatment of 50% exhibited positive progress on some quality specifications of cyclamen plants. Also it was stated that, leaf growth, efficiency of water usage and tuber improvement were take highest values in 50% deficit irrigation treatment.

In an another research, conducted on cyclamen species by Akçal and Kaynaş (2010), it was reported that different irrigation levels were significant effects on number and sizes of the leaves, fresh and dry biomass of the plant, total amount of chlorophyll and level of lipid peroxidation.

The same researchers (Akçal and Kaynaş, 2013) were carried out a study on the effects of different salinity levels on *Cyclamen coum*. In the study it was stated that leaf emergence and flowering period were delayed in cyclamen due to the increase in salinity levels, a significant decrease occurred in the number of leaves and flowers.

Yıldırım et al. (2016) were conducted a study on the effects of drought stress in *Galanthus elwesii* Hook. (snowdrop). In the study deficit irrigation treatments were applied on plants at four different substrates (sawdust, cocopeat, peat, perlite). According to the results of the study, it was observed that there were significant changes in bulb weight and plant height depending on irrigation levels, while vegetative development was negatively affected due to increase by deficit irrigation.

In one of the few stress studies on geophytes was conducted on different *Gladiolus* cultivars by Demirel et al. (2018), researchers were used thermal images to understand the effects of water stress on plants. It was reported that amount of irrigation water changed depending on the gladiolus cultivars. While the water stress increased, leaf temperatures were also increased. Priscilla, one of the popular cultivar of gladiolus used as a plant material in the study, was found to be more sensitive to drought stress than other gladiolus cultivars. They also concluded that thermal images are very useful method to determine the level of water stress in bulbous cut flower species.

Demirel et al. (2020a), were carried out drought stress study on two different cultivars of primula flowers. It was observed that the effect of water deficit on the physiological characteristics was higher than the morphological ones for both cultivars. However, while the cultivars compared for the same treatments, it was also observed that values for the flower characteristics in purple cultivar of primula were higher than white cultivars in terms of morphological features.

In another research of Demirel et al. (2020b), researchers were conducted a stress study on *Cyclamen persicum*. It was stated that, all measured data were negatively affected by the water deficit treatments. Also, the pink cultivar of cyclamen was more resistant to water stress due to lower water consumption value. In Pink cultivar of cyclamen, plant sizes decreased by the irrigation. This situation was not true for red cultivar of cyclamen plant.

Some of the significant results of a study on salinity stress on cyclamen plants were shared by by Akçal and Kaynaş (2021). In the research, while the level of saline treatment is getting on high levels, it was determined that the leaf area of the plant and biomass of the cyclamen tuber decreased, stress caused a delay for flowering and the number of flower buds decreased. It was also stated that salinity values above 2 dSm^{-1} caused a decrease in stomatal permeability, leaf water content and total chlorophyll amount in plant leaves, while lipid peroxidation level, total sugar amount and proline concentration increased.

Demirel et al. (2021) were conducted a study on the effects of water deficit on zinnia (*Zinnia elegance* L.). Zinnia is one of the most important seasonal flower in outdoor ornamental plants, usually used for landscape purposes. According to the results of the study is that the water stress increases in the zinnia plant due to the decrease in the irrigation level. It was also concluded that the most prominent signals of this appear in the physiological characteristics.

One of the few abiotic stress study on snowdrops, which is one of the important geophyte plants in relation to outdoor ornamental plants, was carried out by Akçal (2021). In the study, the researcher was aimed to determine the effects of different moisture levels in different substrates on snowdrop plants. It was stated that, circumference, fresh and dry biomass of the snowdrop bulbs and carbohydrate types were significantly affected by the irrigation levels in different substrates.

CONCLUSION

Today, the effect of mechanism and reasons of environmental stress on different plant species are still not fully clarified. As a result of the rapid increase in environmental pollutants, the decrease on suitable areas in agriculture, the reflections of global climate change in the field of agriculture and the gradual increase in the population, may increases the crop losses in outdoor ornamental plant species used for landscape purposes in the future due to environmental stress factors. Minimizing these losses is very important.

It was clearly seen that, especially drought stress tolerance in bulbous ornamental plants, they grow well in natural habitats without fertilizers and they have high adaptation capacities to abiotic stress. Also, environmental conditions are effective in the growth and development of bulbous ornamental plants, depending on the water requirement, so this situation can determine the size and number of flowers in the next year. For this reason, the results of the researches must be understood very well by the studies on stress on ornamental plants from the past to the present and the correct interpretation of the results, as well as the more effective use of developing agricultural technology in this field, will lead to the production of ornamental plant species that are more tolerant to different types of environmental stress conditions in the future.

REFERENCES

Akat, Ö.(2008). Farklı Tuzluluk Düzeyleri ve Yıkama Oranlarının Gerbera Bitkisinde Gelişim, Verim, Kalite ve Su Tüketimi Üzerine Etkileri. Doktora Tezi. Ege Üniversitesi, Fen Bilimleri Enstitüsü, Bahçe Bitkileri A.B.D. İzmir.

Akçal, A. & Kaynaş, K. (2010). Kuraklık Stresi Altındaki Doğal Siklamen Türlerinde Büyüme ve Çiçeklenme Özelliklerinin Belirlenmesi. IV. Süs Bitkileri Kongresi, Mersin-Erdemli, Türkiye, 20 - 22 Ekim 2010, ss.200-208.

Akçal, A. (2012). Determining the effects of abiotic stress conditions on plant development and flowering on some cyclamen species spreads out naturally in Turkey. Çanakkale Onsekiz Mart University, Graduate School of Natural and Applied Sciences, Chair for Horticulture (doctoral dissertation).

Akçal, A. & Kaynaş, K. (2013). Tuzlu Koşullarda Yetiştirilen Sıklamen (Cyclamen coum)'de Bazı Bitkisel Özelliklerin Değişimi. V. Süs Bitkileri Kongresi, Yalova, Türkiye, 6 - 09 Mayıs 2013, ss.566-572.

Akçal, A. (2021). Determination of Carbohydrate Accumulation and Plant Growth Dynamics in Snowdrop (*Galanthus elwesii* Hook.) Response to Moisture Levels in Different Substrates. Acta Scıentıarum Polonorum-Hortorum Cultus, 20(6), 59–70.

Akçal, A. & Kaynaş, K. (2021). Tuz Stresi Altında Siklamenin Cyclamen hederifolium Aiton Bitki Gelişim Performansı ve Çiçeklenme Özelliklerinin Belirlenmesi. *Lapseki Meslek Yüksekokulu Uygulamalı Araştırmalar Dergisi*, *2*(4), 109–116.

Asada, K. (1994). Mechanisms for Scavenging Reactive Molecules Generated in Chloroplast Under Light Stress. In: Baker, N.R.

Asamaa, K., Sober A., Hartung W. & Niinemets, U. (2002). Rate of Stomatal Opening, Shoot Hydraulic Conductance and Photosynthetic Characteristics in Relation to Leaf Abscisic Acid Concentration in Six Temperate Deciduous Trees. *Tree Physiol*. (22) : 267-276.

Asraf, M. & Ali, Q. (2007). Relative Membrane Permeability and Activities of Some Antioxidant Enzymes as the Key Determinants of Salt Tolerance ın Canola (Brassica Napus L.). *Envionmental and Experimental Botany*, (63): 266-273.

Barış, M.E. (2007). Kurakçıl Peyzaj, *Bilim ve Teknik*, vol.478: 24-26, TÜBİTAK.

Borsani, O., Valpuesta, V. & Botella, M.A. (2003). Developing Salt Tolerant Plants in A New Century: A Molecular Biology Approach. *Plant Cell, Tissue and Organ Culture*, 73: 101-115.

Chinnusamy, V., Jagendorf, A. & Zhu, J.K. (2005). Understanding and Improving Salt Tolerance in Plants. *Crop Science*, 45: 437-448.

Comstock, J.P. (2002). Hydraulic and Chemical Signalling in The Control of Stomatal Conductance and Transpiration. *J. Exp. Bot.* 53: 195-200.

Cowling, R. M. & Holmes, P. M., (1992). Endemism and Speciation in a Lowland Flora from the Cape Floristic Region. *Biol. J. Linn. Soc*., 47: 367-383.

Çırak, C. & Esendal, E. (2003). Soyada Kuraklık Stresi. *OMÜ Zir. Fak. Dergisi,* 21(2): 231-237.

De Lucia B., Mancini, L. & Ventrelli, A. (2003). Effects of Nutrient Solution Salinity (NaCl) on the Yield Level and Quality Characteristics in Lilium Soilless Culture. *Proceedings of The International Symposium on Managaning Greenhouse Crops in Saline Environnement*. A. Pardossi, G. Serra, F. Tognoni (Eds.), *Acta Horticulturae,* Bari, Italy, 609: 401–406.

Demirel, K., Çamoğlu, G., & Akçal, A. (2018). Effect of Water Stress on Four Varieties of Gladiolus. Fresenıus Envıronmental Bulletın, 27(12), 9300–9307.

Demirel, K. , Yıldırım, D. , Ayanoğlu, Z. , Albayrak, F. , Kuşak, İ. , Ersoy, Ç. , Budak, N. , Nar, H. , Çamoğlu, G. , Akçal, A. & Çatıkkaş, G. R. (2020a). İki Farklı Çuha Çeşidinin Su Stresine Tepkilerinin Belirlenmesi . ÇOMÜ Ziraat Fakültesi Dergisi , 8 (2) , 347-358.

Demirel, K., Çatıkkaş, G.R., Kesebir, B., Çamoğlu, G. & Nar, H. (2020b). Farklı Su Stresi Düzeylerinde Siklamenin Fizyolojik ve Morfolojik Özelliklerindeki Değişimin Belirlenmesi. Derg.,34(Özel Sayı), s. 55-69.

Demirel, K., Çamoğlu, G., Akçal, A., Nar, H., Kahrıman, F., & Genç, L. (2021). Effect of Water Deficit on Flowering and Growth Characteristics of Zinnia elegans. *Journal of Ornamental Plants, 11*(2)*,* 77–88.

Drury, W. H. (1974). Rare species, *Biol. Conserv*. 6: 162-169.

Erdoğan, B.S. (2018). Su Stresi ve Bitkilerde Su Stresine Bağlı Fizyolojik Değişimler, Tralleis Elektronik Dergisi 3(2): 219-228.

Eriş, A. (1990). Bahçe Bitkileri Fizyolojisi, U.Ü.Z.F. Yay. Ders Notları No: 11, Bursa.

Erwin, J. (1999). Factors Affecting New Guinea Impatients Flowering. Minnesota Commercial Flower Growers Association Bulletin, Department of Horticultural Science, University of Minnesota. 5p.

Francois, L.E. & Maas, E.V. (1994). Crop Response and Management on Salt-Affected Soils. *Handbook of Plant and Crop Stress*. Mohammad Pessaraklı (Eds.), Marcel Dekker, Inc., 270, New York, USA, 696 p.

Grattan, S.R. (1993). How Plants Responds To Salts. Agricultural Salinity and Drainage. University of California Irrigation Program, University of California, Davis, 3-5.

Hong-Bo, S., Xiao-Yan, C., Li-Ye, C., Xi-Nıng, Z., Gangh, W., Yongbing, Y., Chang-Xing, Z. & Zan-Min, Z. (2006). Investigation on the Relationship of Proline with Wheat Anti-Drought under Soil Water Deficits. *Colloids Surf. B. Biointerfaces*, 53: 113-119.

Hsiao, T. C. (1973). Plant Responses to Water Stress. *Annu. Rev. Plant Physiol,* 24: 519-570.

Irshad, M., Yamamato, S., Enerji, A.E., Endo, T. & Hona, T. (2002). Urea and Manure Effect on Growth and Mineral Contents of Maize Under Saline Conditions. *Journal of Plant Nutrition*. 25(1): 189- 200. ISSN 1018-8851.

Jacoby, B. (1994). Mechanisms Involved in Salt Tolerance By Plants: In:Pessarakli, M.(Eds.), Handbook Of Plant And Crop Stres. Marcel Dekker, Newyork, 97-123.

Jaleel, C.A., Manivannan, P., Sankar, B., Kishorekumar, A., Gopi, R., Somasundaram, R. & Panneerselvam, R. (2007). Water Deficit Stress Mitigation by Calcium Chloride ın Catharanthus Roseus Effects on Oxidative Stress, Proline Metabolism and Indole Alkaloid Accumulation. *Biointerfaces*. 60: 110-116.

Jenks, M.A. & Hasegawa, P.M. (2005). Plant Abiotic Stress, Blackwell, ISBN-10: 1-4051-2238, S.270

Jung, S.(2004). Variation in Antioxidant Metabolism of Young and Mature Leaves of Arabidopsis Thaliana Subjected to Drought. *Plant Sci*. 166: 459 – 466.

Kaçar, B., Katkat, V. & Ş., Öztürk. (2006). Bitki Fizyolojisi. Bursa 563.

Kanber, R., Kırda, C. & Tekinel, O. (1992). Sulama Suyu Niteligi ve Sulamada Tuzluluk Sorunları. *Ç.Ü. Ziraat Fakültesi Genel Yayın* No:21, Ders Kitapları Yayın No:6, Adana.

Kocaçalışkan, İ. (2003). Bitki Fizyolojisi. DPÜ Fen-Edebiyat Fakültesi Yayını, 420.

Kotuby, A.J., Koenig, R. & Kitchen, B., 1997. Salinity and Plant Tolerance. Utah State University Extension. AG-SO-03. Utah State University.

Larcher, W. (2003). Physiological Plant Ecology. 4. Baskı, Springer, 513 p.

Levitt, J. (1980). *Responses of Plants to Environmental Stresses*, Vol 1, *Academic Press*, NewYork.

Linchtenthaler, H.K. (1996). Vegetation Stress: An Introduction to The Stress Concept in Plants. *J.Plant Physiol*.148:4-14.

Mahajan, S. & Tuteja, N. (2005). Cold, Salinity and Drought Stresses. An Overview, Archives of Biochemistry and Biophysics, 444: 139- 158.

McKersie, B.D & Leshem, Y. (1994). Stress and Stress Coping in Cultivated Plants, Kluwer Academic Publishers, Netherlands.

Miller, W.B. (2006). Using Alcohol to Reduce Growth of Paperwhite Narcissus. Royal Dutch Wholesalers Association for Flowerbulbs and Nursery Stock in Cooperation Dr. Bill Miller of Cornell University.

Miller, W.B. (2007). Growth of *Salvia nemorosa* ‘Amethyst’ as Affected by Planting Depth and Soil Water Status. Dept. of Horticulture, Cornell University 134 *Plant Science* Building Ithaca, NY 14853.

Munns, R. (2005). Genes and Salt Tolerance: Bringing Them Together. *New Phytol*., 167: 645-663.

Nadeau, J.A. & Sack F. (2002). Stomatal Development in Arabidopsis. In Somerville, C. R. Et Al. (Eds). The Arabidopsis Book. American Society of Plant Biologists 2-33.

Ofir, M. & Kigel, J. (2007). Regulation of Summer Dormancy by Water Deficit and ABA in Poa bulbosa Ecotypes, *Annals of Botany* 99: 293–299

Özcan, S., Babaoğlu, M. & Gürel, E. (2004). Bitki Biyoteknolojisi Genetik Mühendisliği ve Uygulamaları, S.Ü. Vakfı Yayınları, Konya.

Papadopoulou, E., Gerasopoulos, D. & Maloupa, E. (1996). Effect of The Substrate and Frequency of Irrigation on Growth, Yield and Quality of Gerbera Jamesonii Bolus Cultivated in Pots. Agricoltura- Mediterranea 126:3, 297-302.

Pinheiro, H.A., Damatta, F.M., Chaves, A.R.M., Fontes, E.P.B. & Loureiro M.E. (2004). Drought Tolerance in Relation to Protection 343 Against Oxidative Stress in Clones of Coffea Canephora Subjected To Long-Term Drought. *Plant Sci*., 167: 1307-1314.

Prabucki, A., Serek, M. & Andersen, A.S. (1999). Influence of Salt Stress on Stock Plant Growth and Cutting Performance of *Chrysanthemum morifollium* Ramat. *Journal of Horticultural Science and Biotechnology*, 74 (1): 132- 134.

Ramachandra Reddy, A., Chaitanya, K.V., Jutur, P.P. & Sumithra, K. (2004). Differential Antioxidative Responses to Water Stress Among Five Mulberry (*Morus alba* L.) Cultivars. *Environ. Exp. Bot*., 52: 33-42.

Rhoades, J. D. (1992). Recent Advances ın the Methodology for Measuring and Mapping Soil Salinity. Proc. Int'l Symp. On Strategies for Utilizing Salt Affected Lands, Isss Meeting, Feb. 17-25, Bangkok, Thailand.

Rodriguez, P., Torrecillas, A. , Morales, M.A., Ortuño, M.F & Sánchez-Blanco, M.J.(2004). Effects of NaCl Salinity and Water Stress on Growth and Leaf Water Relations of *Asteriscus maritimus* plants, *Plant sci.*, 203 , pp. 3–12.

Salisbury, F.B. & Ross, C.W. (1992). Plant Physiology, Wadsworth Publishing Co., California.

Schwanz, P. & Polle, A. (2001). Differential Stress Responses of Antioxidative Systems to Drought in Pedunculate oak (*Quercus robur*) and Maritime Pine (*Pinus pinaster*) Grown Under High CO_2 Concentrations. *Journal of Experimental Botany*, 52, (354):133-143.

Sevgican, A. (2002). Örtüaltı Sebzeciligi (Topraksız Tarım) Cilt – II. E.Ü.Z.F. Yayınları, İzmir.

Shannon, M.C. & Grieve, C.M. (1999). Tolerance of Vegetable Crops to Salinity. *Scientia Hort.* 78: 5-38.

Sonneveld, C. & Voogt, T. (1983). Studies on The Salt Tolerance of Some Flower Crops Grown Under Glass. Plant and Soil, 74, 41-52.

Srivalli, B., Sharma, G. & Khanna- Chopra, R. (2003). Antioxidative Defence System in Upland Rice Cultivar Subjected to Increasing Intensity of Water Stres Followed by Recovery. *Physiol. Plant.* 119: 503 – 512.

Szabolics, I. (1985). Salt Affected Soils, as World Problem. *Proceeding of the International Symposium on the Reclamation of Salt- Affected Soils.*

Wolf, GY., Cassing, W., Mosel, U. and Schäfer, M. (1991). Institut für Theoretische Physik, Universität Giessen, D-6300 Giessen, Germany.

Yaşar, F. (2003). Tuz Stresi Altındaki Patlıcan Genotiplerinde Bazı Antioksidant Enzim Aktivitelerinin *ın vitro* ve *ın vivo* Olarak İncelenmesi. Doktora Tezi. Yüzüncü Yıl Üniversitesi Fen Bilimleri Enstitüsü.

Yıldırım, M., Kahraman, Ö. & Akçal, A. (2016). Farklı Yetiştirme Ortamları ve Kısıtlı Su Uygulamalarının Kardelen Soğan Gelişimi Üzerine Etkileri. Yalova Atatürk Bahçe Kültürleri Merkez Araştırma Enstitüsü Dergisi, Cilt.2, ss.910-914.

Yıldırım, M., Akcal, A. & Kaynas, K. (2009). The response of Cyclamen hederifolium to water stress induced by different irrigation levels. Afr. J. Biotechnol., 8, 1069– 1073.

Zolinger, N. (2007). Growth of *Filipendula purpurea* as Affected by Low Water Uses. Dept. of Plants, Soils and Biometeorology, Utah State University, Logan, UT 84322 – 4820, United States.

Zurayk R., Tabbarah, D. & Banbukian, L. (1993). Preliminary Studies on The Salt Tolerance and Sodium Relations of Common Ornamental Plants. *Journal of Plant Nutrition*, 16(7):1309 – 1316.

CHAPTER 13

PLANT-PARASITIC NEMATODES IN HORTICULTURAL CROPS

Assoc. Prof. Dr. Çiğdem GÖZEL[1]

[1]Çanakkale Onsekiz Mart University, Faculty of Agriculture Department of Plant Protection, Çanakkale, Turkey. cigdemgunes@comu.edu.tr, Orcid ID: 0000-0002-0742-7205

1. INTRODUCTION

Horticultural plants like vegetables, fruits, flowers, ornamentals, and lawn grasses, are usually produced on a smaller scale with more intensive management than agricultural crops. In horticultural production, many diseases and insect pests can cause damages and yield losses in products.

Nematodes are one of these pests that are bilaterally symmetrical, non-segmented, elongate, and microscopic roundworms that live in soil, plants, water, or their hosts. Nematodes that found in agricultural systems usually live in soil and can be mainly listed in three categories: (1) plant-parasitic nematodes (PPNs) that feed only on plants; (2) entomopathogenic nematodes (EPNs) that feed on insects; and (3) free-living nematodes that feed on bacteria, fungi, or other nematodes.

While nematodes in 1. category can significantly reduce yields on many crops the nematodes in 2. and 3. categories are quite useful for sustainable agriculture. Plant-parasitic nematodes cause economic losses in crops both quantitatively and qualitatively, and subsequently impose severe restrictions worldwide.

Meloidogyne spp., *Globodera* spp., *Heterodera* spp., *Pratylenchus* spp., *Ditylenchus dipsaci*, *Xiphinema index*, *Radopholus similis*, *Rotylenchulus reniformis*, *Aphelenchoides besseyi*, *Bursaphelenchus xylophilus* and *Nacobbus aberrans*, are more important for commodity crops (Jones et al. 2013). *Meloidogyne* spp. and *Pratylenchus* spp., are considered as highly polyphagous and can infect many different plants (Palomares-Rius et al. 2012). But it can be change, based on nematode population and environmental factors for horticulture crops. In particularly, it varies according to the most abundant plant in a certain area and susceptibility or resistance of this plant to the nematodes.

2. POTENTIAL THREAT TO HORTICULTURE; PLANT-PARASITIC NEMATODES

These small organisms heavily effect the roots of plant by causing special areas on vascular tissues for (syncytia by cyst nematodes and giant cells by root-knot nematodes), pericycle (nurse cells by reniform nematode) and/or feeding on cortical tissues (migratory endoparasites) endangering the nutrient uptake from soil causing poor development (Jones et al. 2013).

They are obligate organisms and modified the tissues of their host plant for themselves by improving a close host-pathogen relationship in which esophageal gland secretions of PPN have great duty (Berg et al. 2009). Moreover they let the entry of secondary organisms like bacteria and fungi into roots and behave like a vector for some plant viruses (Jones et al. 2013).

Plant parasitic nematodes generally remain ignored from plant protection viewpoint leading to avoidable yield loss in plants because of their size and unclear symptoms, together with lack of farmers' perception to behave them as a serious organism. To find a method which is sustainable, effective and harmless to the human, animals and non-target organisms is difficult among the current control strategies of PPNs (Waele 2013).

2.1. Root-Knot Nematode, *Meloidogyne* spp.

Among the PPNs, root-knot nematodes (RKNs), *Meloidogyne* spp., are one of the most harmful and devastating pests of economically important crops (Lima et al. 2018). They are food security issues because they cause serious yield losses.

Meloidogyne spp. are obligate, sedentary endoparasites and have a broad host range, over 3000 host plants globally including almost every fruit, horticultural, and ornamental plant containing more than 100 species (Moens et al. 2009).

Meloidogyne incognita (Kofoid and White, 1919) Chitwood, 1949, *M. hapla* Chitwood, 1949, *M. arenaria* (Neal, 1889) Chitwood, 1949, and *M. javanica* (Trub, 1885) Chitwood, 1949 are known as the most important species, because of their polyphagia and global distribution (Elling 2013; Jones et al. 2013).

The genus *Meloidogyne* is more commonly found in temperate, subtropical and tropical regions, but is considered a cosmopolitan genus. They are recognized as significant pests of horticultural plants and can affect more than 50 plants (Xalxo et al. 2013).

Three main successful properties can be described for this genus: a detailed strategy of parasitism (induction of the host root cells to differentiate into nurse cells), morphology of female (its pear shape and sedentary behaviour lets the presence of two ovaries with many eggs (about 400 eggs)), and different reproduction methods such as sexual and asexual.

Infection by *Meloidogyne* bases on the forming of specific feeding cells in the endoderm and cortex areas and vascular cylinder named nurse or giant cells. Additionally, there is a hyperplastic and hypertrophic cell response in the infected part, causing root thickening throughout this process, but each plant may react differently.

Mostly this period results in gall formation, that compress xylem vessel elements, culminating in vascular cylinder irregularity and therefore interference in internal solute transfer and absorption (Favery et al. 2016).

Numerous vegetables such as tomato (*Solanum lycopersicum*), potato (*Solanum tuberosum*), lettuce (*Lactuca sativa*), carrot (*Daucus carota*), aubergine (*Solanum melongena*), cucumber (*Cucumis sativus*), okra (*Abelmoschus esculentus*), and gourds are susceptible to RKNs. Particularly RKNs can cause severe damages to the roots of tomato (Figure 1).

The initial symptoms of infection in tubers may be internal while the external symptoms can be seen easily after 2 months by surface galls. These galls may be accompanied by cracks to large, isolated lumps and cause rough and dirty appearance on the roots.

Visual diagnosis can be performed after a high level of infection but soil sampling with the correct extraction method make the early detection of infection easier (Vovlas et al. 2005).

Yellowed leaves, withering of plants even in moist soil, and development problems are typical symptoms of root-knot nematodes in potato fields. While more root gall proliferation occurred in potato by *M. hapla*, *M. incognita*, *M. javanica*, and *M. arenaria* cause knobbly tubers in addition to galls.

Pepper, melon, gilo, and cabbage, are some of the economic crops affected by *Meloidogyne*, all of which show significant gall formation that inhibits their development and production. The damages on the roots and tubers are usually very compromising concerning in the plant growth (Mitkowski and Abawi 2003).

Onion (*Allium cepa*), garlic (*Allium sativum*), bell pepper (*Capsicum annuum*), and black pepper (*Piper nigrum*) are some susceptible hosts of *Meloidogyne* spp., and rarely infected by other nematode species.

Figure 1. Heavy damages with typical galls on tomato roots caused by *Meloidogyne enterolobii* (photo by Jeffrey W. Lotz).

Fruits such as grapevine (*Vitis vinifera*), papaya (*Carica papaya*), and banana (*Musa* spp.) are significant hosts of root-knot nematodes. Yield losses due to nematode infection can reach 33% and 50% in the production of melon (*Cucumis melo*) and watermelon (*Citrullus lanatus*), respectively (Sikora and Fernández 2005).

2.2. Root lesion nematode, *Pratylenchus* spp.

The genus *Pratylenchus* has been reported worldwide, and recently more than 75 species identified (Araya et al. 2016). A major group of root migratory ecto-endoparasites in many plants formed by the members of this genus that called lesion nematodes.

Symptoms of lesion nematode in tubers and roots are specific, because they do not form an area, as cyst or root-knot nematodes do, for feeding. *Pratylenchus* can form galleries in host tissues through their free movement in the root and feeding in the cortex of plant, typical lesions or black spots appear as a result (Quist et al. 2015).

Depending on the species, lesion nematodes can reproduce by sexual or asexual. Male and female of *P. penetrans* must mate for fertile eggs but it is not necessary for *Pratylenchus neglectus*, *P. brachyurus* and *P. thornei* because they reproduce by parthenogenesis.

An average of one egg is laid daily and the cycle is completed in 45-65 days at adequate temperatures Nearly one week after egg deposition, when the juveniles emerge from the eggs, all stages can infect the roots (Ryss 2002; Collins and Wilkinson 2015).

Damages caused by lesion nematodes on roots are mostly proved by necrosis and death. *P. penetrans* and *P. scribneri* can be given as examples of the most important species in tubers and potatoes all over the world (Bridge and Starr 2007).

Pratylenchus spp. generally enter inside of tubers through lenticels, infect the tissue, and cause round lesions in different-sized (Pinheiro et al. 2011). Generally these lesions are superficial, limited to the outer 0.5 mm of the tuber but can reduce the marketable quality of the crops (Davis and MacGuidwin 2000). Carrots infected by *P. penetrans* may have delayed maturation and branching of their taproots (Figure 2).

Pratylenchus infection in broadleaf plants, particularly lettuce, reduces growth, causes yellowing, and small head formation which adversely affects the sale of the product in the market (Pinheiro et al. 2010).

Root lesion nematodes causes serious losses in peanut production all over the world. *Pratylenchus* spp. infect roots and cause above-ground symptoms such as chlorosis, premature senescence and stunted crops (Bridge and Starr 2007).

Damages like yield losses caused by root lesion nematodes are mostly related with symptoms on pods and pegs. Nematode infected pods may be defined by small brown tunnels found in the shells and shrivelled pegs. These nematodes are also considered to be associated with losses in fruits like banana, pineapple, grape, and soursop.

Figure 2. *Pratylenchus penetrans* infected carrots (photo by Sarah Collins).

2.3. Burrowing nematode, *Radopholus similis*

Burrowing nematodes, *Radopholus* spp. have a broad host range of more than 300 plants. *Radopholus similis* and *R. citri* are considered as the most important species and may affect banana and citrus, respectively. *Radopholus* spp. cause damages all over the world and may be commonly occurred in tropical and subtropical areas (Luc et al. 2005).

Radopholus spp. have similar life cycle with *Pratylenchus* spp., both juveniles and females are highly infective. They complete their life cycles in the cortical cells of root, resulting in root cell necrosis and death.

Burrowing nematodes may reproduce sexually; females lay nearly 2-5 eggs daily in the root tissues, and the life cycle is ended in 3 weeks (Brooks 2008).

As a result of *Radopholus* movement within the tissue, lesions and burrows are occurred in the roots which are typical symptoms that cause malnutrition and devastating damages (Bridge and Starr 2007) (Figure 3).

Figure 3. Burrowing nematodes damage on banana roots (photo by Michael McClure).

The disease caused by *R. similis* in banana is named as 'blackhead' due to its feeding from the cortex of root and form internal necrosis in tissues. Other burrowing nematode infection symptoms in banana are impaired or poor development, incomplete or yellowing leaves, uprooting and small bunches (Dias-Arieira et al. 2008).

It has been reported that *R. similis* is responsible for 100% yield losses in Cavendish banana (Pinheiro et al. 2015). It also causes damages to ginger, and the symptoms are similar with *Meloidogyne* infection.

Both *R. citri* and *R. similis* cause significant problems in citrus production. *Radopholus citri* damage, which causes stunted growth and reduced fruit production in terms of quantity and quality, is known as a serious topic.

2.4. Stem and Bulb Nematode, *Ditylenchus* spp.

Ditylenchus spp., named as stem and bulb nematodes belong to migratory endoparasitic nematodes may affect leaves and stems (Peng et al. 2014). These devastating nematodes can be found worldwide, particularly in temperate regions (Maule and Curtis 2010).

Swollen, distorted stems, with reddish-brown to black lesions are most common symptoms of *Ditylenchus* spp. (Zhang et al. 2014). The genus *Ditylenchus* induces major problems in potato production. *Ditylenchus dipsaci* and *D. destructor* cause dry rot, while *D. destructor* causes more severe damage particularly (Mwaura et al. 2015).

In onion, *D. dipsaci* infected seedlings become gnarled and misshapen, mostly resulting in plant death. During the plant cycle leaves fall, roots yellow and bulbs get empty (Figure 4).

Dwarfism, swelling, and extensive longitudinal splitting of the cotyledons and leaves are characteristic symptoms in garlic. There are thick, short and generally yellowish or brown spots due to tissue discoloration and swelling above the bulb in the pseudo-stem, resulting in cigar shaped (Pinheiro et al. 2014).

Figure 4. *Ditylechus dipsaci* damages on onions (photo by Ed Kurtz).

Currently, *D. arachis* has been related with pod rot of peanut, that causes smaller and shrunken seeds, discoloured pods, pegs and hull endocarps (Zhang et al. 2014).

2.5. Cyst nematodes, *Heterodera* spp., *Globodera* spp.

Cyst nematodes (CNs), which are obligate sedentary endoparasites, are nematodes of economic importance worldwide. In the list of top ten serious PPNs in the field they rank second.

Heterodera avenae, *H. schachtii*, *H. filipjevi*, *H. glycines*, *Globodera rostochiensis* and *G. pallida* cause great damages economically worldwide and under favorable conditions yield loss can reach up to 90% (Nicol et al. 2011; Jones et al. 2013).

It has been also reported that *H. schachtii* is a significant problem in sugar beet production areas because of its destructive damages (Peng et al. 2015) (Figure 5).

Figure 5. Healthy (left) and *Heterodera schachtii* infected roots (right) of sugar beet (photo by Gerald Holmes).

Second-stage juveniles move intra and intercellularly inside the roots and create lasting areas for feeding continuously. Cyst nematodes are very difficult to eradicate due to their high survival ability in the soil for prolonged time under stress conditions, even in the absence of hosts (Perry 2002).

Although, under controlled agricultural system relatively fewer occurrence of CN species have been encountered, like *H. cruciferae*, *H. carotae*, *H. daverti* and *H. fici*, but their high pathogenicity, adaptability and survival ability raise the status of CN as a potential devastating pest in limited areas (Lung et al. 1997; Djian-Caporalino 2012; Gubin and Sigareva 2014).

2.6. Dagger nematodes, *Xiphinema* spp.

Xiphinema spp. commonly called dagger nematodes that feds broad range of herbaceous and woody plants which are found prevalent in all continents (Taylor and Brown 1997). Members of the genus *Xiphinema* are commonly found in temperate and tropical areas.

Dagger nematodes cause serious damage or even death of host plant both by feeding on roots and transferring viral mosaic and wilting diseases (Taylor and Brown 1997; Gozel et al. 2006; Van Zyl et al. 2012; Jones et al. 2013) (Figure 6).

As vector-capable juveniles feed on virus-infected crops and become adults, they can get plant-pathogenic viruses, usually called nepoviruses. During the feeding, viruses create a lining in the pharynx-stylet tube and are injected inside of the root tissues.

Xiphinema spp. are ectoparasitic organisms, all their stages except eggs are able to attack and feed on the plant roots. While the nematode body stays outside the root its long stylet deep into the root.

Dagger nematodes are heavily affected by fluctuations in soil temperature and moisture and vertically remove away from desiccating conditions on surface therefore they usually live and survive in deep soils (Feil et al. 1997).

Root cells are destroyed and root volume decreased due to the feeding of dagger nematodes at the meristematic root-tips. Root weight loss up to 65% and severe yield reduction can be occurred by damage of *Xiphinema*.

More than 50% yield losses can be occurred on plants such as tomato, potato, pepper, grapevine, and cassava due to the limited plant growth caused by viruses (Evans et al. 2007).

Figure 6. Symptoms of grapevine fanleaf virus transferred by *Xiphinema* sp. (photo by Pablo Castillo).

2.7. Other nematodes associated with horticultural crops

Rotylenchus, *Tylenchulus*, and *Helicotylenchus* are belonging to sedentary endoparasitic nematodes and able to affect cabbage, broccoli, carrot, and some other plants (Lopes-Caitar et al. 2019).

Rotylenchulus spp. called reniform nematodes (RNN) because of their characteristic kidney-like shape. The genus *Rotylenchulus* is generally represented by *Rotylenchulus reniformis* which is a sedentary semi-endoparasite and related with various horticultural plants particularly grown in tropical and subtropical regions.

Rotylenchulus reniformis has been accepted as a serious threat for pineapple production, because it reduces yields and causes slight to heavy stunting and reddening of the leaves. Additionally upland cotton and some vegetables such as lettuce, tomato, okra, and squash can be given as examples of the crops most severely affected by reniform nematodes (Wang 2001).

Citrus nematodes (CTN), *Tylenchulus* spp., and *Rotylenchulus* spp. are both sedentary semi-endoparasite but host range of CTN is limited. Recently, pomegranate has been reported as a host of *T. semipenetrans* in Iran (Rashidifard et al. 2015).

The most important species of CTN is *T. semipenetrans* that causes slow decline in citrus trees. Damages of *T. semipenetrans* are defined by a gradual decline in development, leaf size and health, fruit size and quality as the years passed.

Members of the *Helicotylenchus* genus called spiral nematodes (SRN) due to the spiral form of their body. It is a migratory ecto-endoparasite or semiendoparasites nematodes widely related with turfgrasses and other grass but these nematodes may also affect banana and some other fruit trees.

Members of the *Aphelenchoides* genus, called leaf and bud nematodes, showing migratory behaviour, living in and feeding upon the aerial parts of plants hardly related with the soil.

Aphelenchoides spp. induce significant problems in alfalfa and strawberries production. Due to their wide host range and ability to spread rapidly in hostas and many ornamentals they considered as a potential threat for farmers (Jagdale and Grewal 2006; Feng et al. 2014).

Aphelenchoides fragariae is named strawberry crimp while *A. ritzemabosi* is named chrysanthemum foliar nematode. *A. fragariae* can easily cause plant death on strawberry and *Anthurium* seedlings.

Buds and the stomata of fresh leaves are affected due to the feeding of these nematodes on mesophyll cells. The damaged parts of leaves turn chlorotic, subsequently necrotic and mostly surrounded by big vein structures. Foliar nematodes can reduce yield and ruin the appearance and marketability of ornamentals.

In addition to their host plants, *Aphelenchoides* spp. also feed on fungi and their tendencies reduce the effect of some methods in the nematode control (Wheeler and Crow 2020).

3. MANAGEMENT OF PLANT-PARASITIC NEMATODES

Crop yield loss due to the PPNs in many countries is considerably great. According to an estimate PPNs can cause more damage than insect pests per year. Although farmers identified many organisms and pests, as production problems they overlooked these nematodes. Nematodes are difficult to observe and control due to their cryptic behavior and hence, generally unnoticed.

Another challenge with these nematodes is PPNs not only cause damage but also form disease-complexes with other micro-organism as a result increase yield losses. Symptoms of PPNs are not certain, similar to other pathogens symptoms and abiotic stresses like water and mineral deficiency.

Nematode-free propagating material, resistant cultivars, and plant rotations are some of the available measures against nematodes. In addition, nematicides are used in most countries, but they are greatly restricted due to their high prices and low efficiency, as some of the most effective nematicides are extremely toxic to human, animals, and non-target organisms.

It is absolutely necessary that integrated nematode management should be supported by farmers-scientists cooperation, local production of biocontrol agents and strict pesticide regulations. Because for a sustainable agriculture production, the awareness and skills of farmers are evenly crucial both in controlling nematode infection and minimizing yield losses.

Consequently once PPNs infest an area, it is impossible to remove them. Preferably the aims are minimizing yield losses and plant damages by keeping the nematode population as low as possible.

The best way to control nematodes is to use a combination of the most economic and effective methods for the given production situation according to nematode infestation levels, other pest and pathogen problems, available equipment, economics, and other considerations.

REFERENCES

Araya, T. Z., Padilla, W. P., Archidona-Yuste, A., Cantalapiedra-Navarrete, C., Liébanas, G., Palomares-Rius, J. E., & Castillo, P. (2016). Root-lesion nematodes of the genus Pratylenchus (Nematoda: Pratylenchidae) from Costa Rica with molecular identification of P. gutierrezi and P. panamaensis topotypes. *European Journal of Plant Pathology*, *145*(4), 973-998.

Bridge, J., & Starr, J. L. (2007). *Plant nematodes of agricultural importance: a color handbook*. Elsevier.

Brooks, F. E. (2008). Burrowing nematode. *The Plant Health Instructor*.

Collins, S., & Wilkinson, C. (2015). Pratylenchus penetrans: A horticulturally significant root lesion nematode.

Davis, E. L., & MacGuidwin, A. E. (2000). Lesion nematode disease. The Plant Health Instructor. *American Phytopathology Society, St. Paul, MN, USA https://doi. org/10.1094/PHI-I-2000-1030-02*.

Dias-Arieira, C. R., Molina, R. D. O., & Costa, A. T. (2008). Nematóides causadores de doenças em frutíferas. *Revista Agro@ Mbiente On-line*, *2*(1), 46-56.

Elling, A. A. (2013). Major emerging problems with minor Meloidogyne species. *Phytopathology*, *103*(11), 1092-1102.

Evans, T. A., Miller, L. C., Vasilas, B. L., Taylor, R. W., & Mulrooney, R. P. (2007). Management of Xiphinema americanum and soybean severe stunt in soybean using crop rotation. *Plant Disease*, *91*(2), 216-219.

Favery, B., Quentin, M., Jaubert-Possamai, S., & Abad, P. (2016). Gall-forming root-knot nematodes hijack key plant cellular functions to induce multinucleate and hypertrophied feeding cells. *Journal of Insect Physiology*, *84*, 60-69.

Feil, H., Westerdahl, B. B., Smith, R. J., & Verdegaal, P. (1997). Effects of seasonal and site factors on Xiphinema index populations in two California vineyards. *Journal of Nematology*, *29*(4), 491.

Feng, H., Shao, Y., Wei, L. H., Gao, C. Y., & Zhou, Y. J. (2014). The white-tip nematode, Aphelenchoides besseyi, exhibits an auxin-orientated behaviour affecting its migration and propagation. *Nematology*, *16*(7), 837-845.

Gozel, U., Lamberti, F., Duncan, L., Agostinelli, A., Rosso, L., Nguyen, K., & Adams, B. J. (2006). Molecular and morphological consilience in the characterisation and delimitation of five nematode species from Florida belonging to the Xiphinema americanum-group. *Nematology*, *8*(4), 521-532.

Jagdale, G. B., & Grewal, P. S. (2006). Infection behavior and overwintering survival of foliar nematodes, Aphelenchoides fragariae, on hosta. *Journal of Nematology*, *38*(1), 130.

Jones, J. T., Haegeman, A., Danchin, E. G., Gaur, H. S., Helder, J., Jones, M. G., ... & Perry, R. N. (2013). Top 10 plant-parasitic nematodes in molecular plant pathology. *Molecular Plant Pathology*, *14*(9), 946-961.

Lima, F. S., Mattos, V. S., Silva, E. S., Carvalho, M. A., Teixeira, R. A., Silva, J. C., & Correa, V. R. (2018). Nematodes affecting potato and sustainable practices for their management. *Potato: From Incas to All Over the World*, *107*.

Lopes-Caitar, V. S., Pinheiro, J. B., & Marcelino-Guimaraes, F. C. (2019). Nematodes in horticulture: An overview.

Luc, M., Bridge, J., & Sikora, R. A. (2005). Reflections on nematology in subtropical and tropical agriculture. In *Plant parasitic nematodes in subtropical and tropical agriculture* (pp. 1-10). Wallingford UK: CABI Publishing.

Lung, G., Fried, A., & Schmidt, U. (1997). Biological control of nematodes with the enemy plant Tagetes spp. *Gesunde Pflanzen*, *49*(4), 111-118.

Maule, A., Curtis, R., (2010). Parallels Between Plant and Animal Parasitic Nematodes. In J. Jones, L. Gheysen & C. Fenoll (Eds.), Expoliting genomics and molecular biology to understand plant-nematode interaction. Springer, pp. 221-251.

Mitkowski, N. A., & Abawi, G. S. (2003). *Root-knot nematodes. The Plant Health Instructor. DOI: 10.1094*. PHI-I-2003-0917-01.

Moens, M., Perry, R. N., & Starr, J. L. (2009). Meloidogyne species–a diverse group of novel and important plant parasites. *Root-knot nematodes*, *1*, 483.

Mwaura, P., Niere, B., & Vidal, S. (2015). Resistance and tolerance of potato varieties to potato rot nematode (Ditylenchus destructor) and stem nematode (Ditylenchus dipsaci). *Annals of Applied Biology*, *166*(2), 257-270.

Nicol, J. M., Turner, S. J., Coyne, D. L., Nijs, L. D., Hockland, S., & Maafi, Z. T. (2011). Current nematode threats to world agriculture. In *Genomics and molecular genetics of plant-nematode interactions* (pp. 21-43). Springer, Dordrecht.

Palomares-Rius, J. E., Hedley, P. E., Cock, P. J., Morris, J. A., Jones, J. T., Vovlas, N., & Blok, V. (2012). Comparison of transcript profiles in different life stages of the nematode Globodera pallida under different host potato genotypes. *Molecular Plant Pathology*, *13*(9), 1120-1134.

Peng, H., Gao, B. L., Kong, L. A., Yu, Q., Huang, W. K., He, X. F., ... & Peng, D. L. (2014). Correction: Exploring the Host Parasitism of the Migratory Plant-Parasitic Nematode Ditylenchus destuctor by Expressed Sequence Tags Analysis. *Plos one*, *9*(1).

Peng, D. L., Peng, H., & Liu, H. (2015). Research progress in occurrence, biology and management of the sugar beet cyst nematode Heterodera Schachtii Schmidt. *Plant Protection*, *41*, 1-7.

Perry, R. N., (2002). Hatching. In: Lee, D.L. (Ed.), *The Biology of Nematodes*. CRC Press.

Pinheiro, J. B., Amaro, G. B., & Pereira, R. B. (2010). Ocorrência e controle de nematoides em hortaliças folhosas. *Embrapa Hortaliças-Circular Técnica (INFOTECA-E)*.

Pinheiro, J. B., Amaro, G. B., & Pereira, R. B. (2011). Nematoides em pimentas do gênero Capsicum.

Pinheiro, J. B., De Carvalho, A. D. F., Pereira, R. B., & Rodrigues, C. D. S. (2014). Nematóides na cultura do alho e cebola.

Pinheiro, J. B., Silva, G. O., & Pereira, R. B. (2015). Nematoids in potato culture [Nematoides na Cultura da Batata] Embrapa Hortaliças.

Quist, C. W., Smant, G., & Helder, J. (2015). Evolution of plant parasitism in the phylum Nematoda. *Annual Review of Phytopathology*, *53*(1), 289-310.

Rashidifard, M., Shokoohi, E., Hoseinipour, A., & Jamali, S. (2015). Tylenchulus semipenetrans (Nematoda: Tylenchulidae) on pomegranate in Iran. *Australasian Plant Disease Notes*, *10*(1), 1-6.

Ryss, A. Y. (2002). Genus Pratylenchus Filipjev: multientry and monoentry keys and diagnostic relationships (Nematoda: Tylenchida: Pratylenchidae). *Zoosystematica Rossica*, *10*(2), 241-255.

Sikora, R. A., & Fernandez, E. (2005). Nematode parasites of vegetables. In Plant parasitic nematodes in subtropical and tropical agriculture (pp. 319-392). Wallingford UK: CABI publishing.

Taylor, C. E., & Brown, D. J. (1997). *Nematode vectors of plant viruses*. Cab International.

Van Zyl, S., Vivier, M. A., & Walker, M. A. (2012). Xiphinema index and its Relationship to Grapevines: A review. *South African Journal of Enology and Viticulture*, *33*(1), 21-32.

Vovlas, N., Mifsud, D., Landa, B. B., & Castillo, P. (2005). Pathogenicity of the root-knot nematode Meloidogyne javanica on potato. *Plant pathology*, *54*(5), 657-664.

Wang, K. H. (2001). *Reniform Nematode, Rotylenchulus Reniformis Linford & Oliveira (Nematoda: Tylenchida: Tylenchoidea: Hoplolaimidae: Rotylenchulinae)*. University of Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, EDIS.

Wheeler, L., & Crow, W. T. (2020). Foliar Nematode Aphelenchoides spp. (Nematoda: Aphelenchida: Aphelenchoididae): EENY749/IN1279, 2/2020. *EDIS*, *2020*(3).

Xalxo, P. C., Karkun, D., & Poddar, A. N. (2013). Rhizospheric fungal associations of root knot nematode infested cucurbits: in vitro assessment of their nematicidal potential. *Research Journal of Microbiology*, *8*(2), 81.

Zhang, S. L., Liu, G. K., Janssen, T., Zhang, S. S., Xiao, S., Li, S. T., ... & Bert, W. (2014). A new stem nematode associated with peanut pod rot in China: morphological and molecular characterization of Ditylenchus arachis n. sp. (Nematoda: Anguinidae). *Plant Pathology*, *63*(5), 1193-1206.

İKSAD
Publishing House

ISBN: 978-625-8246-35-3