

*Pistacia vera*



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Agricultural Science Class Monograph, Grade 12  
2024-2025

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## 1.0: Introduction

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*Pistacia vera* L., commonly known as pistachio tree, is a species native to Central Asia. It is a strong tree that can go through tough conditions, and will still produce nutritious and delicious fruits, being the only one edible among its genus. This monograph addresses the species' existence since its origin thousands of years ago, to its present day role in nature, economy, culinary and medicine. First, the Ecology section provides information about the phylogenetic and physical origin of the species, followed by the impressive number of varieties that it has, and its evolution and distribution. It also presents the ideal conditions for the species to live on and the way that it survives in relation with its environment. Then, the Biology chapter goes all the way to the cell of the species, its genes, further explaining its life cycle, growth, reproduction and development. Next is the Propagation and Management section, that refers to everything that the cultivation and planting of the tree requires, and the correct management for a successful orchard. It includes as well the methods used to propagate the species, or the ones used by the species to propagate itself. Finally, it is the Economic Importance chapter, which includes the world trade and potential markets, exporters and importers, and the different uses that it has. This monograph allows one to learn everything that is behind the pistachio nut that is found in the market and consumed as a snack, or turned into butter or ice cream.

## 2.0: Ecology

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### 2.1: Distribution:

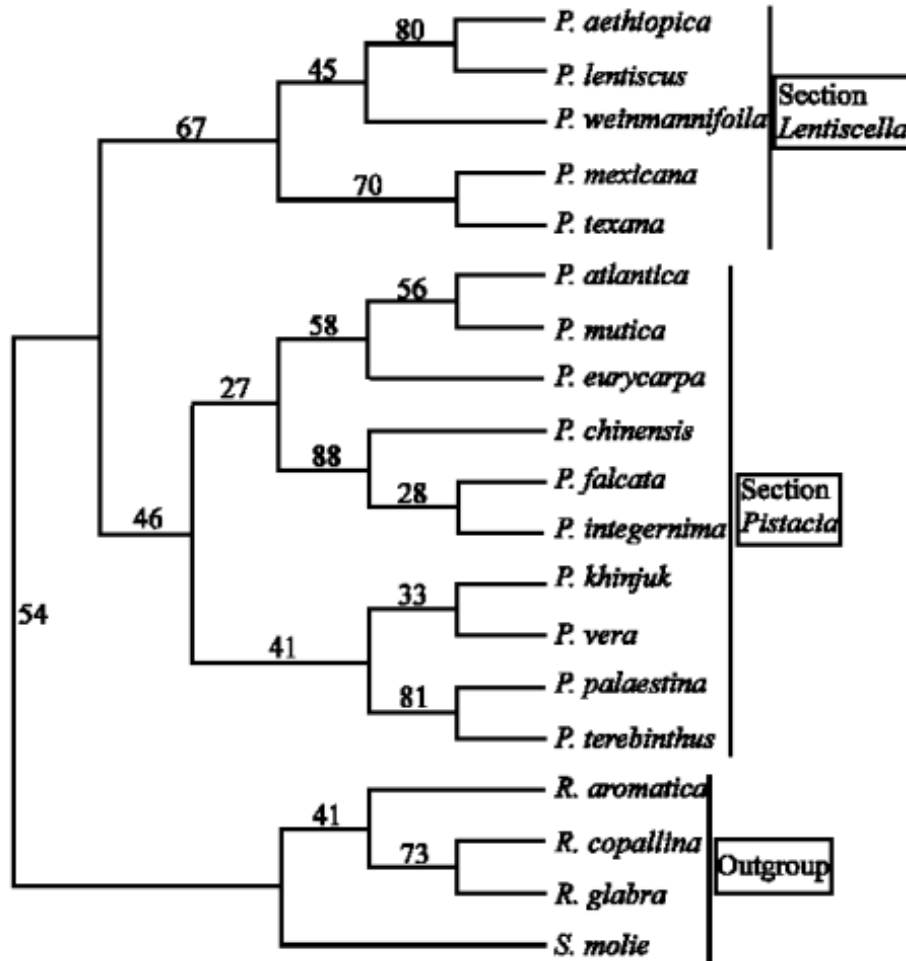
#### 2.1.1: Affinities:

*Pistacia vera* belongs to the Anacardiaceae family (also known as cashew family or sumac family), order Sapindales. The members from this family are distinguished by having resin ducts in the leaves and unisexual flowers, and include: cashew, pepper tree, mango, among others (Britannica, 2017). The genus *Pistacia* L. is divided into two sections: *Pistacia* and *Lentiscella*. Based on neighbor-joining<sup>1</sup> and parsimony<sup>2</sup> analysis, the section *Pistacia* is divided into three groups, containing species such as *P. atlantica*, *P. falcata*, and *P. vera* in the last group (Al-Saghir, 2012). Section *Lentiscella* contains other species such as *P. lentiscus*, and as it shares a common ancestor with the section *Pistacia*, both sections are often called to be monophyletic. This is shown in the following phylogenetic<sup>3</sup> tree (Figure 1).

1. Neighbor-joining: tree construction method; it constructs ancestral relationships.

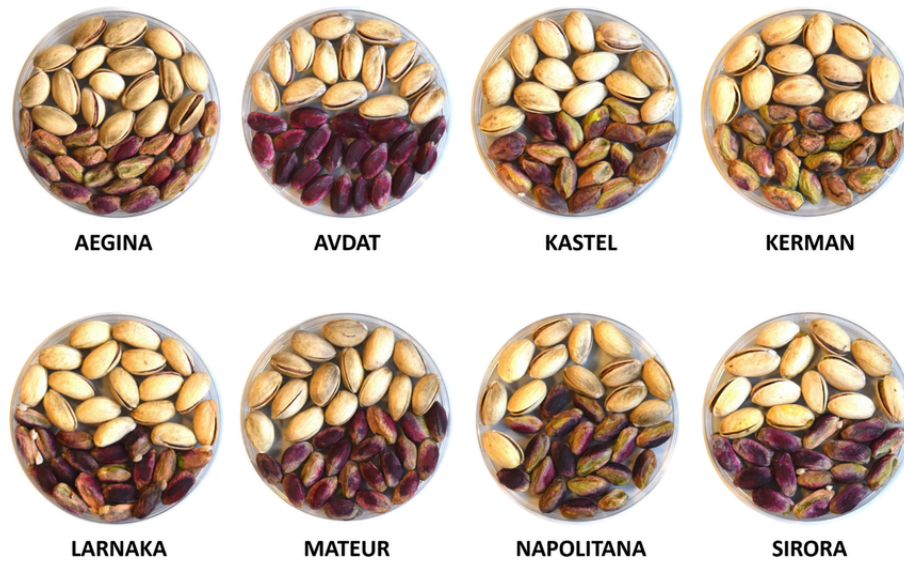
2. Parsimony: the principle of choosing the simpler scientific explanation to support the evidence. In tree building (of species), the best hypothesis is the one that includes the least evolutionary changes.

3. Phylogenetic: evolutionary development and diversification of a species. Analogic to a genealogic tree for humans.

**Figure 1***Pistacia* Phylogenetic Tree

Note: This phylogenetic tree in this figure shows the relationships between *Pistacia* species. (Al-Saghir, 2010). The numbers above the branches are the bootstrap values (which measure the accuracy of times the same branch was observed out of 100, from a resampled set of data. (Ojha et al., 2022).)

*P. vera* is the most important in the genus in terms of economy, as it is the only one edible and grows on the pistachio tree. Among this nut, there are different types and varieties that are classified according to their place of origin, color, and size; some of them are Kerman, Sirora, Larnaka, Aegina, Mateur (Figure 2). (Agróptimum, 2023).

**Figure 2***Pistacia vera* Varieties

Note: The figure shows eight different varieties of *Pistacia vera*, differentiated by their country of origin, color, and size (Noguera-Artiaga, L. et al., 2019).

**2.1.2: Taxonomy:**

The pistachio nut is taxonomically ranked as a species, with the generic name *Pistacia*, the specific epithet *vera*, of Genus *Pistacia* L, and scientifically called *Pistacia vera* L. *Pistacia vera* is categorized in the *Plantae* Kingdom (Table 1, below) which includes all plant species: algae, bryophytes, pteridophytes, gymnosperms and angiosperms. Pistachio is part of the angiosperms, which are “plants that produce flowers and bear their seeds in fruits” (Dilcher et al., 2024). It is further divided in the *Tracheobionta* Subkingdom of plants with vascular tissues (vascular plants). It is classified in the Superdivision *Spermatophyta*, which includes seed bearing plants, and in the Division *Magnoliophyta*, for all flowering plants.

*Pistacia vera* is part of the Class *Magnoliopsida*, that includes dicotyledonous plants, (that have cotyledons<sup>4</sup> in their embryos). It belongs to the Subclass *Rosidae*, that includes species with bitegmic (that have two covers) and crassinucellate (the central part of the ovule is thicker) ovules. It is further classified in the Order *Sapindales*, which includes all dicotyledonous flowering plants. Among the nine families in this Order is the *Anacardiaceae* Family (also known as cashew family) of which *Pistacia vera* is part of. This family has about 870 different species, including flowering plants, trees, shrubs and lianas.

**Table 1***Pistachio Nut Taxonomic Classification*

Term	Interpreted
Kingdom	<i>Plantae</i> - Plants
Subkingdom	<i>Tracheobionta</i> - Vascular plants
Superdivision	<i>Spermatophyta</i> - Seed plants
Division	<i>Magnoliophyta</i> - Flowering plants
Class	<i>Magnoliopsida</i> - Dicotyledons
Subclass	<i>Rosidae</i>
Order	<i>Sapindales</i>
Family	<i>Anacardiaceae</i> R. Br. - Sumac family
Genus	<i>Pistacia</i> L. - pistache
Species	<i>Pistacia vera</i> L. - pistachio nut

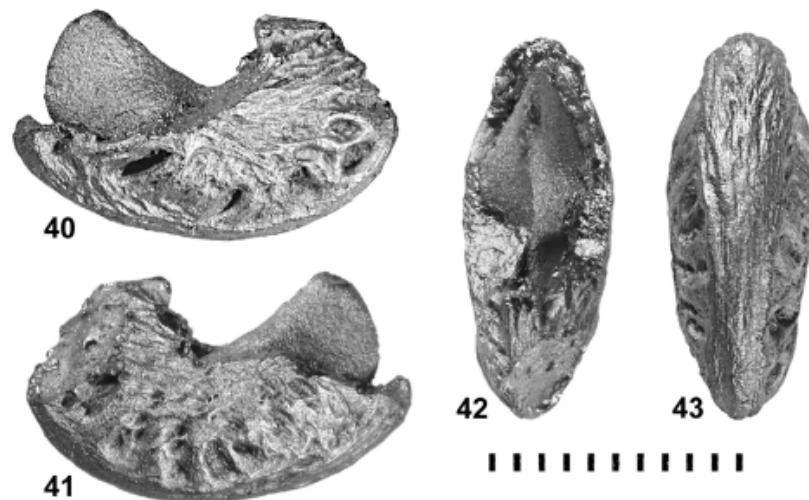
4. Cotyledons: part of the seed nucleus. When the seed grows, the cotyledon often becomes the first leaves of the plant.

### 2.1.3: Fossil Record:

Pollen fossils within Anacardiaceae first appeared in the Paleocene period (Muller, 1984) and the oldest fossil records of *Pistacia* were found in the Oligocene period in both Europe (France) and North America (Mexico) (Ramirez et al., 2002). Moreover, late Eocene age fruits and seeds including Anacardiaceae (which includes *Pistacia*) fossils were found in Post, Oregon. (Manchester, Stever R et.al, 2007). (Figure 3).

#### Figure 3

##### *Anacardiaceae Fossils*



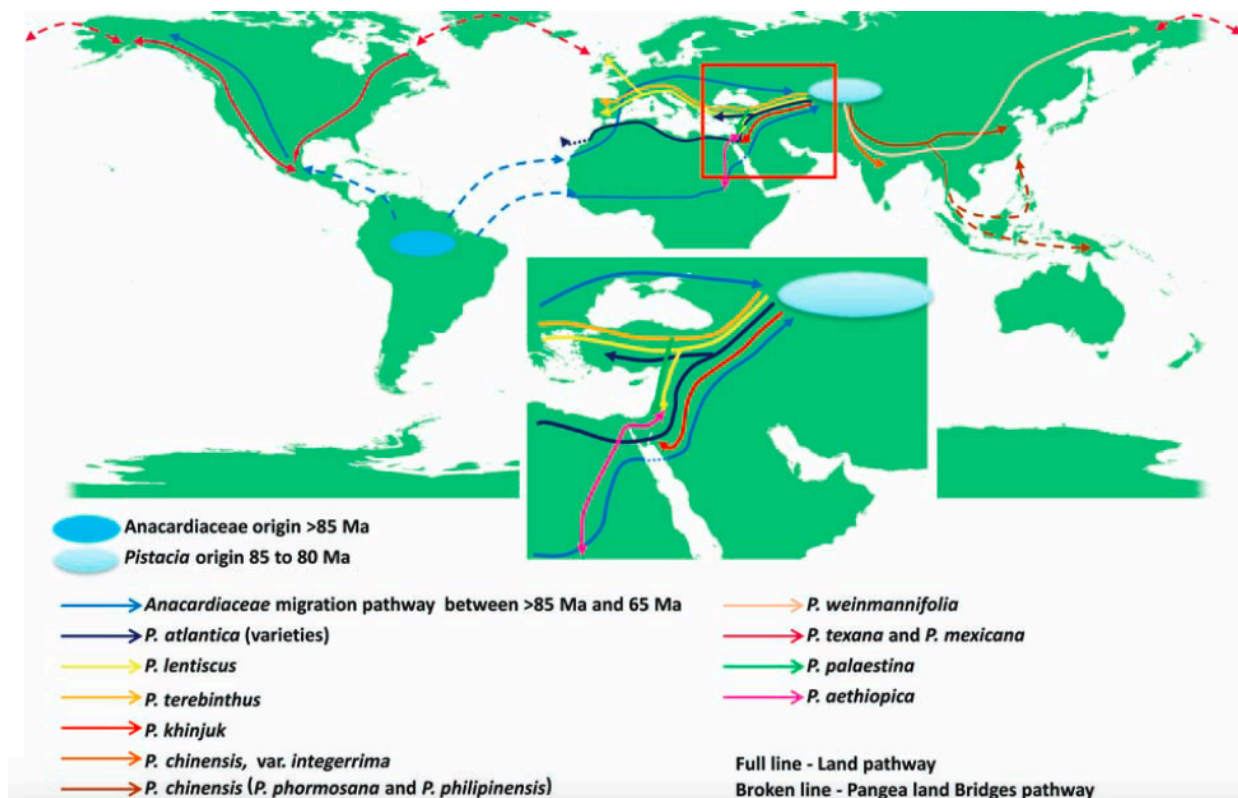
Note: The figure shows four late Eocene Anacardiaceae fossils found in Oregon (40-43). (Manchester, Stever R et.al, 2007).

#### 2.1.4: Origin and migration of Pistacia species:

*Pistacia vera* L. originated in Central Asia (Mir-Makhamad et al., 2022). There are two centers of diversity that include: the Mediterranean region of Southern Europe, Northern Africa, and the Middle East; the West and Central Asia. This one migrated eastward, southward and westward (Figure 4). The Anacardiaceae genus originated in the tropical Americas, specifically in the Amazonian Region of Brazil (Nair, K. P. P., 2010), and migrated northward and eastward. The figure below shows both origins; *Pistacia* (in light blue)–85 to 80 million years ago– and Anacardiaceae (in the strongest blue)–more than 85 million years ago.

**Figure 4**

*Migration Trends of Pistacia Species in Relation to their Origin*



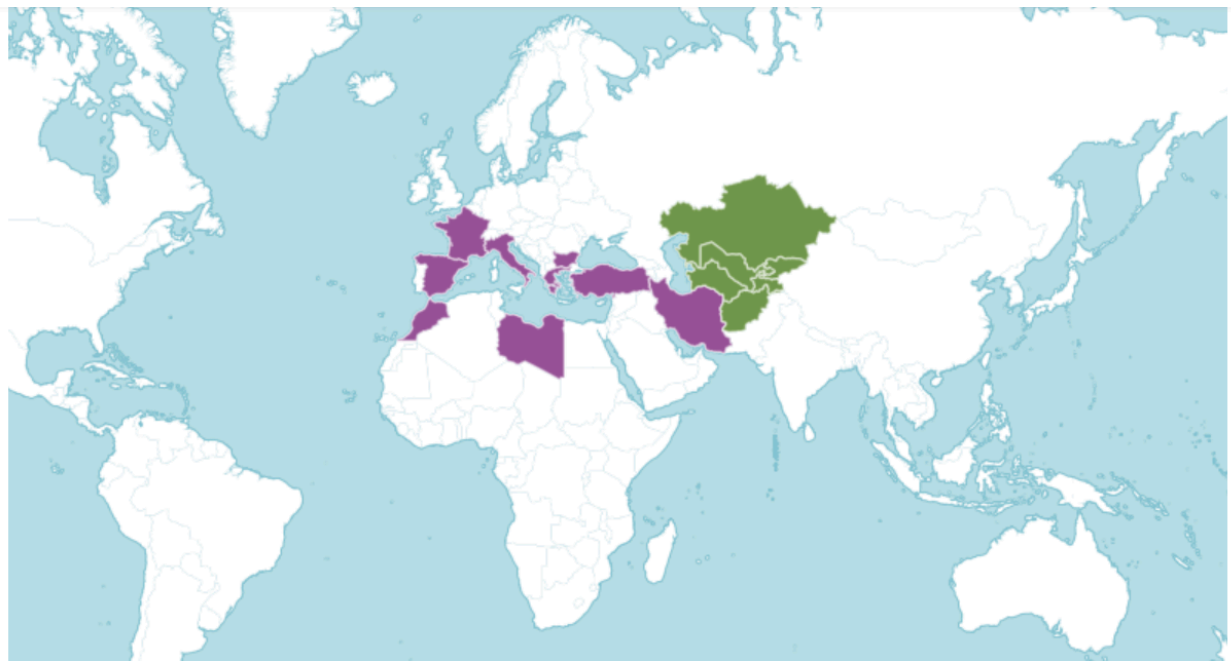
Note: The arrows in this figure show migration trends for Anacardiaceae and *Pistacia* in relation to their origins. (G.Kozhoridze et al., 2015).

### 2.1.5: Present Distribution:

*Pistacia vera* L. is native to Afghanistan, Kazakhstan, Kirgizstan, TadzhiKistan, Turkmenistan, Uzbekistan. It has been introduced to Bulgaria, East Aegean Is., France, Greece, Iran, Italy, Libya, Morocco, Spain, Turkey. (Plants of the World Online, 2020) (Figure 5). The northeSt distribution of *Pistacia vera* forests is in southeastern Kazakhstan, and to the northwest, it grows in Kyrgyzstan. “Old pistachio trees have been recorded at Damghan, Ghazvin, and Ardekan, and a 700-year-old pistachio tree was reported in Kerman” (Mir-Makhamad et al., 2022).

#### Figure 5

##### *Pistacia vera* L. Distribution



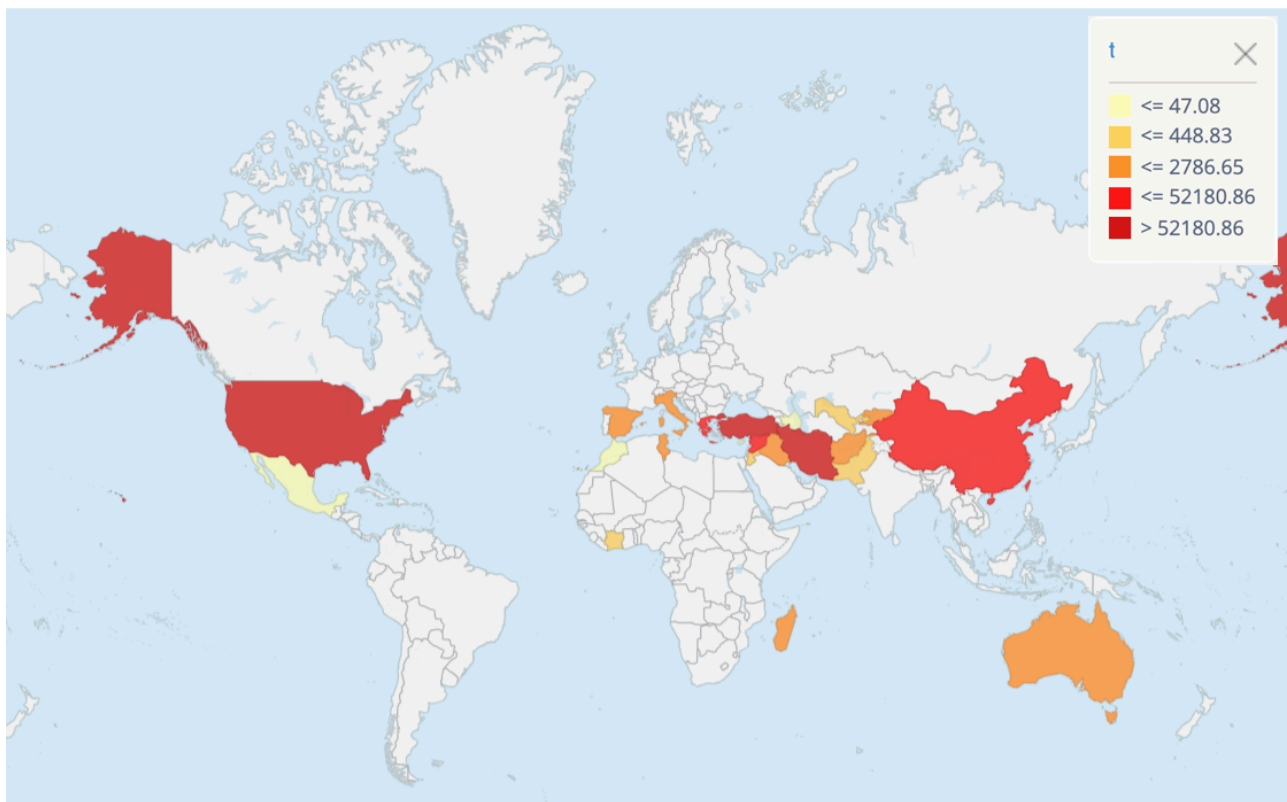
■ Native ■ Introduced

Note: *Pistacia vera* distribution; countries where it is native (green) versus countries where the species was introduced (purple). (Plants of the World Online, 2020).

Moreover, The Food and Agriculture Organization of the UN analyzed the main production of pistachio in 21 different countries (Figure 6). The data covers the production from 1994 to 2023. These main producing countries and the amount of tons they produce are: Iran (270672.61 t), US (215316.07 t), Turkey (103098.13 t), Syria (44528.89 t), China (52180.86 t), Greece (8493.99 t). (FAOSTAT, 2024). These main producers are countries where the species was introduced.

### Figure 6

#### *Production Quantities of Pistachios by Country*



Note: As shown in the key of this map, the color darkness of the countries is related to the amount of tons of Pistachio that they produce. The species was introduced to some of the shaded countries. (FAOSTAT, 2024).

## 2.2: Environmental Factors in Distribution:

### 2.2.1: Elevation:

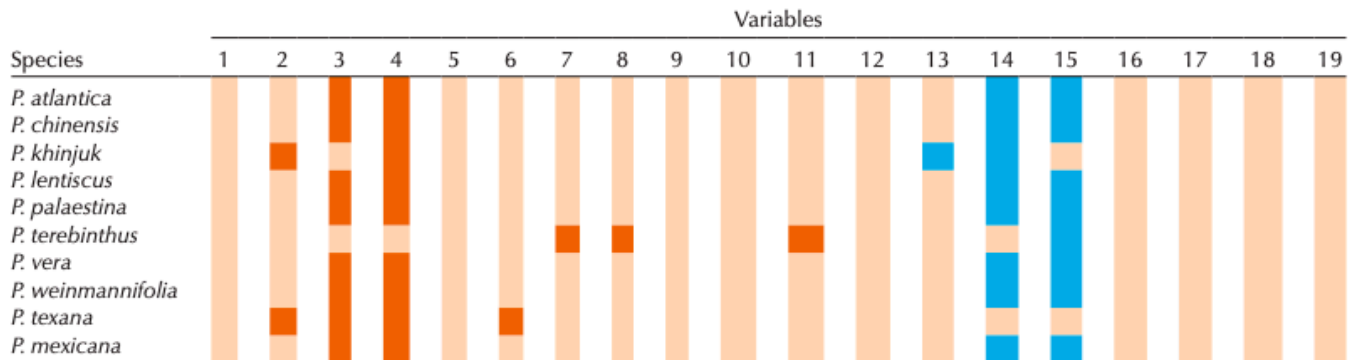
Wild pistachios grow best between 500 and 800 masl in Central Asia. Some variations can be found 450 or 2000 masl. In southeastern Kazakhstan pistachio grows among 700 and 1100 masl, and in northwestern Kyrgyzstan, on slopes between 800–1600 masl. (Mir-Makhamad et al., 2022). Landscape variables (slope and land appearance) do not have a major impact on the species distribution. All species of *Pistacia*, including *Pistacia vera* can properly grow low and high altitudes and a maximum slope of 25–30% (Kozhoridze et al., 2015).

### 2.2.2: Climate:

*Pistacia vera* L. migration pathways are related to climate change, which changes their distribution to the most suitable environmental conditions for the species. This species has good tolerance to hard environmental conditions; it can grow in both semi-arid deserts, and dry slopes of low mountains (Mir-Makhamad et al., 2022). The environmental factors that mostly influence the areal distribution changes are: climate (in the coldest months of the year), and precipitation. (Table 2).

**Table 2**

*Climate Variables that Mostly Affect on the Areal Distribution of Pistacia Species*



\*See Table 2.

PLS analysis of the probability distribution model inputs, for selection of the most effective climate variables

- Light Orange Variables not affecting the areal distribution changes.
- Dark Orange Temperature variables affecting the areal distribution changes.
- Blue Precipitation variables affecting the areal distribution changes.

Note: Variables affecting the areal distribution of 10 *Pistacia* species. (Kozhoridze et al., 2015).

The most important for *Pistacia vera* L. production is a hot climate between 25-35° C, during the summer (2-3 month period), with low humidity. During the highest summer temperatures, pistachio trees produce the best nuts. They can also grow in cool but not freezing winters.

### 2.2.3: Geology and Soils:

*Pistacia vera* can grow in rocky or stony soils, but it grows best in deep well-drained light, sandy loams, with high calcium carbonate ( $\text{CaCO}_3$ ) concentration, and pH between 7.0 and 7.5. (Farm Plastic Supply, 2022). It can also grow in clay loam soil, though it would need “mounds or raised beds for drainage” (Chaudhary, 2024). Figure 7 below shows the two major soil preferences for the species. It is important to avoid very watery soils or heavy clays. Soil types do not have a significant effect on distribution. (Kozhoridze et al., 2015).

#### Figure 7

*Pistacia vera* Soil Type Preferences



Note: Two types of soil where *Pistacia vera* can grow best. (Chaudhary, R., 2024).

## 3.0: Biology

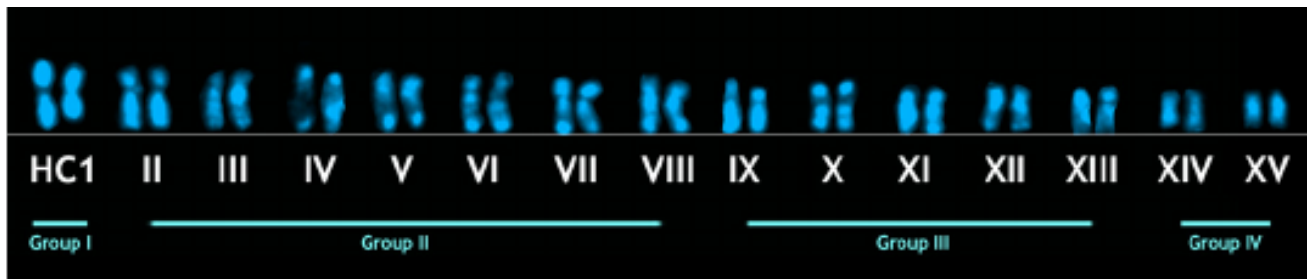
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### 3.1: Chromosome Complement:

*Pistacia vera* L. has a diploid chromosome complement of  $2n=30$ ; it has 15 pairs of chromosomes ( $n=15$ ), and there are 30 haploids in total. (Basr Ila et al., 2003). Its chromosomes are divided into four groups as shown in Figure 8.

#### Figure 8

*Karyotype of Pistacia vera L.*



Note: Karyotype of *P. vera* chromosomes ( $n=15$ ) stained with DAPI. (Sola-Campoy et al., 2015).

### 3.2: Life Cycles and Phenology:

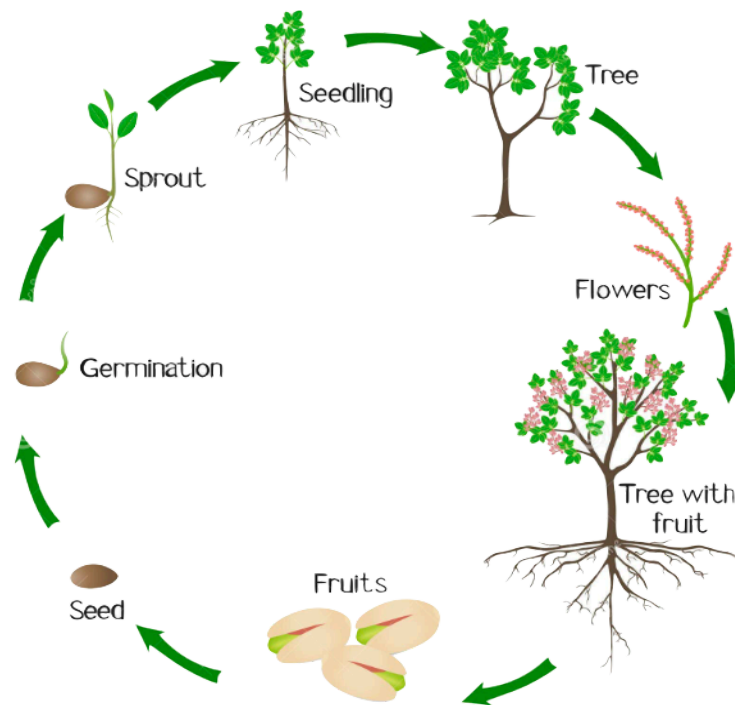
#### 3.2.1: Life Cycle:

The life cycle of *Pistacia vera* L. includes four main stages: germination, seedling, vegetative growth, and flowering and seed production (Rankel, 2024). Initially, the species seed can stay dormant until the conditions are right for its germination. The germination stage of the seed lasts 2-4 weeks. It is when the seed starts turning into a plant, and involves the absorption of

water in the soil, and use of stored energy to sprout. Then between germination and seedling occurs the first sprout of the plant (as shown in Figure 9), and the seedling stage lasts 6-12 months. The seedling stage is when the plant roots develop and the cotyledons turn into the first leaves. Photosynthesis begins after this phase. Then, the longest stage is vegetative growth of the plant, that lasts 2-5 years to grow completely. This stage involves photosynthesis, and the development of the roots, stem and more leaves. Finally, flowering and seed production— 2-4 weeks. In the flowering stage pollination occurs, and flower buds are formed (which is where the seeds are going to form inside). Finally, the seed production stage involves the development of the seed and hardening of shell, and the seed's maturation. (Otieno et al., 2020). See the whole life cycle in Figure 9 below.

## Figure 9

*Pistacia vera* Life Cycle Diagram



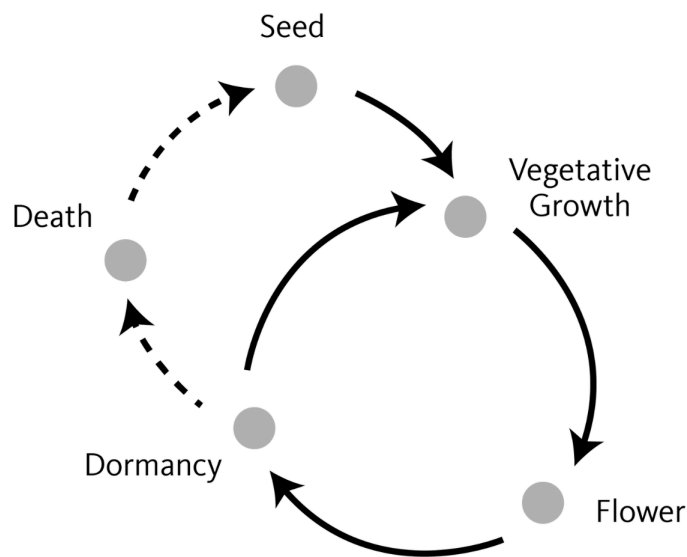
Note: Detailed diagram of each stage in *Pistacia vera*'s life cycle. (Kharzhevskia, n.d).

### 3.2.2: Growth Cycle:

Once the pistachio tree has grown, the species undergoes a repetitive growth cycle. *Pistacia vera* L. has a perennial<sup>5</sup> growth cycle, which involves mainly, vegetative growth, flowering, and dormancy. Plants go dormant during unfavorable conditions where they cannot produce leaves, but can naturally go back to vegetative growth. However, sometimes the plant can die after dormancy, and when this happens, the cycle begins again with a new seed. (Figure 10). Perennial plants live more than two years. (VanDerZanden et al., 2008).

**Figure 10**

*Perennial Plant Growth Cycle*



Note: Stages of the growth Cycle in a Perennial plant. (Thompson, 2008).

5. Perennial: plant that lasts several years and involves multiple new stages of vegetative growth.

### 3.2.3: Phenology:

Perennial plants such as *Pistacia vera* commonly grow and flower in the spring and summer, and then in the fall and winter they die back or go dormant. The trees are dormant (they do not produce leaves) from November to March. Then in the last week of March, the flower buds (small terminals on the stem of a plant) start to grow, and they bloom into flowers starting April. Pollination occurs next, and then, from late April to late May, the terminal buds expand and leaves grow. Simultaneously, the hull (outer shell of the seed) expands from mid April to the end of May, and then it hardens during all June. The development (nut-fill) stage goes from in the last week of June until the first week of August. The shell splits in half from the last week of July until the half of September. Lastly, the nut ripens from late August to the end of September, and is ready to harvest (Mosz, 2002). See Table 3 below.

**Table 3**

*Pistacia vera* Phenology- Annual Timeline

	Jan				Feb				March				April				May				June				July				August				Sept				Oct				Nov				Dec							
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4				
<b>Crop Stage</b>																																																				
Dormant	█																																█																			
Bud swell - Bloom													█				█																																			
Shoot growth/foilage																	█				█																															
Hull expansion																	█				█																															
Shell hardening																					█				█																											
Nut-fill																									█				█																							
Shell-split																													█				█																			
Nut maturation																																	█				█															

Note: Duration of each of the eight crop stages of *Pistacia vera*. (Mosz, 2002).

### 3.3: Photosynthetic Pathways:

There is a phylogenetic pattern with the C<sub>4</sub> photosynthetic pathway that “has evolved only in the flowering plants”, and as *Pistacia vera* is part of the flowering plants order, Sapindales, this suggests that it might as well use this mechanism. (Kellogg, 1999). C<sub>4</sub> photosynthesis concentrates CO<sub>2</sub>, and turns it into a four-carbon compound. With this mechanism, species can improve their photosynthetic efficiency in hot and dry environments and be productive. (Kellogg, 2013).

### 3.4: Reproductive Biology:

#### 3.4.1: Sexuality:

*Pistacia vera* L. is a dioecious species, meaning that each tree can be either male or female, and both are needed for the successful production of nuts. (Rezaei et al., 2021). The male produces pollen and the female produces flowers that develop into nuts. (Bai et al., 2019). This species reproduces asexually through pollination, and the sex can only be known after flowering/sexual maturity, because it is primarily by seeing the flowers that male and female trees can be distinguished (Figure 11). They also have morphological differences; male trees are mostly bigger than females (Rezaei et al., 2021).

#### Figure 11

*Dioecious Nature of Pistacia vera Flowers*



**Male pistachio flower**

**Female pistachio flower**

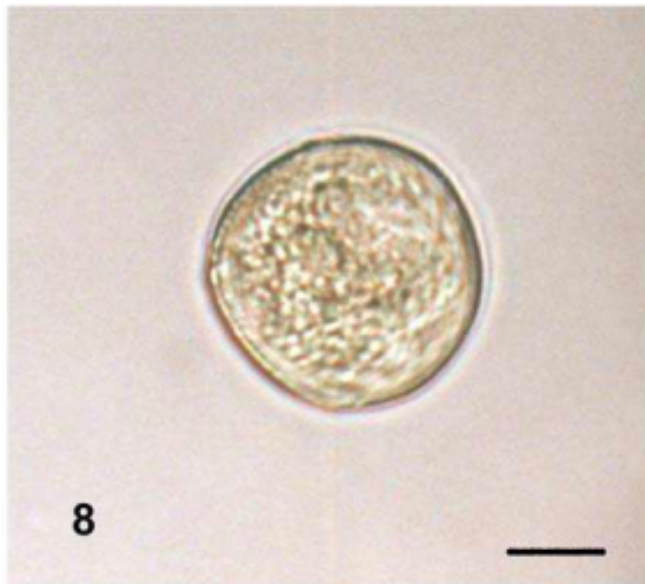
Note: Male and female pistachio flowers on separate trees. (Choulak et al., 2023).

### 3.4.2: Pollen:

Only the male trees of pistachio produce pollen, which helps for fertilization of female flowers. The pollen grains are small, light, yellow. The image below (Figure 12) is a sample of *P. vera* pollen grains that were observed in light microscopy as part of a taxonomical comparison between Iranian *Pistacia* species according to their pollen morphology. (Behboodi et al., 2005).

#### Figure 12

##### *Pistacia vera* Microscopic Pollen Grains



Note: *Pistacia vera* pollen grains in light microscopy. (Behboodi et al., 2005).

### 3.4.3: Pollination and Potential Pollinators:

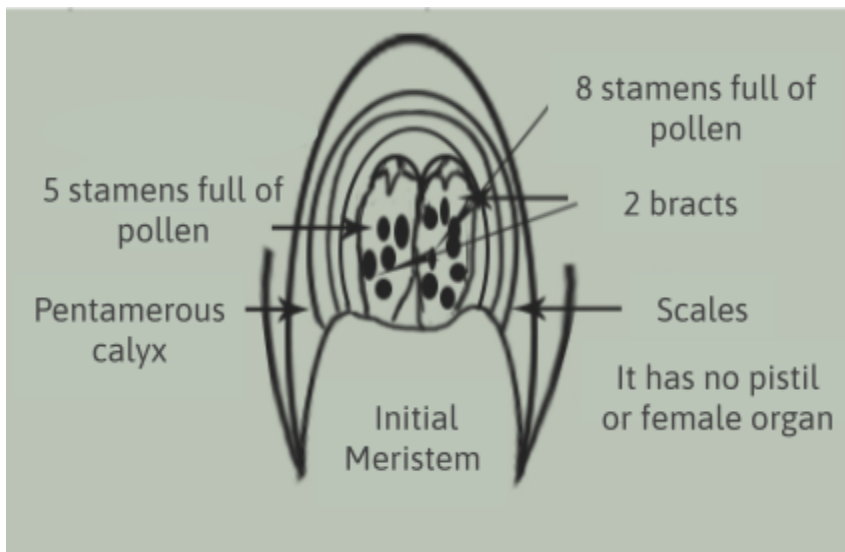
Pistachio tree flowers do not attract insect pollinators through their petals, so pollination and fertilization occurs with the transportation of pollen with the help of wind from female to male trees. The better the pollination is, the better nut production. (Abu-Zahraand et al., 2024).

Both genders contribute to the pollination, but the male is the main pollinator, and the female uses the pollen to produce flowers.

The male flower carries pollen within its stamens (Figure 13), which are their reproductive organs. Inside the stamens, there are the anthers, which produce the pollen, and the filament, that helps the pollen be dispersed by the wind. (Singh, 2022). The other flower parts in Fig.13 are not directly involved in pollination, but serve as protectors of the flower.

### Figure 13

#### *P. vera* Male Flower



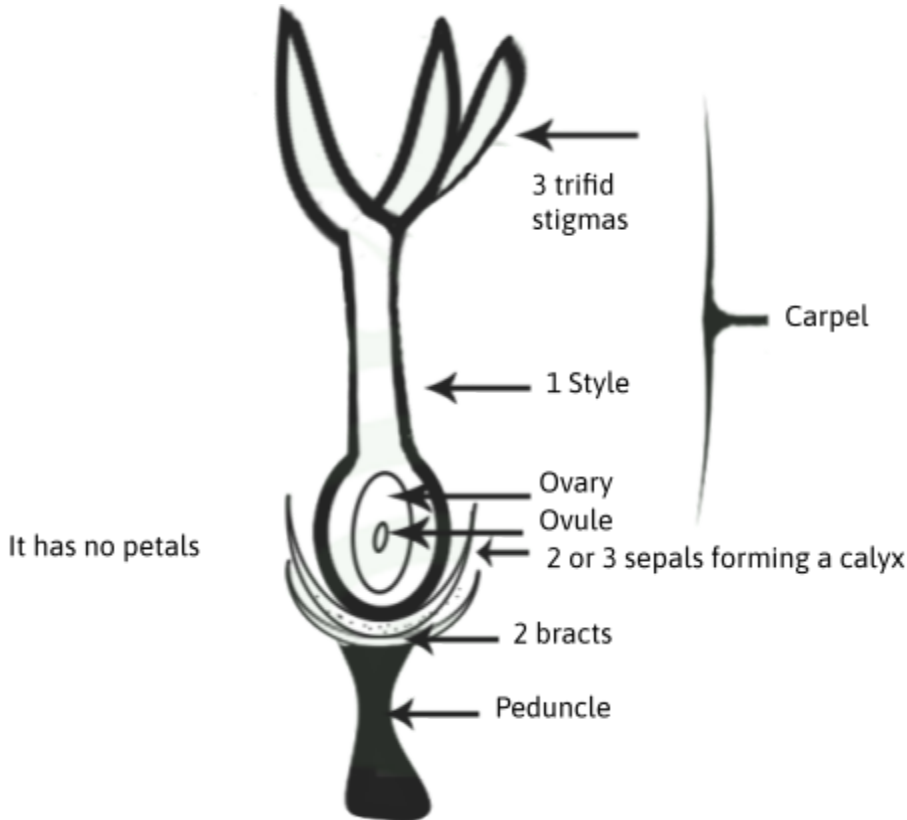
Note: Parts of the male pistachio flower (pollinator). (Plantae, 2020).

As it is displayed in Figure 14 below, *P. vera* female does not have petals (which in other flowers attract pollinators) as it pollinates with the wind movement of pollen. The carpel is the female flower's reproductive organ, and it is made up of the 3 stigmas—that trap the pollen

produced by the male flower—, the style— the “tube through which pollen is delivered to the ovary”—, and ovary— which has unfertilized fruits (ovules). (Singh, 2022).

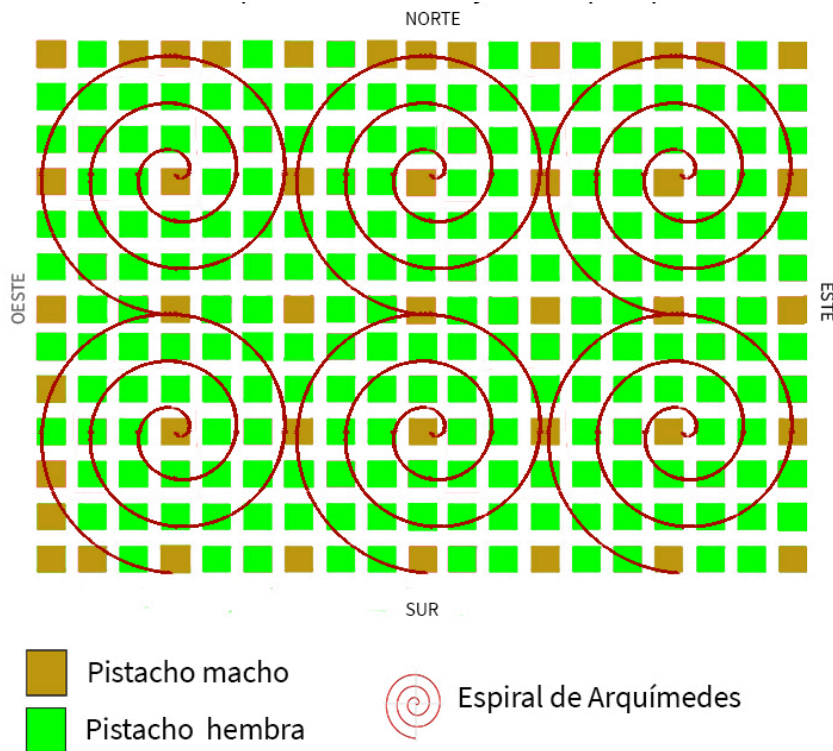
### Figure 14

#### *P. vera* Female Flower



Note: Parts of the female pistachio flower. (Plantae, 2020).

While the male is the strongest pollinator, “both male and female trees are needed in the orchard for pollination, with ratios of 1:14 to 1:25 male to female trees” (Mosz, 2002). This means that 1 male tree can successfully pollinize from 14-25 female trees (Figure 15). The sepals, bracts, and peduncle have other functions unrelated to pollination.

**Figure 15***Distribution of Male and Female Pistachio Trees for Pollination*

Note: The green squares are female trees and the orange ones are male trees. The Archimedean spiral indicates the distribution of pollen from the male trees to the outer females. (Plantae, 2020).

#### 3.4.4: Fruit Development and Seed Set:

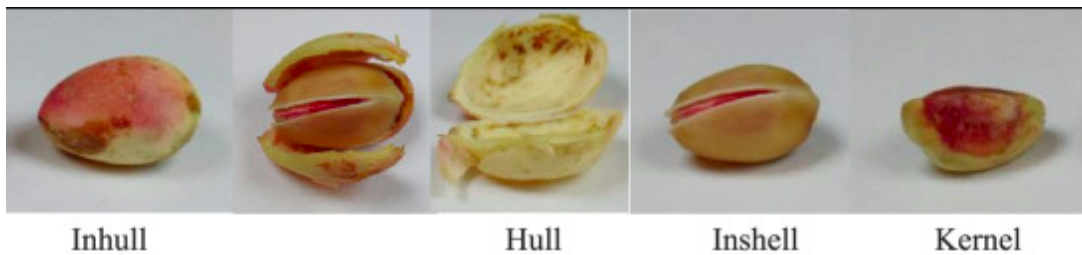
The fruit of *Pistacia vera* L. is a drupe, meaning it is a fleshy fruit covered by a hard shell (endocarp). These develop during 8 weeks. (Shuraki, Sedgley, 1996). The flower buds in the pistachio tree contain the unfertilized fruits inside them (ovules), that turn into kernels. The shell development and nut-filling takes place inside the hull (outer coat of a fruit) as shown in Figure 16. The nut or fruit development has three stages (Figure 17). Stage 1 is when the pericarp (outer shell) grows completely. Stage 2 is when the endocarp (inner layer of pericarp) hardens. Finally, stage 3 involves the growth of the embryo. As the fruit matures, it changes its color from green

to yellow to reddish to purple, and the outer skin of the flower begins to split (Figure 18).

Overall, the shell hardens and the fruit grows in size, and after fertilization, the fruit/kernell is visible and ready to consume.

**Figure 16**

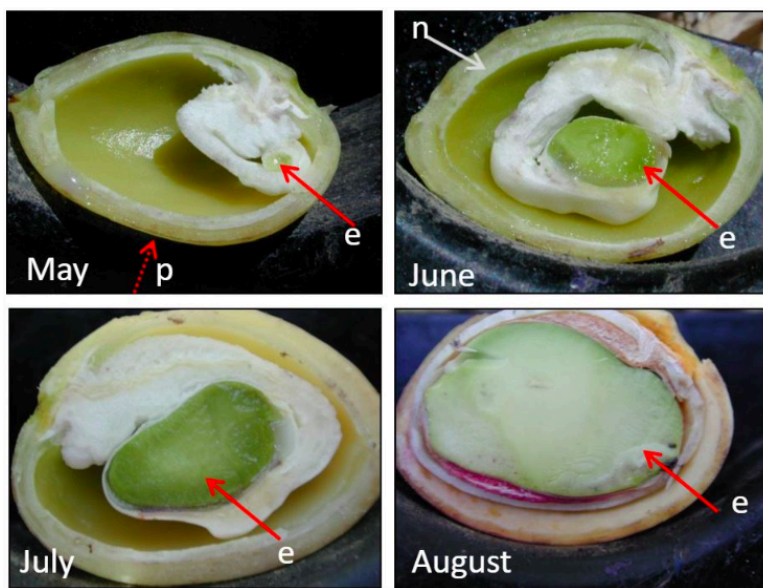
*Pistachio Harvest Components*



Note: (Moussavi et al., 2019).

**Figure 17**

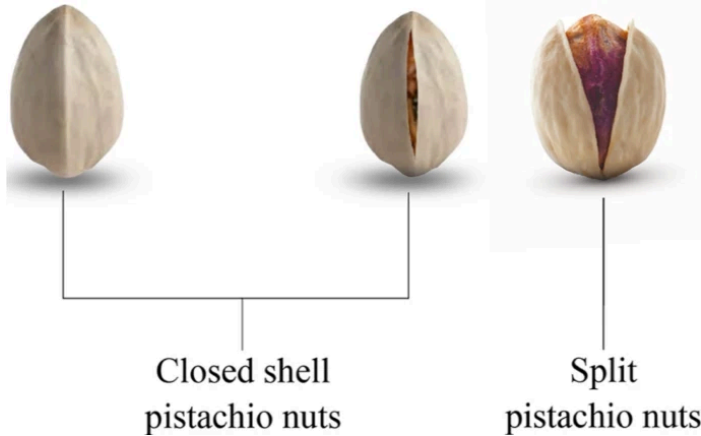
*P. vera* Seed Set



Note: *Pistacia vera* seed formation during 4 months. (e)=Embryo, (p)=Pericarp, (n)= Endocarp. (Fichtner et al., 2019).

**Figure 18**

*P. vera* Endocarp Splitting



Note: (Sukunza et al., 2024).

## 4.0: Propagation and Management

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### 4.1: Cultivation and Planting:

With careful planting conditions, irrigation, and nutrition, *Pistacia vera* trees can grow up to 20-30 feet tall. Figure 19 below displays how the species' orchard looks like.

#### Figure 19

##### *P. vera* Plantations



Note: (Olmos, 2022).

#### 4.1.1: Conditions:

The most important conditions for the complete and successful cultivation of the species *Pistacia vera* L. are temperature and soil. As seen in sections 2.2.2 and 2.2.3, the best temperatures for the species planting is 25-35°C, and the soils (Figure 7 above) must have a pH of 7 to 8. The nut filling phase thrives in heat, although winter is also needed for the tree's dormancy phase. The pistachio tree requires being in a sunny position, though it is important to avoid its branched sunburning. (Herrera, 1997).

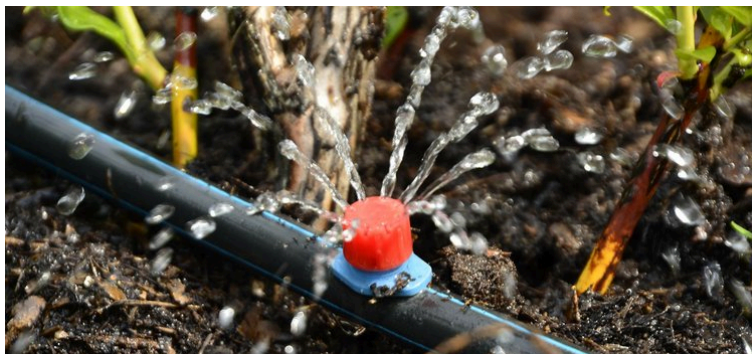
#### 4.1.2: Irrigation:

*Pistacia vera* plantations should be irrigated as it is necessary to maintain the soil moist, but it is important to avoid waterlogging, as they need minimal amounts of water to produce the best nuts, and sometimes can even grow properly in dry conditions (Herrera, 1997). The quality of the nuts can reduce if there is too much irrigation. Watering timing is also relevant and specific to different planting phases. During the growth phase, the tree needs to be regularly irrigated, whereas during the nut maturation phase (see Table 3 above), there should be less irrigation to avoid the nut splitting before the right time. (Herogra Especiales, 2023).

A drip irrigation system is optimal for pistachio crops as it keeps the soil moisture levels in an ideal range. It works by slowly dripping water to the roots of the crop trees as seen in Figure 20 below. This system contributes as well on preventing disease growth as the leaves have a minimum contact with water, and prevents as well waterlogging in the soil. (University of Rhode Island, n.d).

#### **Figure 20**

##### *Drip Irrigation System*



Note: (Kohfeld, 2024).

#### 4.1.3: Fertilizers:

For the successful and healthy production of pistachios, the plant needs specific fertilizers and nutrients. Fertilizers can be introduced through the irrigation system used, and should be applied to the plant after one year of planting, but not in the first 12 months. During the growth phase, there should initially be two applications of ammonium sulfate, and then it can be supplemented with nitrogen fertilizer. Fertilizing should stop in June (following Table 3), to prevent the plant's dormancy phase getting delayed. (Herrera, 1997).

The essential nutrients that the species needs to be fertilized with are: nitrogen, phosphorus, potassium, magnesium, calcium, among other micronutrients like zinc and boron. While nitrogen is necessary for the crop's growth and plant strength during this phase, phosphorus is important for the plant's metabolism and photosynthesis. Potassium is essential for the plant's capacity of absorbing water, strength during hard environmental conditions, and nut maturation phase. Lastly, magnesium is important for the plant's nutrition, and calcium supports the growth of tissues within the plant. (Herogra Especiales, 2023).

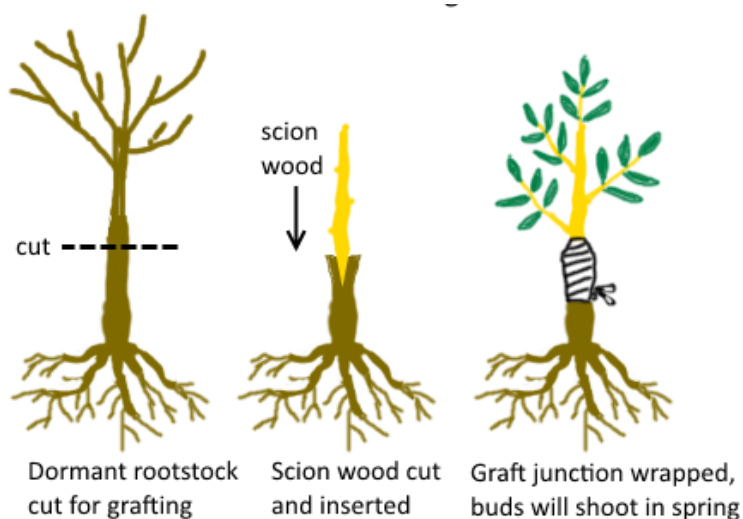
## 4.2: Vegetative Propagation:

### 4.2.1: Grafting:

Grafting is an vegetative propagation method that consists in placing a bud section (scion) from one plant to another dormant (rootstock) stem, root, branch, so that the scion continues to grow (Figure 21) (Britannica, 2025). As the pistachio tree does not “lend itself to simple vegetative propagation”, grafting is used for its domestication. It is a good technique to prevent diseases, modify plant size, repair damaged plants and “obtaining seedlings with certain sex types at the early stages of growth” (Mohammed, 2024). With graftings, there are three things that occur with the contact of the plants: transport of water and nutrients, hormone production, protein movement. For pistachio trees, grafting is used to ensure pollination and nut production. (Mir-Makhamad et al., 2022).

**Figure 21**

#### *Grafting Method*



Note: (Eliades, 2017).

#### 4.2.2: Pollination:

As seen in sections 3.4.2 and 3.4.3 above, *Pistacia vera* is a species that propagates through wind pollination, and indeed, crop success depends deeply on the sufficient pollen production (Herrera, 1997). The recommended plantation scheme is like the one on Figure 15 above, where a male tree is planted at the center of female trees in every direction, and one male tree can pollinate over 20 female trees (Mosz, 2002). The correct spacing between trees is significant for a successful pollination, and “a good planting system seems to be spacing the trees 12 feet [(3.6 meters)] apart in rows spaced 24 feet apart” (Herrera, 1997).

#### 4.3: Management:

Pistachio crops are managed with canopy management practices; its plantations are mechanically or hand pruned to control tree size and benefit the quality of nut production. This method also ensures the spacing between plantation lines (Figure 22), irrigation, fertilization, and can modify the amount of sunlight that intercepts the trees, as “tree shape determines the presentation of leaf area to incoming radiation” (Singh, 2010).

For a successful canopy management, pistachio trees should not pass the 18 feet tall. Topping and hedging are mechanical pruning techniques and should be done “every other row every other year” (West Coast Nut, 2012). These two ways of pruning can cost \$28 to \$35 per acre. Contrarily, hand pruning consists primarily in removing low branches that interfere with the harvest, or creating shade in the interior canopy (see Figure 23 below). This type of pruning can cost \$500-\$600 per acre. Pruning costs can be reduced if mechanical and hand methods are combined. (West Coast Nut, 2012).

**Figure 22**

*Mechanical Pruning of Pistachio Tree Crops*



Note: (Beede, 2017).

**Figure 23**

*Hand Pruning of Pistachio Tree Crops*



Note: (Beede, 2017).

## 4.4: Pests and Diseases:

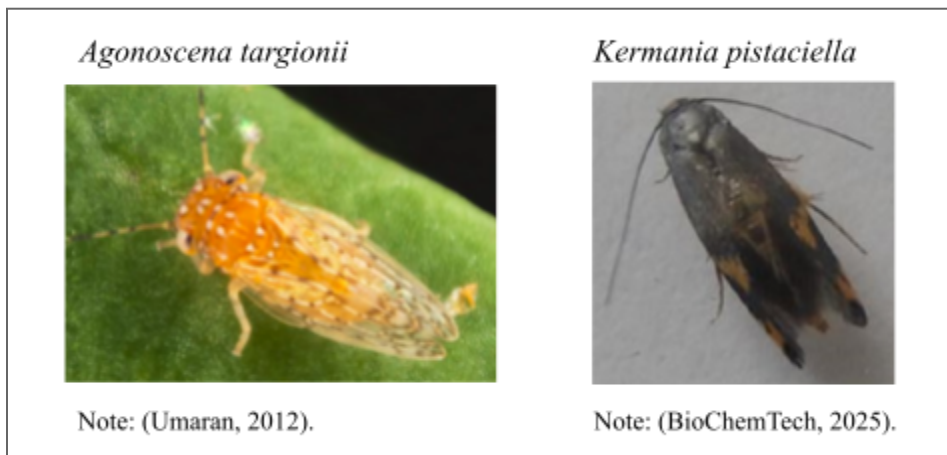
### 4.4.1: Organisms:

The most common pests affecting *Pistacia vera* trees are insects (Figure 24), and its diseases can be categorized as fungal or bacterial. This text would be referencing two main pests and eight common diseases.

The pest *Agonoscena targionii* makes the leaves turn yellow, to curl, dry out, and drop before they should. It also provokes a sticky substance in the leaves and creates mold. On the other hand, *Kermania pistaciella* pest, also known as Pistachio borer, makes the tree flowers turn black and fall down. Then it can make the whole fruit drop, cause lack of branch growth, and provoke a dark excrement on the tree. (Teviotdale et al., 2002).

### Figure 24

#### *Pistacia vera* Common Pests



As for the diseases, the main ones affecting the Pistachio tree production are the fungal (caused by fungus) and bacterial (caused by bacterium) diseases on Figure 25 below.

**Figure 25**

*Pistacia vera* Common Diseases



Note: The first six diseases above the line are fungal diseases on Pistachio trees. The last two diseases below the line are bacterial diseases.

Each of these diseases has symptoms that help harvesters identify them for treatment. *Alternaria* late blight disease causes black spots to appear on leaves and hull of the fruit, makes immature nuts to expand before corresponding time, and can even make the tree leaves fall. *Armillaria mellea* causes leaves to lose their color, and fall down. Branches die, then the plant dies, and clusters of mushrooms grow out of the plant. *Botryosphaeria dothidea* is another disease that causes black spots to invade the plant, and infects all through the branches. Contrarily, *Phyllactinia guttata* disease causes powdery white spots on the plant's buds and leaves that later expand and infect bigger portions. Black spots later appear within the white patches. *Uromyces terebinthi* is known by the appearance of pus-filled red-brown lesions on the leaves and fruit. Leaves fall down early and acquire a red color. Finally, *Septoria spp* fungal disease also provokes dark spots (sometimes black or brown) on leaves that expand in size over time. (Teviotdale et al., 2002).

As for bacterial diseases, *Agrobacterium tumefaciens* disease causes abnormal dark outgrowths in the branches and trunk, affecting the plant's vascular tissue and growth speed. Instead, *Xanthomonas translucens* causes plant dieback (dies progressively from the crown to the roots), production of resin, and black patches and lesions on branches and trunk. (Teviotdale et al., 2002).

#### 4.4.2: Pests and Disease Control:

Pests are primarily controlled with the use and application of insecticides. Diseases instead are treated with multiple methods to treat the disease impact on the Pistachio tree.

For fungal diseases, preventive and curative fungicide applications during summer are effective, as well as it is very important to ensure the correct irrigation management in order to reduce ground wetness and canopy wetness (so diseases don't grow due to humidity). Some of these diseases, such as *Armillaria mellea* require the pruning of infected trees to prevent disease from spreading. Lastly, they can be controlled with primary prevention and fungicide applications in the first leaf expansion. (Teviotdale et al., 2002).

Bacterial diseases can be controlled with preventive methods like “plant disease-free nursery stock” to avoid the disease from the beginning, accompanied by planting in well-drained soils, as bacteria can easily grow in wet conditions (Teviotdale et al., 2002). It is also important to avoid having unnecessary wounds in the plants as diseases like *Agrobacterium tumefaciens* enter through wounds, and “fresh wounds can be treated with a biocontrol agent (*Agrobacterium radiobacter* strain K84)” (Teviotdale et al., 2002). Lastly it is important to sanitize and disinfect the equipment that is used for pruning to prevent spread of disease from one tree to another.

## 5.0: Economic Importance

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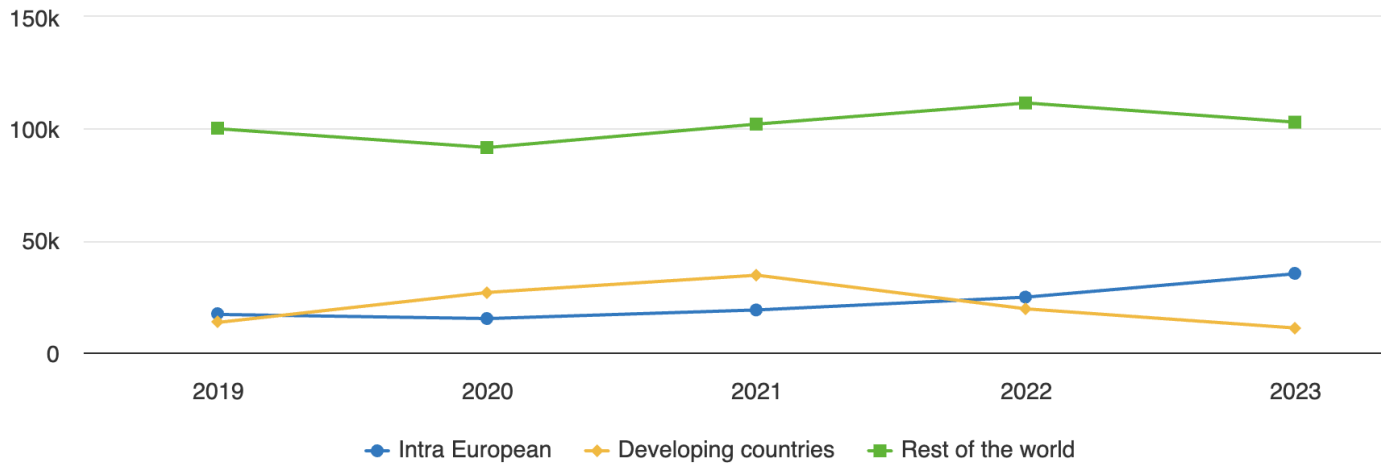
### 5.1: World Trade:

#### 5.1.1: Main Suppliers:

*Pistacia vera*'s main supplier countries are the USA, Turkey and Iran, forming a concentrated market and supplying more than 92% of the total global market. The largest is the United States which “accounts for 78% of total supply, followed by Turkey (8%) and Iran (6%)” (CBI, 2024). See figure 6 above to see the main global producers.

#### 5.1.2: Imports:

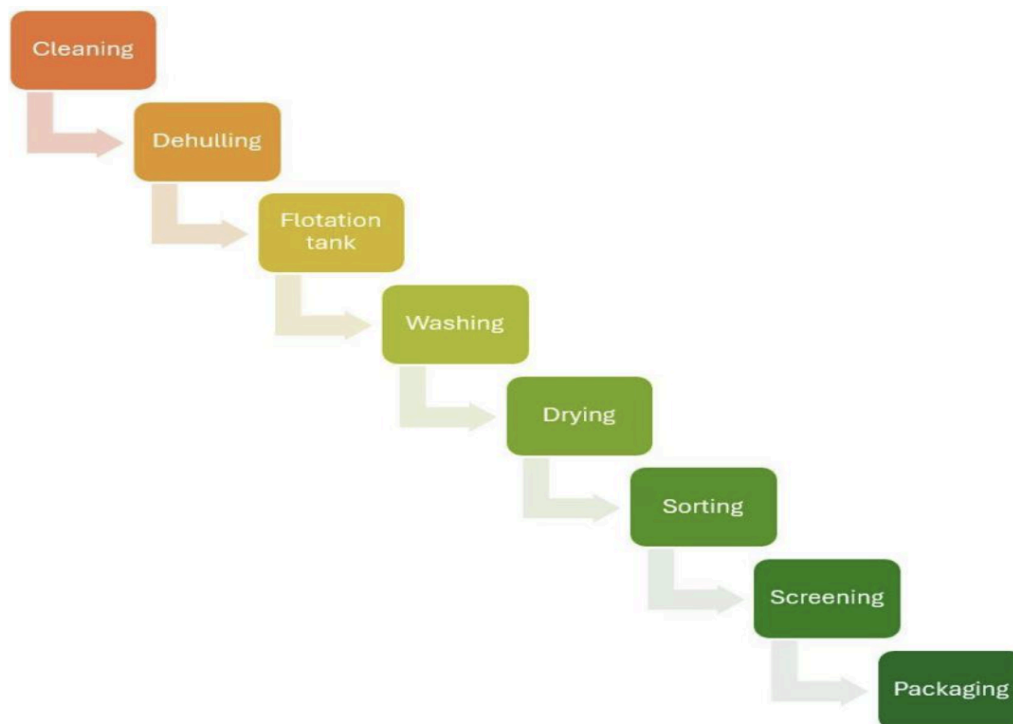
Europe is the largest pistachio importing region in the world, having intra European imports, developing countries imports, and from other countries (see figure 26 below). Germany is the second-largest European importer of pistachio after China, and its import value of pistachios “amounted to €428 million in 2023”, as it imported “33,800 tonnes of in-shell pistachios and 1,100 tonnes of shelled pistachios in 2023”. (CBI, 2024). Globally, Germany imports 82% of the total United States pistachios and 9% from Iran. It imports mainly unprocessed pistachio, focusing on organic products. Changes and fluctuations in imports are influenced mainly by harvest and price levels, but the demand is always constant.

**Figure 26***European Pistachio Imports by Origin (in tonnes)*

Note: 10% of all imports came from developing countries in 2023. (Autentika Global, 2024).

### 5.1.3: Exports:

Large quantities of pistachio are commonly exported as “raw in-shell split nuts”, but some exporters change the processing according to the buyer's requirements. The normal stages of processing raw pistachio are displayed in figure 27 below. Exports change as well according to pistachio trees' bearing pattern, meaning that they produce a large harvest during one year, followed by a small harvest the next year. “Iran’s exports to Europe have been falling at an annual rate of 14%. Turkey’s exports to Europe have been rising at a rate of 13% per year” (CBI, 2024). Furthermore, pistachio can be exported in many processed forms, such as in paste form or confectionary products. Germany is one of the largest re-exporters of imported pistachios, and almost 40% of the total imported pistachio in Europe is exported by Germany. The main potential markets for German export are “Italy (with a 24% share in 2023), followed by the Netherlands (13%), France (13%) and Spain (12%)” (CBI, 2024). Exports increased 15% from 2019 and 2023.

**Figure 27***Stages of Processing Raw Pistachio for Export*

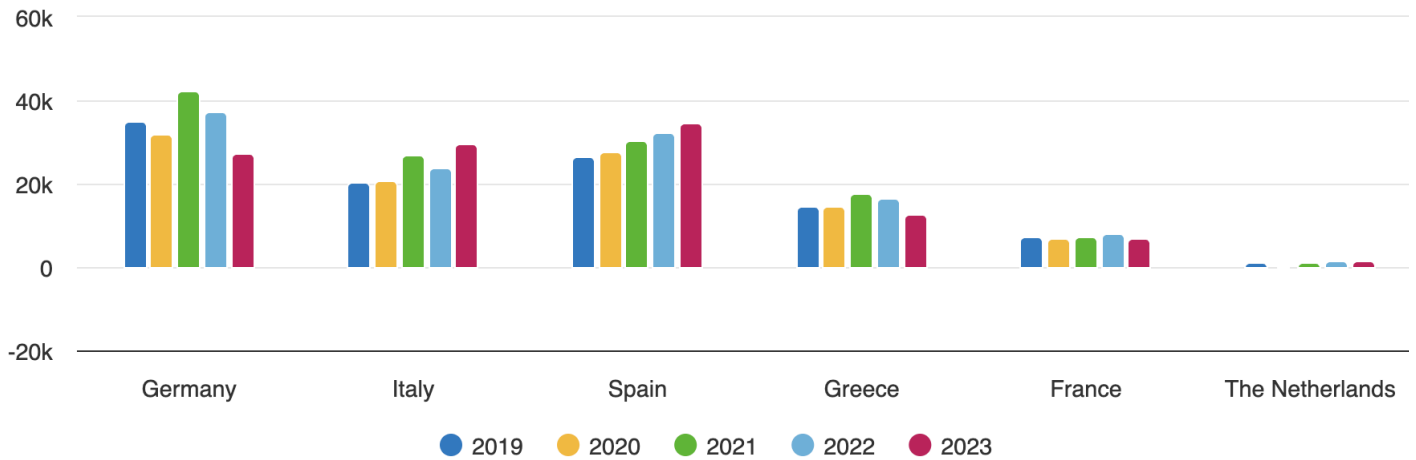
Note: Note: (Autentika Global, 2024).

#### 5.1.4: Potential Markets:

Europe is the biggest potential market of *Pistacia vera* (see figure 28 below). This is due to the “rising health and wellness trends and growing demand for on-the-go nutritious snacks”, and to the oppendes to plant-based products (CBI, 2024). In Turkey, the market concentrates in providing benefits to Turkish culture and cuisine. Italy, Spain, and Greece are markets with high demand and producers. Germany and France are interesting potential markets. Belgium and the Netherlands contribute in both imports and exports, being consumer and transit countries for trade.

**Figure 28**

*Largest Consumers of Pistachios in Europe (in tonnes).*



Note: (Autentika Global, 2024).

## 5.2: Uses:

*Pistacia vera* L. has a variety of uses, and among the genus, it is the only one edible. It is used most for consumption after it is processed, used for baked goods, ice cream, and candy. It also has health benefits and medicinal uses. In the Middle East, and parts of Europe, its resin is used for blood-clotting, and its processed seed is used as dying inks in India. (Al-Saghir, 2012).

### 5.2.1: Culinary Uses:

Pistachio nut's main use is the culinary use that its delicious flavor provides in gastronomy. Its fruit, as a nut, can be eaten as snacks, or it can be used for both sweet and savory dishes. As for sweets, the most common on the market include ice cream, baklava, butter or paste, and pistachio flour for several pastry desserts as it is seen in figure 29 below. (American

Pistachio Growers, 2017). Its nut can also be incorporated in salty salads, blended for pasta sauces, and turned into pistachio pesto. (MasterClass, 2021).

## Figure 29

### *Pistachio Baked Goods and Desserts*



Note: (American Pistachio Growers, 2017).

### 5.2.2: Medicinal Uses:

*Pistacia vera* offers many health benefits, being a great source of “protein, dietary fiber, potassium, magnesium, vitamin K,  $\gamma$ -tocopherol, and a number of phytochemicals” (Dreher, 2012). It has medicinal uses for toothache, low circulation conditions, sclerosis in the liver, abscesses, etc. (Al-Saghir, 2012). This nut provides antioxidants, it helps with weight loss, and can lower blood pressure, blood sugar, and cholesterol. (Benediktsdottir, 2024).

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