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Almond (*Prunus dulcis*): Comprehensive overview of cultivars, requirements and field Management

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Abstract. almond [*Prunus dulcis* (Mill.) D.A. Webb, syn. *P. amygdalus* (L.) Batsch] is located in the Mediterranean countries, and its cultivation is restricted to areas that have a Mediterranean climate. Almonds, a type of tree nut, are widely recognised as a healthy snack. They are an excellent source of protein, carbohydrates, antioxidants, and lipids. Almonds also contain flavonoids, vitamin E, riboflavin, amino acids, and minerals such as manganese, magnesium, copper, and phosphorus. Overall, almonds are a nutrient-rich and delicious addition to any diet. Flowering occurs when the requirements for chilling and heat are fully satisfied. When growing self-incompatible cultivars, it is essential to design pollinizers properly. For optimal pollination, it is recommended to have a minimum of 30% pollinizers. Almonds can be classified into soft- and hard-shell varieties based on their shell characteristics. There are two types of almonds: sweet and bitter. The weather, including humidity, temperature, and time of day, heavily influences the water usage of almond orchards. Nutrition is crucial for the proper development of almonds, regular fruiting, and high-quality yields. Almond propagation through grafting has allowed for an improved selection of scions to be clonally propagated. New rootstocks should possess desirable traits such as tolerance to poor soils, including calcareous soil, ease of propagation through hardwood cuttings or micro-propagation, as well as high rootstock vigour. New hybrids with increased tolerance to heavy and water-saturated soils are currently in development. Locally adapted elite genotypes are captured through clonal propagation, resulting in the identification and propagation of hundreds of cultivars in specific production areas. Furthermore, numerous molecular studies have been conducted, facilitating the transfer of these desirable traits. Generally, this article focuses on the process of managing the fields, from selecting cultivars to harvesting, in order to achieve high quality and high-quality almond production.

Keywords: Almond, *Prunus dulcis*, cultivars, requirements, fields Management, production.

INTRODUCTION:

Almond(*Prunus dulcis* (Miller) D. A.Webb syn. *Prunus amygdalus* Batsch., *Amygdalus communis* L., *Amygdalus* dulcis Mill.) is the earliest domesticated nut tree to flower in spring, due to its low chill requirements and quick response to warm temperatures (Javaid et al 2019).

Almonds are commonly grown and consumed in Mediterranean countries, which include regions in California, in the Central Valley of the Middle East, Syria, Turkey, and Iran; Central Asia; the slopes of the Himalayas; and the Southern Hemisphere, including Chile, Argentina, Southern Africa, and Australia (Badenes & Byrne 2012, Javaid et al 2019). Several international breeding programs have spread almond cultivation to colder regions, such as northern Europe and America, by delaying the timing of flowering (Sakar et al 2019).

Almond cultivation is limited to Mediterranean climates with minimal rainfall in late winter, summer, and early fall. Almonds thrive in mild winters and hot, dry summers thanks to their low requirement for cold temperatures to initiate early flowering, their rapid initial growth, and their ability to tolerate summer heat and drought. Almond trees are the first to flower among temperate latitude trees, but this also means that their production is limited to areas with minimal spring frost risk (Badenes & Byrne 2012).

The almond tree is a deciduous tree that typically grows between 4 and 10 meters tall and can reach over 20 meters in height. Moreover, it lives for 100 years or more, and the trunk diameter reaches 30 cm (Mori et al 2011a).
In the first year of cultivation, the immature/young branches appear green and turn purple when exposed to sunlight; in the second year, the purple colour changes to grey (Mori et al 2011, Mushtaq et al 2015).

Lanceolate leaves are 1.2-4 cm broad and4-13 cm long, featuring a serrate edge and a 2.5 cm petiole. In early spring, individual or paired white or pale pink flowers with five petals measuring 3-5 cm in diameter grow before leaves (Bailey et al 1976, Verma 2014, Mushtaq et al 2015).

Almond is a species that mostly cannot fertilize itself (self-sterile). A single locus controls gametophytic self-incompatibility with multiple codominant alleles. This means that cross-pollination is required, leading to increased genetic diversity and greater adaptability to new environments (Benmoussa et al 2017, Gradziel & Martínez-Gómez 2013).

In addition, the almond fruit is botanically classified as a drupe. It is typically 3.5 to 6 cm long and consists of three parts. Firstly, the edible section of the almond is the kernel, or meat, which consists of two big cotyledons covered by brown skin (exocarp) and protected by an exterior hull and an intermediate shell (Gradziel 2009). Second, a fleshy, leathery green-grey coat with a thin hull (mesocarp) expands slightly during development before becoming dry, leathery, and dehiscing at maturity. Third, depending on genotypes, the mature endocarp in the separate hardened shell (endocarp) ranges from hard to soft and papery (Jain & Priyadarshan 2009, Badenes & Byrne 2012a, Mushtaq et al 2015, Barreca et al 2020).

Almonds can be classified into soft- and hard-shell varieties based on their shell characteristics. For instance, In Australia and California, most almond cultivars have soft shells, but most varieties in Spain have hard shells (Shirmohammadi & Fielke 2017).

Fig. 1. Different parts of almond nut in the late-stage of growth.

Almonds begin to bear an economic crop in the third year after planting the trees. Trees achieve their full potential five to six years after planting, depending on varieties and growing conditions. Fruits ripen in the autumn, around 6-7 months after blossoming (Mark & Huxley 1992).

There are two categories in which almonds are classified: sweet and bitter. Sweet almonds are edible, whereas bitter almonds are harmful. Bitter almonds are somewhat more extensive and shorter than sweet almonds. The fixed oil in sweet almonds is 50%. Hydrogen cyanide is produced by bitter almonds (Mouaffak et al 2013).

When wild almonds are chewed or crushed, their glycoside amygdalin turns into hydrogen cyanide, making them poisonous. It is important to note that cultivated almonds are entirely safe to eat, as they do not contain amygdalin (Verma 2014).

1. History of Almond Cultivation

The almond tree was one of the earliest trees to be grown by humans because of its nutritious and long-lasting kernels, which remain appetizing even when consumed over an extended period of time. It was first cultivated around the third millennium BCE and has been present in the early range of plant domestication across Asia (Spiegel-Roy 1976) The almond is different from other Prunus crops both botanically and horticulturally. These differences have significant implications for its role in human history and its transmission. Botanically, the part that is consumed is a seed, not a fruit. It is a long-lasting source of propagation and a concentrated, desirable, and relatively non-perishable food item, making it a valuable commodity for trade since ancient times (Gradziel 2017).

During prehistoric times, almonds were a valuable commodity in trade across Asia, North Africa, and Europe. This led to the creation of a market standard. The sweet almond, also known as the "Greek nut," is a distinct species and is currently becoming a developing market standard. Also, it is known as *Prunus amygdalus* Batsch, *Amygdalus communis* L., and *Amygdalus dulcis* Mill, *Prunus dulcis* (Mill.) D.A. Webb (Gradziel 2017).
Around 11,000 BCE, Franchthi cave in southern Greece showed evidence of almond and pistachio, It's possible that lentil farming was practiced before grain farming in Asia Minor, indicating a trend (Hansen & Renfrew 1978, Farrand 1999, William, 1999).

Almonds have been a part of culinary culture since ancient times. They were mentioned in Sumerian banquet menus and were commonly used in Palestine, as shown in biblical references (Rosengarten 1984, Goor & Nurock 1968, Janick 2007).

The cultivation of almonds in the eastern Mediterranean began in the second millennium BCE, as evidenced by the remains found in Tutankhamun's tomb (Zohary & Hopf 1993). There are four stages of almond cultivation and distribution: Asiatic, Mediterranean, Californian, and Southern Hemispheres (Kester et al 1990).

The Asiatic stage is the period in which almonds were first domesticated and subsequently spread over central and southwestern Asia. The Greek naturalist Theophrastus wrote about almonds, which he named Amygdalai, in his dissertation on the history of plants around 300 BCE. Almond cultivation was known in Turkey (Ayfer, 1975), Iran (Grigorian 1976), Syria (Spiegel-Roy 1976), China (Gustafson et al 1989), Pakistan, and north-west India (Singh et al 1977) within a few hundred years. The first almond cultivation took place in Kashgar, Xinjiang Province, after being brought from central Asia across the Tian Shan Mountains to the west (Gustafson et al 1989).

The spread of almond cultivation towards the west in the Mediterranean occurred in two stages. Between 300 and 400 BC, the cultivation of almonds had expanded across the Peloponnesian peninsula and the Greek islands (Stylianides 1976). Almonds gradually spread to all suitable regions of the Mediterranean, including Spain, Portugal, Southern France, Portugal, Northern Africa and the Madeira Islands. These introductions may have originated from various groups, as numerous trade channels were well-established by this time, including the early ocean traders, the Phoenicians of Asia Minor (Egea & Garcia 1975), and the Greeks, who founded colonies in Sicily, Europe, and North Africa. During the Arab conquest of North Africa around 500 to 600, almonds were introduced into Tunisia and Morocco. Later, they were brought to Spain and Portugal. Before this, the cultivation of almonds was mainly confined to an area of Spain's central plateau and river valley slopes within 50 miles of the Mediterranean coast. This information is based on the research conducted by Jaouani in 1976 and Laghezali in 1985, respectively. It is believed that one of the Silk Road caravan routes passed through north-central Africa, specifically through Timbuktu and into Morocco. This suggests that there may have been an earlier route for the dispersion of goods to North Africa and Western Europe. Some remnants of these pre-Arabic introductions may still exist today in the diverse germplasm, which is only now being recorded in Morocco's and Tunisia's geographically isolated Atlas Mountains. Studies by Laghezali in 1985 and Lansari et al in 1994 provide evidence of this.

The New World was colonised by early European and Asian settlers, which resulted in commercial almond cultivation in Australia,South Africa and North and South America. It is necessary to test different regions and germplasm to successfully cultivate almonds due to their vulnerability to winter cold, spring frosts, and summer rains. California introduced almonds as an extension of Mediterranean culture, using limited European germplasm (Wood 1925).

From 1850 to the present, he has been a representation of the New World stage. However, California's methods of almond cultivation deviated from conventional methods used in the rest of the world.Significant adaptations were made in the production of crops, including the selection of specific cultivars and rootstocks that are vegetatively propagated to increase production. Markets were standardized based on the cultivar used, and growing sites were selected and optimized. New cultural and management techniques were developed, such as increased mechanization, and agrochemical inputs, and supplemental pollination. These enhancements have increased yield while also supporting current industrial and commercial strategies (Kester et al 1990, Micke 1994).

Beginning in the middle of the 1950s, California's population of almond seedlings, which can be found either in orchards made from un-budded almond seedling rootstock 'escapes' or along roadsides and close to commercial orchards became the primary source of new cultivars. Numerous choices from this source have been patent and released as commercial cultivars by individual growers through commercial nurseries since 1957 (Brooks & Olmo 1997).

The majority, including "Merced," "Price," "Carmel," and "Fritz," were utilized to cross-pollinate "Nonpareil." Later blooming varieties like "Thompson" and "Livingston" were combined with "Texas." The cooperative breeding program was established in 1923 at Davis, California, between USDA and University of California following early polling nation and cultivar assessment studies (Wood 1938).

In 1948, this program was divided. Up until 1975, the USDA program was still in effect.

Numerous cultivars and rootstocks have been released as a result of the University of California program's ongoing efforts (Kester & Gradziel 1996). The Nikitsky Botanical

Garden, located in Yalta, Crimea, was established under the guidance of A.A. Rikhter in 1972. And Yadrov (1994), has had the second-oldest continuous breeding program for almonds, behind California. These had their origins in Nikolai Vavilov conducted extensive studies in 1930 on collections of species and cultivars, primarily in the Asiatic regions of the former Soviet Union. Ongoing programs continue this work (Denisov 1988).

2. Almond classification

Almonds (*P. dulcis*) belong to the *Rosaceae* family. This family is of great significance in the temperate zone, with many economically important species such as apples, apricots, plums, cherries (both sweet and sour), strawberries, and roses (Arús et al 2009). Almonds belong to the Prunoideae (or Amygdaloideae) subfamily, with a single monocarp-late pistil maturing into a drupe (Soundararajan et al 2019), but they are now classified as their own family, the Prunaceae or Amygdalaceae. Prunus evolved from the Spiraeoideae subfamily, which has recently been discovered (Potter et al 2007).

The classification of almonds has been a challenge because they are considered an outlier within the *Prunus* species. The scientific name most commonly used today is *Prunus dulcis*, which acknowledges its similarities in morphology and genetic makeup with other *Prunus* plants, as well as its reported ability to hybridize with apricot, peach, and some plums. This name has been replaced by the newer name of Prunus dulcis, although some European literature still refers to it as *Prunus amygdalus* (Gradziel 2009). Experts with knowledge of almond species native to Central Asia prefer to classify them under a separate genus called *Amygdalus communis* (Ladizinsky 1999). This is because they believe that the unique botanical structures and development patterns that have evolved in these extreme environments are distinctive enough to warrant a separate genus (Mori et al 2011b).

3. Almond worldwide distribution

Numerous types are available worldwide. However, due to superior export quality, only a few cultivars, varieties, and species dominate the global market.

3.1. Nonpareil (USA variety)

The dominant almond cultivar in California is ‘Nonpareil’, accounting for 34.8% of total bearing acreage and 38.7% of total tonnage produced. ‘Nonpareil’is an old cultivar that was chosen in the 19th century. It is still widely used today because it regularly yields high-quality kernels that are harvested early and fast, processed without harm, and useful for a variety of products (Ledbetter & Sisterson 2013).

3.2. Iran species

3.2.1. *A. lycioides*

A. lycioides, also known as "Badamak", is located in some parts of Iran and is an indigenous species found primarily in the south. This plant has many uses, such as producing edible nutritive oil and kernels after debittering. It is valuable as a food source and has medicinal properties such as being an anti-diabetic, anti-inflammation, antimicrobial, and laxative substance (Kermanshah et al 2014).

3.2.2. *A. wendelboi*

A. wendelboi is an endemic species found only in the southern region of Iran, specifically in the Mountains of Gnow protected area. The fruit of this plant is known locally as "Archen" and is widely used in folk medicine to treat colds, coughs, headaches, and skin burns. In addition to its medicinal uses, it is also consumed as an edible kernel by the locals(Kermanshah et al 2014).

Spanish varieties

3.3.1. *Marcona*

Spain is known for its diverse range of almond varieties, with the Marcona type being the most widely grown (Varela et al 2006). This variety is usually consumed as a roasted or fried snack or used in the production of turrones. However, the *Marcona* variety is quite costly because of its exceptional taste and low yield (Vázquez-Araújo et al 2008).

3.3.2. *Guara*

Another noteworthy variety is *Guara*, known for its late blooming, ability to self-pollinate, and excellent quality, which has resulted in significant commercial success (Kodad et al 2014).

3.3.3. *Largueta, Planeta, Rumbeta, and Desmayo*

Other important Spanish varieties, such as *'Largueta', 'Planeta', 'Rumbeta', and 'Desmayo'* are also produced in large volumes (Cortés et al 2018).

3.4. Indian varieties

3.4.1. *Shalimar*

The Indian variety known as *Shalimar* blooms in the second week of March and can be harvested 143 days after full bloom.The Shalimar tree has a drooping growth habit and produces a light papery shell, which has a high shelling ratio of 50%. It is also qualified for export. Under irrigated conditions, the average productivity of Shalimar is between 2.0-4.0 t/ha. (Verma 2014).

3.4.2. *Makhdoom*

The *"Makhdoom*" tree blooms in the first week of March and is typically harvested 141 days after full bloom. This tree grows in a spreading and drooping manner, and its shells are medium, soft, with a shelling percentage of 42%. This tree has an average production of more than 2.0-3.5 t/ha under irrigated circumstances (Verma 2014).

3.4.3. *Waris*

The Waris cultivar blooms in the third week of March and matures in 145 days. It grows vertically, making it ideal for high-density orcharding. The shell is medium in colour, and the nuts are medium in size, with soft shells and full kernels. The shelling rate is 48%. Under irrigated conditions, the tree yields more than 2.0-3.0 tonnes per hectare (Verma 2014).

3.5. Afghanistan variety

3.5.1. *Satarbai Sufi* (Afghanistan variety)

One of the finest almond varieties in Afghanistan is known as Satarbai Sufi. It hails from the Khulm District in Balkh Province and boasts an early bloom (occurring in the fourth week of February) with a mid-July harvest(Verma 2014).

3.5.2. *Satarbai Bakhmaly* (Afghanistan variety)

Satarbai Bakhmaly is a high-quality export cultivar from Aybak in Samangam Province. It blooms in the first week of March and is harvested in mid-July. This variety is sought by markets that want whole kernels for direct consumption(Verma 2014). This variety is a top choice for export markets seeking whole kernels suitable for direct consumption. It enjoys high demand in India and the Middle East(Verma 2014).

4. Almond production

The global production of almonds during 2021 was approximately 2 million tons (FAO 2023).

The world's largest producer, the United States and the Major producers include Spain, Australia, Turkey, Morocco, and Iran. California produces the most almonds in the United States, making it the state's biggest agricultural export. Afghanistan is also known for producing high-quality almonds (Verma 2014)

Ranking	Country	Production	Unit
1	United States of America	2189040	t
2	Spain	365210	t
3	Australia	285605.05	t
4	Türkiye	178000	t
5	Morocco	169255	t
6	Iran (Islamic Republic of)	163568.2	t
7	Syrian Arab Republic	87768.07	t
8	Tunisia	75000	t
9	Italy	71620	t
10	Algeria	55448	t

Tabe (1): Almond production in the world (**Source:** FAO 2023).

5. The economic importance of almond

Complementary medicine practitioners have long used almond oil, also known as [*Oleum amygdalae*], due to its numerous health benefits (Ahmad 2010). Nowadays, it is extensively used in the cosmetic and pharmaceutical sectors (Felipe 2000, Schirra 1997). Sweet almond oil is extracted from the dried kernel of the almond plant and is known for its anti-inflammatory, immunity-boosting, anti-hepatotoxicity, and massage benefits (Ahmad 2010). Additionally, bitter almond oil is used as a flavoring in foods, soft drinks, and medicines, and as a fragrance in perfumes, soaps, and cosmetics. It is important to note that the hydrocyanic acid, which is responsible for the bitter taste, is removed before the oil is used (Wirthensohn et al 2010). According to some researchers, results of work on almonds indicate that they have high oil yield and are a potential feedstock to produce biofuels and oleo chemicals (Moen et al 2008).

Almond residues are a great source of raw materials for creating energy and value-added products. These residues contain a significant amount of energy that can be transformed into various forms of usable energy by using different commercially available processes. Pyrolysis is considered to be the most suitable process to convert almond residues into liquid fuels, biochar, and activated charcoal (Saberi-Moghadam et al 2015).

Gasification is a high-temperature partial oxidation procedure that turns lingo-cellulosic feedstocks into a combustible gas mixture known as syngas or production gas. The procedure usually takes place between 700 and 1,100 degrees Celsius. The economics of hydrogen production from biomass gasification indicate that hydrogen may be economically produced. Furthermore, studies suggest that almond shells contain approximately 23% syngas (hydrogen and carbon monoxide) and have a low calorific value (LHV) of about 4 MJ/m3. This gas is classified as low to medium value(Akubude et al 2016).

The almond shells underwent pyrolysis to produce solid char, liquid hydrocarbons, and gases. In addition, a study on the widespread use of bitter almond shells shows that almond shells are suitable feed for the production of activated carbon (Akubude et al 2016).

The use of biomass feedstock as an alternative to fossil fuels has an additional meaning in terms of climate change, as biomass has the potential to be carbon neutral. For example, using biodiesel or its mixes in automobiles produces less gaseous pollutants and emits no net carbon dioxide or sulphur to the atmosphere than normal fuel. Furthermore, producing biodiesel from non-edible almond seeds could serve as a vital poverty alleviation initiative for the rural underprivileged population. This could not only ensure energy security in general and for rural areas in particular but also improve the non-agricultural sector in rural areas. (Akubude et al 2016).

Almond shells were often used to make activated charcoal moreover, sliced almonds were used to make activated charcoal so that, high calorific value of almond residues is almost the same as that of forest residues 18.4 MJ/kg (Nwosu et al 2008). Almond residues have been used directly or after some treatments as absorbents to remove metals and colorings, as animal feed ("New World Encyclopedia" 2008, FAO 1995, Jafari 2011, Yalchi 2011).

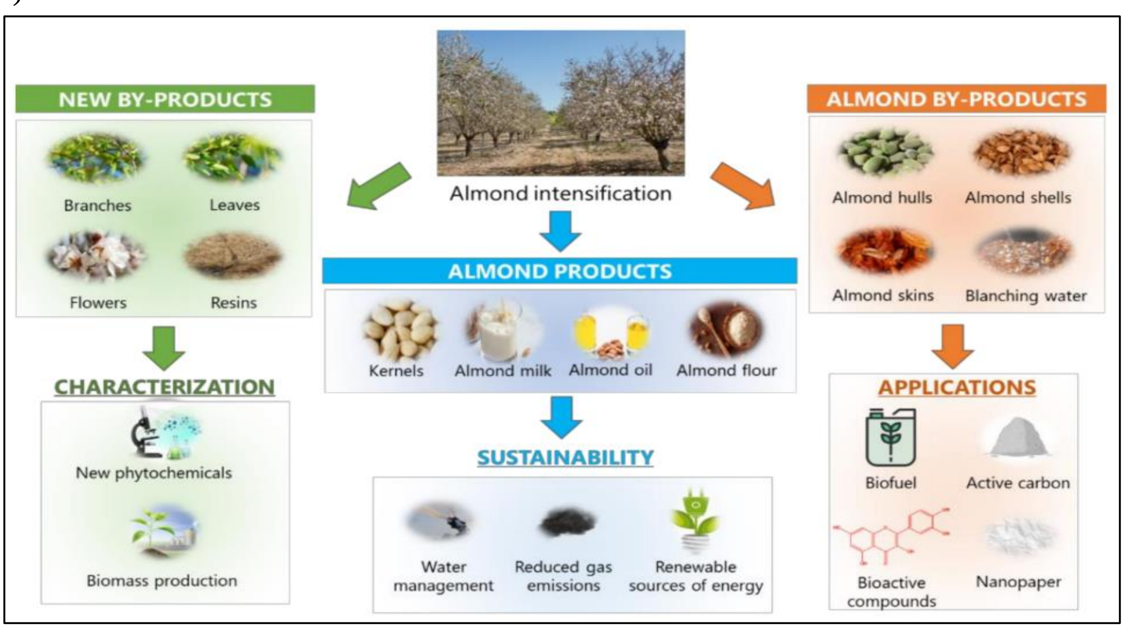

Fig. 3. shows the potential future opportunities for making use of almond products and by-products (Garcia-Perez et al 2021).

6. The nutritional value of almonds and their health importance

Table (2) displays the composition of almonds (Kalita et al 2018)

Nutrients	Units	Value per 100 g Whole Almonds
Proximates		
Calories	kcal	579
Water	g	4.41
Protein	g	21.15
Lipids (total)	g	49.93
Dietary fiber (Total)	g	12.5
Sugars (Total)	g	4.35
Ash	g	2.97
Minerals		
Calcium	mg	269
Iron	mg	3.71
Magnesium	mg	270
Phosphorus	mg	481
Potassium	mg	733
Sodium	mg	1
Zinc	mg	3.12
Copper	mg	1.03
Manganese	mg	2.18

Almonds have natural properties that make them healthy. They contain high amounts of fiber, unsaturated fatty acids, antioxidants and phytochemicals which help protect the body. When consumed, almonds have either neutral or positive effects on glycemia/insulinemia and satiety. More studies are needed to determine the effects on gut peptides. (Mori et al 2011b). Almonds are also traditionally used to heal wounds, anemia, insomnia, headaches, sore throats, brain infections, kidney diseases, urinary tract infections, uteralgia, pityriasis, and hysteria(Mushtaq et al 2015). The main pharmacological properties of almonds include hepatoprotective, antidepressant, antioxidant, memory-enhancing and anti-aging effects (Mushtaq et al 2015).

Almonds are high in magnesium, which helps control blood sugar; It lowers blood sugar levels and improves insulin functions and helps lower blood pressure. Obesity and high blood pressure can be caused by a lack of magnesium (Javaid et al 2019). Almonds are high in protein, fiber and healthy fats. They can help reduce hunger and calorie intake(Javaid et al 2019).

Consuming almonds in higher quantities has been linked to a reduced risk of cancer. Research indicates that those who consume more almonds have a 2 to 3 times lower risk of breast cancer. Additionally, studies on rats have shown that almonds may reduce the risk of colon cancer. In humans, consuming almonds has been linked to increased levels of HDL cholesterol and reduced levels of LDL cholesterol (Javaid et al 2019).

7. Environment requirement.

7.1. Temperature and humidity.

Climate significantly affects plant physiology and yield production. Temperature, precipitation, humidity, and luminosity are crucial during the phenological stage (Jin et al 2020). Almonds typically grow in regions where the average temperature ranges between 15-20 degrees Celsius annually (Fernandes de Oliveira et al 2023, Queirós 2020).

Photosynthesis is most productive during fruit development when the temperature ranges between 20°C and 30°C (Queirós 2020, Cultifort 2023). Temperatures outside the 15°C to 35°C range can negatively impact tree growth (Queirós 2020, Karaat & Denizhan 2023). The mesocarp detaches from the kernel shell under ideal environmental circumstances, disclosing the stone during fruit development. (Freitas et al 2023).

The level of tocopherol homologues present in nut crops can be influenced by temperature and drought during the growth of the fruit or nut (Maranz & Wiesman, 2004). Thus, temperature is a significant factor that affects the accumulation of tocopherol in different species, including almonds (Kodad et al 2018).

Various environmental factors can affect the pollination behaviour of bees, including wind, low temperatures, and rain. Pollination activity is observed to be the highest when the temperature ranges from 15 to 30 degrees Celsius. However, when the temperature drops to 10 to 12 degrees Celsius and there is precipitation, pollination activity is hampered. Bees become less active or may even stop their activity altogether in such conditions (Socias i Company et al 2017, Cultifort 2023, Thomas 2019).

Seeds are susceptible to mould development during maturity, harvesting, and storage due to high humidity and temperature fluctuations (Arya & Monaco 2007). Before processing, large stockpiles of almonds, including their hulls and shells, are stored under tarps. However, this can increase humidity levels, leading to fungal growth and aflatoxin production caused by Aspergillus fungi (Lampinen & Michalaides 2008).

It is crucial to consider the impact of high temperatures and humidity on the quality and safety of almonds during transportation. it is important to keep in mind that almonds that have been peeled are more susceptible to damage compared to those that are still inside their shells. The protective barrier provided by the shells helps to prevent moisture and oxygen exchange. Hence, peeled almonds are more likely to undergo changes in their water content and lipid oxidation, which can lead to faster spoilage when compared to almonds still inside their shells (Kazantzis et al 2003).

7.2. Photoperiod:

Many fruit crops are affected by the amount of daylight they receive, which can impact both their flowering and growth patterns leading up to the dormant season. For deciduous plants in the Prunus family, flower buds can appear along with new shoots that emerge throughout the year. As autumn arrives, the photoperiod becomes a crucial factor in slowing down the growth process, allowing the plant to prepare for leaf shedding, increase cold resistance, and eventually enter dormancy (Alonso 2017).

In most almond leaves, the rate of photosynthesis reaches its maximum at about half of full sunlight because the photosynthetic apparatus becomes 'light-saturated' at this point. (DeJong 1996).

In recent times, various studies have emphasized the importance of light in enhancing the productivity of stone fruit crops. The energy balance of a plant and the photosynthetic capacity of its leaves are influenced by solar radiation. Moreover, it can also impact particular photomorphogenic or photoperiodic responses (Alonso 2017).

7.3. Chilling unit:

Almonds have specific environmental requirements that need to be met in order to end their dormancy. Chilling is required to end endodormancy, while a certain amount of heat is necessary for flowering (Egea et al 2003). Estimating the chilling requirements is crucial for selecting appropriate tree cultivars, maintaining profitable plantations, and minimizing the detrimental impact of climate change (Gao et al 2012). After accumulating enough chilling hours, the plant initiates its reproductive process, which becomes apparent through the emergence of inflorescence (Sakar et al 2019). In Prunus species, flower buds develop before leaf buds (Sakar et al 2019). Bloom season typically begins in late January for early varieties and lasts until April for ultra-late varieties (El Yaacoubi et al 2019; Di Lena et al 2018). In addition, the process of flowering in plants is highly influenced by weather conditions, particularly the air temperature and the occurrence of spring frosts (Sakar et al 2023). Research conducted by Martínez-Gómez et al (2017) suggests that exposure to temperatures of -3°C for a duration of 30 minutes can be harmful to plants. Moreover, temperatures of -2°C and -0.5°C can cause damage to flowers and fruits, respectively.

Various methods have been created to determine the necessary amount of chilling and heat. The chilling hours model (Weinberger, 1950), the Utah model (Richardson et al, 1974), and the dynamic model (Fishman et al 1987a, 1987b) are some of the most commonly used chilling models. In addition, the Growing Degree Hours Model (Anderson et al 1986) is the standard model used for estimating heat requirements. Multiple studies have elucidated the dormancy process and predicted the necessary amounts of chilling and heat required for almonds.

Alonso et al developed a model (2005) that used data from multiple years to calculate the mean transition date from endodormancy to eco-dormancy for 44 different almond cultivars that covered the entire almond bloom range. They conducted a study to investigate the relationship between dormancy temperatures and the timing of full bloom in almond cultivars. The research revealed that the chilling requirements of the different cultivars ranged from 400 to 600 Chill Units, while their heat needs varied from 5500 to 9300 GDH. The optimal temperature for chilling varies depending on genetic variability. Some studies have suggested that cultivars with a low chill factor need higher temperatures to accumulate enough chill units than those with a high chill factor (Gurdian and Biggs 1964). Furthermore, each cultivar may react differently to abrupt temperature changes, such as extreme temperatures or alternating cold and warm temperatures in temperate locations during spring (Couvillon & Erez 1985, Erez & Couvillon 1987).

8. Almond flowering and flowering time:

The almond is the species of *Prunus* that blooms the earliest in comparison to all cultivated species (Alonso Segura et al 2017).

One of the most important agronomical characteristics of almonds is flowering. The phenological phase of almond flowering is caused by the consecutive application of two temperature stimuli: To begin, the flower bud remains dormant until it has had sufficient exposure to cold temperatures. When it hits a certain threshold. Second, flowering within the bud is triggered and progresses at a temperature-dependent rate until the bud blooms (Ashcroft et al 1977).

Flowering occurs only when the plant has received the necessary amount of both cooling and heating, meeting the specific requirements (Sánchez-Pérez et al 2014, Alonso Segura et al 2017, Martnez-Gómez et al 2017). This makes almond trees in more temperate growing areas susceptible to spring frosts and limits their planting to more temperate, almost subtropical but arid climates (Mori et al 2011). Almond blossom buds are able to resist cold temperatures and can tolerate temperatures as low as -7°C. (Socias i Company et al 2017). When flower buds open and display their petals, their sensitivity rises until the petals fall off (Brewer 1978). Therefore, early flowering, when the spring cold and late spring frosts occur, may damage reproductive organs and reduce productivity (Sakar et al 2019).

The process of flowering only occurs after the end of the dormant period. Endo-dormancy refers to the state in which a tree is unable to initiate the process of bud rupture for flowers or vegetation even when the temperature is moderate. Endo-dormancy is followed by eco-dormancy, which happens in late winter and early spring as a result of temperatures that are not favourable to growth (Lang et al 1987, Campoy et al 2011, Sánchez-Pérez et al 2007).

It is essential to grow at least two cross-compatible almond cultivars with overlapping flowering periods on the same orchard to ensure good pollination and higher commercial yield since most almond cultivars are self-incompatible. (Martínez-García et al 2012). According to Williams (1970), wind doesn't have a significant impact on pollination. However, effective pollen transfer from an anther to receptive stigmas can be achieved with the help of pollinating insects. Among them, honeybees are considered to be the most effective (Socias i Company et al 2017). It is recommended to place 2.5–5 hives per hectare in almond orchards during blossoming to enhance flower visits and improve pollination (Free 1970, Rikhter 1972, Meith et al 1974). Identifying the susceptibility of yield to frosts is crucial for flowering time, which has low heritability (0.20) and is closely associated with temperature (Dicenta et al 1993).

Flowering time varies significantly among different almond cultivars. Moreover, varieties with an early or medium flowering time have a long flowering period, This can be regarded as advantageous for two reasons. First, the long blossoming time helps to avoid the damaging impacts of frost and potentially devastating weather. (Socias i Company 1998).

Second, it is a desirable characteristic. regarding the early ripening of fruits (Dicenta & García1992). Late-flowering cultivars have a shorter flowering period, which is one of the primary goals of almond breeding and is considered a desirable characteristic in frost-prone areas (Socias i Company et al 2003, Socias i Company et al 2012 , Dicenta et al 2016).

9. The almond breeding aspects.

9.1.Breeding objectives

Breeding objectives often fall into one of the following three categories: raising yield, raising market quality, or lowering production costs. Inadequate cross-pollination is typically a significant factor in determining commercial production because almond is self-sterile (Asai et al 1996, Micke 1994).

A key gene regulates self-compatibility and self-incompatibility.(Dicenta & Garcia 1993b), Modifier genes are also essential (Gradziel et al 2002, Socias i Company et al 2005). While several almond species can self-pollinate, only the self-compatible genes from *P. mira*, *P. persica*, and *P. webbii* have resulted in fruit set above the commercially desirable 30% (Gradziel et al 2001b).

Breeding populations resulting from crosses between different species segregate for self-compatibility in accordance with the expected Mendelian ratios, which are governed by a single gene (Socias i Company & Felipe 1988, 1992, Dicenta & García 1993a, Gradziel et al 2001). *P. mira*, which exhibits high levels of self-pollination, displays the highest selfing percentages when crossed with almond after the self-compatibility gene was introduced. In 1990, Socias i Company conducted a review of the ongoing efforts to breed self-compatible almond varieties over the long term.

Improving the quality of almonds has become a primary goal in breeding (Socias i Company et al 2008). Defining an ideal kernel quality is a challenging task due to the fact that consumer preferences vary greatly (Janick 2005). Kernel quality should consider both the chemical composition that determines the specific taste and the physical attributes that affect usability. Therefore, the preferred shell type varies according to regional customs. In Mediterranean countries, a hard shell is preferred, in California and other similar areas with a developing system, a soft shell is preferred (Badenes & Byrne 2012).
Because of its favourable impacts on human health, the chemical composition of almond kernels is significant for breeding. These benefits are attributed to the almond's antioxidant compounds, high oleic acid content, and desirable nutrient and fiber levels. While newly released almond varieties do not yet include these aspects, they are gaining attention from breeders, growers, processors, and consumers (Gradziel & Martínez-Gómez 2013). A recent summary by Socias i Company et al 2008a) reviews almond quality components and their heritability.

The primary objectives of breeding are genetic improvement and cultivar development. The former aims to transfer self-compatibility to local genetic backgrounds, while cultivar development involves large commercial plantings for profitability. Commercial success requires the absence of deficiencies in multiple characteristics, not just superior performance in one or a few traits. This task entails optimising numerous important breeding goals, which are classified as genetic improvement and cultivar development. In locally adapted genetics, genetic enhancement improves specialised features such as disease resistance. Substantial commercial plantings during the lengthy production period necessary for commercial viability indicate cultivar development success. Rather than outstanding performance in a few qualities, cultivar success is determined by the absence of defects in several fruit and tree attributes required for commercial viability (Gradziel & Martínez-Gómez 2013).

The biggest challenge in breeding strategies for almond crops is optimizing numerous essential traits simultaneously; this includes using molecular-based techniques and other marker-assisted selection (MAS) (Gradziel & Martínez-Gómez 2013).

9.2. Breeding through Interspecific Hybridization

Researchers are incorporating breeding material from other regions to increase genetic variability for desirable characteristics like self-fertility and resistance to diseases (Kester & Gradziel 1996, Socias i Company 1998, Martínez-Gómez et al 2003). Many of these cultivars may have originated from different species (Kester et al 1991, Ladizinsky, 1999; Socias i Company, 2002).
Certain features of *P. dulcis* may have been improved by natural hybridisation by the transfer of genes from other almond species. *P. webbii* grows throughout the Mediterranean region and naturally hybridises with cultivated almonds in Italy (particularly Sicily), Spain, and Greece, resulting in introgression and self-fertility (Gradziel & Martínez-Gómez 2013). According to a (2002) study by Godini, *P.webbii* is believed to be the source of these characteristics in the Italian region of Apulia. Gradziel et al (2001b) and Gradziel (2001) have reported that controlled crosses can be used to breed hybrids between *P. dulcis* and

other almond species belonging to Sections Euamygdalus and Spartiodes. Even though hybridization with Section Lycioides is also possible, it may be more challenging, and crosses with Chamea-mydalus are even more difficult to achieve. Despite both physical and differences in development, *P. persica*, which is the cultivated peach, and its wild relatives, *P. mira* and *P. davidiana*, can be easily crossed with P. dulcis. These crosses have been discovered to be valuable as rootstocks and sources of commercially useful characteristics (Gradziel et al 2001 , Gradziel 2001).

Incorporating breeding material from other places improves breeding choices for desirable qualities such as self-fertility and disease resistance. *P. dulcis* and other almond species have commonly hybridised, resulting in introgression (Godini 2002).

10. Propagation

Seed propagation is still standard in many regions, including the Middle East and Central Asia (Kester et al 1990). Conventional seed propagation resulted in substantial genetic heterogeneity due to almond's self-incompatible nature (Kester et al 1990, Socias i Company & Felipe 1992). A localized ecotype or landrace may have limited genetic diversity, resulting in efficient reshuffling that still produces genetic variability. Over the last century, the replacement of native cultivars and landraces with commercially chosen breeding releases has resulted in a severe reduction in overall crop variety. In Europe, many countries have replaced their cultivars with Puglia and French 'Ferragnès' cultivars that bloom later in the season (Grasselly & Crossa-Raynaud 1980).

Early almond production was concentrated in particular areas, and regional varieties developed because of selection for good local adaptability. Local genotypes with considerable variation proliferated because of seedling propagation. However, because they came from a small pool of germplasm, they frequently needed a large amount of genetic variety. This condition is common in remote regions such as the Mediterranean islands, solitary valleys, and the Canary Islands. The most promising seedlings were handpicked for clonal propagation, including several centuries-old choices (Estelrich 1907).

Furthermore, the peach and almond peach hybridization rootstocks have good graft compatibility with almonds. Clonal hybrids of almonds and peaches are becoming increasingly common in Europe. Tolerance to calcareous and/or other poor soils; ease of multiplication by hardwood cuttings and/or micro-propagation; ability to distinguish rootstock growth from scions (i.e., red leaves) to identify unsuccessful scion bud growth; and high vigour are all desirable qualities in new rootstocks. It is becoming increasingly vital to develop hybrids with greater tolerance to heavy and water-saturated soils (Xiloyannis et al 2007).

Grafting was used to propagate almonds in the first century AD, allowing for a better selection of scions for clonal multiplication (Columella 1988). Clonal cultivar selection was insignificant until graft and bud propagation became popular in the past 150 years. Clonal propagation is used to identify and propagate hundreds of cultivars in specific production locations, capturing regionally adapted elite genotypes (Estelrich 1907, Kester et al 1990).

Most nurseries use rootstocks planted the previous year for late spring or early autumn budding. T-budding is typically accomplished by separating the scion cultivar bud from the inner woody tissue, which is actively growing and, hence, easily separated. Chip budding is typically done when growth is insufficient to ensure easy separation of the bark from the inside of the wood (Gómez Aparisi & Felipe 1984).

Mini-chip budding on small in vitro propagated rootstocks is becoming increasingly common. This strategy, as opposed to just planting bare-root plants during inactive seasons, allows for the creation of plants in pots, table-budding operations, quick plant growth in greenhouses, sale of plants in containers, and the potential of field planting over a longer period of time. Appropriate irrigation and fertilization promote strong growth of the scion bud in T-budding, allowing for the development of a marketable tree in only one season of growth. Mini-chip budding decreases production time to 3-4 months and can be performed year-round (Badenes & Byrne 2012).

In all budding approaches, the shoot above the placed bud is eliminated once it begins to grow. The most convenient rootstocks are those with red leaves for this operation because they allow for easy distinction between the scion and rootstock (Badenes & Byrne 2012).

Almond has been found to be more challenging than other species for micropropagation and callus regeneration (Kester & Gradziel 1996), stifling the development of other propagation mechanisms. In vitro propagation is widely utilised to create almond peach hybrid rootstocks. with many plants in Mediterranean countries and California being propagated in this manner (Badenes & Byrne 2012).

11. Almond orchard management

Selecting the appropriate spacing for plants and performing tree planting tasks are crucial. Any mistake made during this phase can significantly impact the orchard’s output throughout its entire commercial lifespan. Even if the error can be corrected, it comes at a substantial expense (Arquero & Jarvis-Shean 2017).

11.1. Field practices

11.1.1. Ploughing

It is recommended to perform deep ploughing of at least 50 cm before planting to encourage root growth and enhance water absorption in the soil. One of two main types of ploughing machinery may be used for this task: the soil or subsoiling is turned over by a deep plough, which is the most effective way to break through the lower soil layers. In the first type, the placement of the various soil profiles is somewhat altered. As a result, the second ploughing, which should be done cross-directionally when the soil is dry, is advised. To remove weeds and prepare the soil for planting, shallow ploughing may be performed later. This can be performed using various tools, such as disc or spur harrows, cultivators, or rakes. It is important to clear out any previous plant material and stones, modify the soil, set up irrigation and create access roads before starting any planting operations (Arquero & Jarvis-Shean 2017).

11.1.2. Planning to plant trees

When planning to plant trees, three important factors must be considered: the environment, the growth potential of the trees, and the machinery needed for maintenance. It is essential to ensure that each tree has sufficient soil to obtain all the water and nutrients it needs. When the soil quality is low, more space is necessary between trees to accommodate larger soil volumes. In orchards without irrigation and with poor soil quality, it is best not to plant more than 150 trees per hectare to avoid potential drought problems (Arquero 2013).

At present, almond orchards are established through the use of grafted plants, which are grown in nurseries and sold either as bare-root specimens or with soil. Planting bare-root plants should only be done between December and February, when the plants are dormant. It is important to maintain the moisture of the roots from the time they are removed from the nursery until they are planted in the soil. Potted plants with soil around their roots can be planted at any time; however, autumn may be the best season to do so if there is no risk of frost. Spring planting should be done before May-June, long before the high summer heat (Arquero & Jarvis-Shean 2017).

11.1.3. Planting distance

The growth of plants depends on various factors, including the strength of climatic conditions and plant material (both scion and rootstock). For orchards with high density, it is crucial to select plant material that is not excessively vigorous. Additionally, to avoid overshadowing and limitations in machinery transit, it is recommended to increase the planting distance (particularly between lines) under optimal environmental and management conditions, such as irrigation. Currently, irrigated commercial orchards have rows that are 7–8 m apart and tree distances within the rows of 5-7 meters. This results in planting densities of 179 to 286 trees per hectare, based on the plant material, environmental and growing conditions, and type of harvesting equipment (Arquero 2013).

11.1.4. Pollination

When growing self-incompatible cultivars, it is important to properly design pollinizers. It is advisable to have a minimum of 30% pollinizers to ensure the best possible pollination outcomes. It is also advised to avoid exceeding two consecutive rows of the same self-incompatible cultivar. To make mechanical harvesting easier, it is advisable to have two rows of the same cultivarThere is no need for another cultivar if the cultivar is self-compatible. The orchard may include only one variety. It may be beneficial to have two cultivars in large orchards but in lower percentages than for self-incompatible cultivars. The blooming time is the most important factor to consider when choosing a polliniser. It is important to take into account the ripening time in order to ensure that it concurrency with the main cultivar. Pollinators should have agronomic and productive value as cultivars, as they take up valuable space in the orchard (Arquero & Jarvis-Shean 2017).

11.2. Pruning

Pruning is typically done to assist with cultural practices, such as spraying and harvesting, and to remove dead and diseased wood. Throughout history, pruning has also been utilized to stimulate tree growth. However, studies conducted over a long period have revealed that trees that are slightly pruned (pruned for cultural practices and eliminated of diseased twigs) produce similar or better yields than those that are pruned more heavily. The intensity of pruning required primarily depends on each cultivar's vegetative pattern, as explained by Arquero et al. (2008). The way an orchard is pruned depends on various factors such as the density of planting, the growth habits of the cultivar, the strength of the trees, the irrigation system, how the orchard is managed, the harvesting method, and the availability and cost of labor and equipment (Arquero & Jarvis-Shean 2017).

Pruning cuts are classified into two types: thinning cuts and heading cuts. Each variety causes a varied growth response and should be used for different purposes. Thinning cuts are made to direct development in a specific area and/or to eliminate dead or diseased wood. To do this, the limb or branch should be completely removed by cutting it at the branch collar where it originates from the parent limb (Arquero & Jarvis-Shean 2017). When making heading cuts, the aim is to promote healthy and plentiful growth immediately below the cut. This was accomplished by growing multiple new shoots while pruning one major branch or shoot. Remove the terminus of an existing branch to make a heading cut. This triggers the growth of multiple buds just below the cut, resulting in a dense and robust area of new branches (Arquero & Jarvis-Shean 2017).

Various tools can be used. Pole saws and long-handled loppers are the most commonly used tools for cutting almond limbs. They come in manual, electric, or air-powered varieties. Handsaws and chainsaws are also frequently used, with both air-powered and mechanical options and electric and combustion engine models available. These tools are designed to fit different sizes of almond limbs and cutting points, so they are suitable for various cutting needs. Choosing the appropriate equipment is crucial based on the size of the orchard (Arquero & Jarvis-Shean 2017). It is important to use clean and sharp equipment while ensuring that they do not touch the ground. (Arquero &Jarvis-Shean 2017).

11.3. irrigation

Almond trees in the Mediterranean region have been traditionally grown without irrigation (Espadafor et al 2017, Oliveira et al 2018). Because of the higher output, the setting up of irrigation systems in freshly planted orchards has raised water demand in these areas. (Romero & Botía 2006, Durán-Zuazo et al 2020). Assessing the water requirements of crops and their efficiency in water usage is becoming more crucial, particularly in regions with scarce water availability, such as the Mediterranean Basin (Navarro et al., 2009). As a result, sustainable irrigation methods have been introduced in some Mediterranean regions. (Egea et al 2010). Selecting plant materials such as rootstock and scion genotypes with less water needs or enhanced water use efficiency (WUE) is critical for water-lacking areas' sustainable agriculture. (Álvarez et al 2019). It is crucial to understand the water requirements of each cultivar to choose the appropriate plant material and prevent underestimating irrigation needs. This can lead to increased costs, water waste, and negative environmental impact, particularly in water-scarce regions such as the Mediterranean Basin, where some crops may not receive sufficient water (García-Tejero et al 2015, Álvarez et al 2023).

Although almond trees have a high tolerance to water stress, irrigation is generally considered essential to improve crop performance. Effective irrigation is the most critical factor impacting almond yield and quality among agricultural practices. (Lipan et al 2018). Egea et al (2013), García Tejero et al (2018a) also support this claim. According to research, trees in California typically produce between 137-147 cm of water, while they can survive on as little as 19 cm (Shackel et al 2011; Sanden 2007). This increase in growth and yield is caused by higher rates of photosynthesis and respiration resulting from reduced water stress, leading to increased productivity (Doll 2017). Different techniques have been conducted worldwide to control irrigation water utilisation and crop production, such as deficiencies irrigation, orchard vegetation management, mulches, and foliar implementation of reflective or anti-transpirant film protection (Girona et al 2005, Rosati et al 2006, García-Tejero et al 2018a, Lipan et al 2018, Guti´errez-Gordillo et al 2019, Lepsch et al 2019, Galindo et al 2020). It is known that almond trees are highly productive with water (García-Tejero et al 2018a), and have strong drought tolerance (Goldhamer et al 2006). Deficit Irrigation (DI) was established for almond trees along with other crops such as olive trees and vineyards (Barreales et al 2023).

Two of the most common methods for watering an almond plantation are surface irrigation and pressurized systems. Surface irrigation systems, such as flood and furrow systems, often result in higher irrigation efficiency because of faster water movement from the field's beginning to its end. Sprinklers, drips, and micro-sprinklers are examples of pressurized systems that distribute water according to design characteristics such as the type and size of the nozzle, riser height, and operating pressure. Pressurized systems require more maintenance and filtration than surface-based systems. However, water is distributed via pressurized systems such as sprinklers, drippers, and micro-sprinklers based on several design considerations such as nozzle size and type, riser height, and operational pressure. Compared with surface-based systems, pressurized systems require more maintenance and filtration (Doll 2017).

After the sprouting, plants experience a period of rapid growth. The objective of this phase is to develop shoots and leaves to carbohydrate reserves for future yields and establish fruiting positions. Water requirements are low at first, but increase as the canopy grows. Water requirements for trees begin low and gradually increase as the leaves expand and the canopy grows. During cooler temperatures, shorter days, and higher humidity, trees need less water and can rely on stored soil water from winter rains. This typically results in relatively stress-free growth until full leaf expansion around 4-5 weeks after bloom (Doll & Shackel 2015).

Micro-irrigation systems minimize water losses due to evaporation and apply water frequently in smaller amounts. Proper maintenance is necessary for the distribution of water. Soil intake rates should not be exceeded (Schwankl et al 2007). Reducing water applications in flood or furrow irrigation systems is difficult because they require a minimum amount of water to move across the field. The only option is to increase the interval between irrigation (Doll 2017).

Irrigation timing should consider the impact of rising temperatures and wind speeds on evaporative losses. Thus, it is recommended to start irrigation in the evening and finish in the late morning to minimize evaporative losses (Doll 2017). The optimal run time for micro-sprinkler systems should be at least 6 hours to minimize water loss due to evaporation, but not exceed the soil intake rates or water-holding capacity (Doll 2017). Drip systems require less run time because of the reduced wetted area (Doll 2017).

11.4. Fertilization

In the fruit industry, it is crucial to maintain a balanced ratio of micronutrients and macronutrients for the reproductive and vegetative development of fruit plants (Datnoff et al 2007). Furthermore, the fruit yield and quality are influenced by the biological characteristics of the variety, appropriate soil and climatic conditions, and controlled plant nutrition (Dzamič & Stevanović 2000, Glintic & Krstic 1990).

Nutrition is essential for the proper growth and development of almonds, including healthy flowering, fruiting, and high-quality yield.This is achieved by replenishing the essential elements in the soil (Mengel et al 2001). However, determining the proper doses, types, time, and method of fertilizer application depends on the soil's nutrient content. Frequently, soil application does not yield the expected results due to physical properties or dryness (Saric et al 1986; Šaciragic and Jekic1988). Foliar feeding or applying fertilizers through the leaf is therefore crucial for the successful production of almonds. Foliar fertilisation is a method that allows for prompt correction of acute nutrient deficiencies. Both macro and micro components are present in foliar fertilizers (Kostadinov & Kostadinova 2014, Stojanova 2017, Stojanova 2018, Stojanova 2020). The advantage of foliar fertilizing is its rapid effects and ability to be performed multiple times during vegetation growth

(Stojanova 2018). Foliar nutrition and soil positively impact almond growth, ultimately improving production quality and quantity (Stojanova et al 2022)

In any cultivation system, the plant's nutrient availability is affected by the type and quantity of fertilizer applied, timing of application, and solubility in water (Lester 2007). Furthermore, agricultural irrigation has a considerable impact on plant productivity, last structure, and physical attributes of the fruit (Valverde et al 2006).

Organic fertilizer has enormous potential due to its versatility and advantages in business, environment, and society. Among many other advantages, it helps to improve lives, food safety, resilience to climate change, raise yields, lower financial risks, open up new markets, improve the environment and health, and stop desertification (Terdoo & Adekola 2014, Diallo et al 2020). Although organic farming has the potential to improve soil, ecological, and human wellness and also increase the farmers' revenue, farmers' adoption of organic fertiliser has been gradual due to a lack of information about organic farming(Farouque & Sarker 2018).

The current low agricultural productivity is mainly due to poor soil fertility, as well as other factors such as inadequate input supply, low-quality seeds, lack of knowledge and techniques, inefficient management, labor shortage, and insufficient infrastructure (Neuhoff et al 2014).

The effectiveness of organic fertilizer in crop growth is influenced by several factors, including the level of awareness among farmers about the environmental benefits of using organic fertilizer and their knowledge of its application(Thapa & Rattanasuteerakul 2011). Farmers need to understand the importance of improving soil quality and utilizing organic fertilizers for sustainable agriculture(Dhar et al 2018). According to Sodjinou et al (2015), the use of organic fertilizer requires frequent communication between farmers and extension officers/agents because of its knowledge-intensive nature. For farmers to be educated on the technical aspects of organic farming, a functional extension system is critical. This system would also help in distributing information and open discussion forums (Suvedi et al 2017).

11.5. Harvesting

In traditional Mediterranean almond cultivation, manual harvesting accounts for 30-35% of direct production costs. Due to the increasing difficulty in finding part-time seasonal workers, this operation has become more challenging. The percentage of conventional orchards that remain unharvested is on the rise due to a shortage of labour, low productivity, and physical difficulties such as unevenly grown trees and difficult terrain. The use of harvest mechanisation provides numerous advantages for orchard management, including a safer working environment for employees, reduced labour requirements and production costs, and the production of high-quality fruit. To achieve the desired results, it is essential to operate the various harvesting machines, and It is vital to control harvesting costs for profitability and meet future demands in all countries that produce almonds (Carbó & Connell 2017).

Almond harvesting usually starts in mid-July for early-ripening varieties and lasts until mid-October for later-ripening ones. The majority of almonds are sold as dry fruits, as they need to fully ripen before being harvested. Green almonds are commercially available only in France and North Africa during May and June (Carbó & Connell 2017).

In the Mediterranean region, almonds should be harvested when their hulls are relatively dry and dehiscent, with minimal nut fall before maturity, to ensure maximum efficiency of harvesting machines (Carbó & Connell 2017). The harvesting process involves using machines to shake, sweep, collect nuts, and transport them to a processing location. To ensure that no nuts are left behind during harvest, a small amount of manual raking is necessary. The harvest costs associated with in-field operations account for 18% of the total direct production expenses (Connell et al 2012).

The ideal method for harvesting involves shaking the tree with a precise oscillation and frequency balance that prevents harm to the trunk, branches, leaves, and root system to a lesser extent. Trunk shakers have prompted the development of better nut collection systems, The nut removal rate typically ranges from 85% to 95%, depending on the orchard and how the harvest is managed. Mesh and inverted umbrellas have been improved to collect more nuts. An efficient way to harvest nuts in the Mediterranean region is by using a trunk shaker with an attached inverted umbrella (Carbó & Connell 2017).

The mechanized gathering of nuts significantly lowers the requirement for manual labour and reduces costs. Advancements in agronomics, such as cultivating varieties for mechanical harvesting, trimming for vibration transmission, and increasing production, will make almond farming more profitable (Carbó & Connell 2017).

It is common for hailstorms to cause almonds to drop earlier than expected before they are harvested. This condition allows for an evaluation of the performance and feasibility of the mechanised collection operation during the harvesting process. A horizontal cylindrical cage consisting of equally spaced steel rods (2.87 m x 0.30 m) was used for hulling. The hulling machine consisted of a spinning shaft with moulded steel rods that separated the hull from the grain (Pascuzzi 2017).

During the growth cycle of almonds, harvesting is the most labour-intensive stage. Even today, it is often done manually by knocking the nuts out of the tree with long sticks during hull dehiscence and then collecting them in nets that are spread out on the ground. It is worth noting that an average of 13-17% of the total commercial value of the almond crop is attributable to the harvest alone (Schiril 2005). Traditionally, hulling and drying are done away from the farm. The usage of trunk shakers in olive harvesting, on the other hand, shows that they can also be employed for almonds (Manetto & Cerruto 2013, Vivaldi et al 2015). The use of trunk shakers increases productivity, and self-propelled shakers with a reversed-umbrella interceptor further improve it (Manetto et al 2017,Bianchi et al 2013).This solution seems most effective for managing almond orchards. The work chain consists of only two or three units, which reduces costs by 20% (Clodoveo et al 2014, Cecchini et al 2011).
Almonds bloom in February, mature into July, and can be harvested as late as October, depending on the variety, with the trees dormant from November to January (UCANR 1996). Almonds are harvested by shaking the trees, sweeping the fallen nuts into windrows, and collecting them from the orchard floor. Weeds on the orchard ground can interfere with equipment and reduce harvest efficiency. Therefore, many growers use intensive herbicide programs to keep the ground bare prior to harvest. (Connell et al 2001, UCANR 2002).

11.6 Pests and diseases

Genetic improvements in scions and rootstocks that increase resistance to diseases and pests can significantly reduce production costs. The most prevalent severe diseases that affect almond foliage are shot holes caused by *Stigmina carpophila* (also known as *Coryneum beijerinkii*), travelure (*Fusicladium amygdali*), polystigma (*P. ochraceum*), fusiccocum (*Fusicocum amygdali*), and anthracnose (*Gloeosporium* amygdalinum and *Colletotrichum acutatum*) (Gradziel & Martínez-Gómez 2013).

Blossom and twig blight, a fungal disease that limits crops worldwide, as a result of *Monilinia laxa* and *Monilinia cinerea*. These fungi pose a threat to flowers, particularly during rainy bloom seasons. *Botrytis cinerea* can also be an issue in the same conditions (Özdemir et al 2021).

Infections of the kernel by the aflatoxin-producing *Aspergillus flavus* are a serious issue. In particular, this applies to areas that experience frequent insect damage. (Gradziel & Kester 1994, Gradziel & Wang 1994, Gradziel et al 2000, Dicenta et al 2003). Although fungicides have been successful in disease control, it is crucial to consider natural resistance due to the ongoing loss of agrochemicals (Martínez-García et al 2004).

When nuts are harvested in California, the peach tree borer (*Anarsia lineata*) and navel orangeworm (*Paramyelois transitella*) can seriously harm the nuts (Rice et al 1996). According to Gradziel & Martinez-Gomez (2002), this issue is caused by the susceptibility to delicate, paper-shelled, and inadequately sealed sutures that are typical of California cultivars, including "Nonpareil," "Ne Plus Ultra," "Winters," and "Merced." Integrated pest management, particularly orchard cleanliness, can achieve partial control (IPM Manual Group of University of California at Davis 1985). Some cultivars, including "Carmel," "Mission," and "Butte," have been shown to exhibit resistance through better-sealed shells (Hamby et al 2011). Because of the significant cultivars' distinctively thick, complex, and well-sealed shells, this issue is not severe in the Mediterranean region.

The Pacific spider mite (*Tetranychus pacificus*), the two-spotted spider mite (*T. urticae*), the European red mite (Panonycusulmi), and the brown almond mite (*Bryobia rubriculus*) In certain areas, production can be negatively affected by various factors, which may have a significant impact, especially in situations when there is of high moisture stress. Variable cultivars have varied susceptibilities (Gradziel & Martínez-Gómez 2013).

Almond graft-transmissible pathogens, such as viruses, viroids, and phytoplasmas, are responsible for spreading diseases globally and regionally. Some of these diseases, especially those caused by multiple infections, can have a significant economic impact when they reduce almond production or cause almond trees to decline.in addition, The long-distance exchange of infected plant material is the main reason for pathogen distribution in the almond industry. Depending on the cultivar's susceptibility, the strain of the pathogen, and environmental factors, the yield of common single graft-transmissible infections can be reduced by 10% to 25%. As a result, if these pathogens are prevalent in the crop, economic losses cannot be ignored. Insects, nematodes, and other vectors naturally disseminate some infections. Thus, the use of unnoticed infected trees in nurseries for grafting or propagation considerably helps their spread (Palacio-Bielsa et al 2017).

Currently, many nurseries routinely use in vitro propagation and appropriate cultivation in glasshouse or screen house facilities to reduce infection risks. Thermotherapy, meristem tip culture, and micro-shoot-tip grafting have been used for sanitation.

Encouraging and exploring conventional breeding and biotechnological approaches for developing almond cultivars resistant to graft-transmissible pathogens can prevent diseases in the future (Palacio-Bielsa et al 2017).

Detecting and diagnosing viruses in almonds, viroids, and phytoplasmas has traditionally relied on biological assays for decades. ‘GF 305’ or ‘Nemaguard’ peach seedlings can be inoculated through chip budding grafts, or the cherry indicator 'Shirofugen' which is quite sensitive. can be used for the genus Ilarvirus (Desvignes 1999, Marcone et al 2011).

In Europe's Mediterranean region, the *Aglaope infausta L*., also known as the almond-tree leaf skeletonizer, is a moth from the Zygaenidae family that can cause significant damage to almond trees. When it feeds on the foliage and young fruit, it becomes a major pest, resulting in extensive losses of fruit and foliage during the earliest part of the season (Meliá & Almajano 1972).

In California orchards, pests such as leaf-footed plant bugs (belonging to the Coreidae family) and stink bugs (belonging to the Pentatomidae family) can cause significant economic damage by feeding on developing almonds before the shells harden. The leaf-footed plant bugs that are commonly found in this region include *Leptoglossus clypealis Heidenmann*, *Leptoglossus occidentalis Heidenmann*, and *Leptoglossus zonatus* (Dallas), as reported by (Zalom et al 2015).

Various types of mites belong to different Acari families, which are known to be harmful to almond crops. Tetranychus web-spinning spider mites are the most destructive globally, but the significance of each Tetranychus species varies depending on the location, as pointed out by (Marsh et al 2002).

Burrowing rodents, such as ground squirrels, pocket gophers, voles, and various rat and mouse species, are among the most destructive vertebrates. In addition, the harm caused by birds can be linked to the environment they inhabit and whether it provides them with nesting areas, places to rest, or a sufficient food supply. This damage can begin when the almonds are still in their infancy and persist until harvest time, as noted by the University of California Statewide IPM Project in 2002. In general, solutions to bird-related issues are not specific to one species and often involve methods of scaring them away. As a result, birds that harm almond crops are addressed as a collective group rather than individually. Additionally, shooting and trapping are less commonly used methods that have also been discussed (Zalom et al 2017).

12. Almond molecular studies

In the past, almond cultivars were identified and characterized based on their physical traits. However, this method had limitations as it was not always possible to analyze these traits, which may be affected by environmental changes. Additionally, physical traits could only be observed in mature samples, which prolonged the analysis process. Fortunately, molecular markers have provided a solution to these issues (Martínez-gómez et al 2007).

Molecular markers are specific variations in a particular region of DNA that exhibit Mendelian inheritance. Markers can be genes or sections of the genome that have no known function. DNA-based markers are rapid, accurate, discriminative, stable, and allow for early trait selection. Crucial for breeding programs, early selection helps identify specific traits linked to markers. Almonds use markers to identify cultivars and genetic variations (Of et al 2011).

They offer a steady, rapid, accurate, and highly discriminative test in varying environmental conditions. These markers have been used for various purposes, such as analyzing variability, determining pedigrees, and identifying cultivars (Wünsch & Hormaza 2002, Martínez-Gómez et al 2003b, Sánchez-Pérez et al 2004a). Some markers, such as isozymes, restriction fragment length polymorphisms (RFLPs), and simple sequence repeats (SSRs), allow for the comparison of variability among homologous regions of the same or different species derived from specific genome sequences (Martínez-gómez et al 2007).

In almond studies, the essential molecular markers utilized are isozymes, restriction fragment length polymorphisms (RFLPs), randomly amplified polymorphic DNAs (RAPDs), simple sequence repeats (SSRs), and markers derived from distinct DNA sequences (Martínez-gómez et al 2007, Jain & Priyadarshan 2009).

Through the study of isozymes, researchers have discovered that almond plants have vast amounts of diversity, thus, The identification of most genotypes has been made possible through this process. In 1990, Byrne conducted a study to compare the variability of isozymes in Prunus. The study showed that almond and Japanese plum, which have a solid self-incompatibility system, exhibited higher variability than apricot and peach, which have different degrees of self-compatibility. The use of isozymes is restricted as conventional enzyme staining methods can only analyze a limited number of loci. Additionally, there is low variation at most loci, as observed by Martínez-Gómez et al 2007, Jain & Priyadarshan 2009.

PCR-based markers have expanded prospects for diversity studies and trait mapping by substituting isotope detection with widely available amplification of PCR. The RAPD method amplifies random locations in the genomic DNA using short arbitrary primers, resulting in dominant markers with variable repeatability (Of et al 2011). Additionally, PCR amplification of arbitrary primers for RAPDs is a valuable method for characterizing germplasm diversity (Bartolozzi et al 1998, Martins et al 2003).

Another essential point Microsatellite markers, also known as SSR markers, based on PCR, are ideal for genetic studies in plants. as a result of their highly polymorphic and abundant, and allow for assessing variability and genetic correlations (Gupta et al 1996, Powell et al 1996, Martínez-Gómez et al 2003a, Jain & Priyadarshan 2009). They are used to identify cultivars (Martínez-Gómez et al 2003b, Martins et al 2003), and to create maps (Dirlewanger et al 2004).

In different Prunus species, SSR markers encompassing nearly the complete genome have been obtained, including peach, apricot, Japanese plum, cherry, and almond (Cipriani et al 1999, Downey & Iezzoni 2000, Sosinski et al 2000, Testolin et al 2000, Cantini et al 2001, Dirlewanger et al 2002, Georgi et al 2002, Wang et al 2002, Yamamoto et al 2002, Aranzana et al 2002, 2003, Clarke & Tobutt 2003, Decroocq et al 2003, Schueler et al 2003, Hagen et al 2004, Messina et al 2004, Mnejja et al 2004).

Recently, Testolin et al (2004) published the initial group of almond SSRs, which have been effectively employed for the identification and characterization of almond cultivars (Martínez-Gómez et al 2003a, Testolin et al 2004) and related Prunus species (Martínez-Gómez et al 2003c).

13. Future progress:

The challenge in breeding cultivars for commercial success lies in optimizing numerous essential traits. Selection of exceptional almond cultivars has been ongoing for hundreds to thousands of years in quest of uncommon individuals with great potential for diverse genomic and epigenetic interactions.. Clonal propagation enables the preservation of rare and superior genotypes for future plantings and genetic improvement through bud sport transformations or favourable recombinations. Molecular markers can provide a quick, precise, and environment-independent way to evaluate seedlings, which offers valuable opportunities for increasing selection efficiency. The selection of trees with desired traits is easier through molecular markers. This is especially useful for crops like almond, which have a long juvenile period and for evaluating traits that are difficult to measure, such as biotic or abiotic stress resistance. Marker-assisted selection can cut the number of generations required to remove undesirable donor genes dramatically in backcrossing programs once enough mapping information is available (Gradziel & Martínez-Gómez 2013).

14. Conclusion :

Several previous researchers have elucidated the almond characteristics, growth habits, production, nutritional and economic importance of almonds and their role in improving health. Previous research has indicated that the farming methods used in almond cultivation impact the quality of the crops. Molecular studies and their different approaches have also been said to help and make it easier to transfer traits that were found to be desirable through breeding programmes.

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نظرة شاملة على أصناف اللوز (Prunus dulcis) ومتطلباتها والممارسات البستانية

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مستخلص. تتواجد أشجار اللوز (*Prunus dulcis*) في دول البحر الأبيض المتوسط وتقتصر زراعتها على المناطق ذات مناخ البحر الأبيض المتوسط. اللوز هي أحد أنواع الجوزيات، التي تعرف بأنها وجبة خفيفة صحية ومصدر جيد للبروتين والكربوهيدرات والدهون ومضادات الأكسدة. تحتوي بذور اللوز على مركبات الفلافونويدات ، فيتامين E ، الريبوفلافين ،الأحماض الأمينية ،المعادن الأساسية ، المنغنيز، المغنيسيوم ،النحاس والفوسفور. يحدث الإزهار عندما يتم استيفاء متطلبات البرودة والحرارة بالكامل. عند زراعة أصناف غير متوافقة ذاتيًا، من المهم توزيع الملقحات بشكل صحيح، حيث يستحسن أن يحتوي البستان على ٣٠% على الأقل من الملقحات لضمان التلقيح الأمثل. بناءً على خصائص القشرة يتم تصنيف اللوز إلى أصناف ذات قشرة ناعمة وصلبة. كما يتم تصنيف اللوز أيضا إلى فئتين، الحلو والمر. تتأثر كمية المياه التي تستخدم في بساتين اللوز بشكل كبير بالطقس بما في ذلك الرطوبة ودرجة الحرارة والوقت من اليوم. يعتبر التسميد أمرًا بالغ الأهمية للتطور السليم للوز والإثمار المنتظم والمحصول عالي الجودة. ولقد أتاحت طرق إكثار اللوز من خلال التطعيم تحسين اختيار الطعوم التي سيتم إكثارها. كما يجب أن تتمتع الأصول الجديدة المستخدمة في التطعيم بالصفات المرغوبة التالية: تحمل التربة الجيرية و/أو غيرها من التربة الفقيرة؛ سهولة التكاثر باستخدام العقل الخشبية و/أو التكاثر الدقيق وكذلك تمتعها بنمو قوي. أصبحت زيادة التحمل للتربة الثقيلة والمشبعة بالماء هدفًا مهمًا للأصناف الهجن الجديدة. حيث يتم انتخاب الطرز الجينية الجديدة المتكيفة محلياً وإكثارها بطرق الإكثار الخضري ، مما يؤدي إلى التعرف على مئات الأصناف وإكثارها في مناطق إنتاج محددة. بالإضافة إلى ذلك، فقد تم إجراء العديد من الدراسات الجزيئية التي تسهل نقل تلك الصفات المرغوبة. وبشكل عام، فإن هذه المقالة تركز على كيفية إدارة الحقول ابتداءً من اختيار الأصناف وحتى الحصاد بهدف الوصول إلى محصول لوز بجودة وكمية عالية.