A Comprehensive Review on persimmon (*Diospyros kaki)*: Botanical, Horticultural, and Varietal Perspectives

Abstract

Persimmon, belonging to the genus Diospyros, is a deciduous fruit tree renowned for its distinctive fruit and nutritional richness. This review provides a comprehensive examination of persimmon, encompassing its botanical taxonomy, morphological features, and genetic diversity. The horticultural section explores optimal cultivation practices, varietal characteristics, and methods of propagation, while addressing challenges like pest management. Persimmons are not only valued for their sweet and flavorful taste but are also rich in fiber, vitamins, and antioxidants, contributing to potential health benefits. The paper discusses the nutritional composition, bioactive compounds, and emerging evidence of persimmon's positive impacts on health. Furthermore, it touches upon global consumption trends, trade dynamics, and the economic significance of persimmons. Future research directions and areas requiring further exploration are highlighted, underscoring the importance of this fruit in agriculture and human nutrition.

Keywords: deciduous fruit trees, health, nutritional, varietal, trade

Fig 1. Morphology of fruits

Botanical Name:

The edible fruit of several species of trees in the genus Diospyros is known as the persimmon. The Oriental persimmon, *Diospyros kaki*, is the variety that is most often grown of these. It is debatable as to who initially described the species—Carl Peter Thunberg or Carl Linnaeus the Younger[1]. For this plant, the scientific name Diospyros kaki L. f. may be used incorrectly. However, the 1781 publication of Diospyros kaki L. f. is a later homonym of the 1780 publication of Diospyros kaki Thunb. As a result, the term Diospyros kaki L. f. is invalid from a taxonomical perspective[2].

"*Diospyros kaki*" The Japanese kaki persimmon, also known as kakiand "shizi" in Chinese, is the persimmon species that is most commonly grown. These fruits have a delicate to occasionally fibrous texture and are delicious with a hint of tartness. This plant, which is indigenous to China, has large, stiff leaves. The fruit was first cultivated in other parts of east Asia before being

transported to California and southern Europe in the 1800s. Various cultivars have since been chosen. Although it is edible in its crisp, firm state, after harvesting it should be given some time to rest and gradually soften for the greatest flavour. A popular cultivar is the Japanese variety, Hachiya[3]. The fruit's high tannin content turns the immature fruit bitter and astringent. As the fruit ages, the tannin content decreases. Hachiya and persimmons both need to fully ripen before eating. This fruit's thick pulpy jelly and thin, waxy skin are what it looks like when it's ripe. The trade name for D. kaki fruit that has been chemically artificially matured is "Sharon Fruit". Another name for it is "Korean Mango."

"*Diospyros virginiana*," is the native home of the American persimmon. A few more names for it include the common persimmon. This tree's distribution closely corresponds to the Southeastern United States. Its ranges extend westward to Texas, Oklahoma, and Kansas and eastward to New England and Florida. Native Americans have been cultivating the tree for its fruit and timber since prehistoric times, despite the fact that it grows wild. A tiny tree with a typical height range of thirty to eighty feet, D. virginiana has spreading, frequently pendulous branches, a short, slender trunk. It has whole, oblong leaves. Summertime brings about the tree's fragrant blossoms, which are dioecious, meaning that if seed is needed, both male and female plants must be produced. The female flowers are solitary, whereas the male blooms have sixteen stamens that are arranged in pairs. Insects and wind both pollinate the monosexual flowers. Around the age of six is when the tree usually starts to bear fruit. The American persimmon's fruit is oblong or spherical in shape. The fruit is often orange, but can also be black. The astringency of the fruit is diminished by freezing or the bletting procedure[4].

"*Diospyros digyna*" is the black sapote or persimmon is a native of Mexico. When ripe, the fruit's white meat turns black and has a green skin.

D. sintenisii, the Chinese persimmon, and *D. texana*, the Texas persimmon, are two other species having the common name persimmon[5].

Family:

Persimmon belong to family of Ebenaceae. The Ebenaceae are a family of flowering plants belonging to order Ericales. The family includes ebony and persimmon among about 768 species of trees and shrubs. It is distributed across the tropical and warmer temperate regions of the world. It is most diverse in the rainforests of Malaysia, India, tropical Africa and tropical America[6].

Origin:

The most significant persimmon in terms of trade is the Oriental persimmon, also known as Chinese or Japanese persimmon or Diospyros kaki. It is indigenous to northern Indochina, northeastern India, and China. It was initially grown in China more than 2,000 years ago, and in the 7th and 14th centuries, it was introduced to Japan and Korea, respectively. South Korea, China, and Japan are the top persimmon producers[7].

Chromosome number:

Japanese persimmon (*Diospyros kaki)* is a hexaploid tree fruit having a somatic chromosomal number of 90 (2n = 6x, x = 15). There are two races of persimmon: the tetraploid (60-chromosome) race is located in the southern Appalachian region, while the hexaploid (90-chromosome) race normally covers a range north and west of the tetraploid range. These ranges overlap in Kentucky[7].

Taxonomy

Multivariate and isozyme analyses were undertaken for cultivar identification and assessment of taxonomic relationships of 141 persimmon (*Diospros kaki Thunb*.) cultivars that consisted of 110 Korean native and 31 Japanese cultivars. Variables substantially connected with the first principal component (PC 1) were those related to fruit astringency, pollination constant non-astringent (PCNA), pollination variant non-astringent (PVNA) and pollination variant astringent (PVA) were distributed in the positive region of PC 1 axis. Variables substantially connected with second principal component (PC 2) were those related to fruit form. By Ward's minimum variance cluster analysis, cultivars were separated into two groups; first group contained cultivars of pollination constant astringent (PCA) type and second included those of non-PCA type[8]. The four isozyme systems—glucosephosphate isomerase (GPI), malate dehydrogenase (MDH), peroxidase (PER), and phosphoglucomutase (PGM)—were polymorphized, according to electrophoretic examination of isozymes. Twenty-one different GPI band patterns (from A to U) were found, and native Koreans tended to have C, F, and J zygotes. Four distinct zygotes (A to D) were identified in MDH[9]. Cultivars could be divided into 92 categories based on the results of four isozyme analyses, and 64 different cultivars could be uniquely identified.
By Cho (1964), 180 cultivars were gathered in Korea, and around 400 whereas China has over 900 cultivars centered on centuries, cultivar in Japan. D. Kaki has 15 haploid chromosomes, whereas cultivars have 60 or 90 tetraploid or hexaploidy chromosomes. When the flesh of a mature fruit with seeds turns orange-yellow, a cultivar is categorized as pollination-constant (PC), and when the flesh around the seeded locule turns brown due to tannin polymerization and oxidation, it is categorized as pollination-variant (PV)[10]. Astringent (A) cultivars include Hachiya, Fuji, and Saijo, whereas non-astringent (NA) cultivars include Fuyu, Gosho, and Jiro. Finally, cultivars are categorized based on post-pollination modifications and astringent flavour. For instance, Fuyu and Jiro are categorized as PCNA, or "perfect sweet persimmons," which are pollination-constant and non-astringent[11].

Saijo and Atago are pollination-constant astringent (PCA), also known as perfect astringent persimmons; Hiratanenashi and Tonewase are pollination-variant, astringent (PVA), also known as imperfect astringent persimmons; and Nishimurawase cultivar is pollination-variant, non-astringent (PVNA, so called imperfect sweet persimmon). (1984; Yamada and Kurihara). Tannin concentration in fruits is the basis for grouping cultivars according to their astringent flavour. However, when fruits mature, tannins polymerize. Persimmons cannot be consumed even if they contain more than 0.5% of soluble tannins[12].
The size and quality of the tannin cells distinguish sweet persimmons from astringent persimmons. Perfect or imperfect astringent persimmons all had less tannin cells than imperfect sweet persimmons, according to 1986. The tannins in fruits are well polymerized by the treatment of ethanol and acetaldehyde, which is another characteristic of perfectly delicious persimmons. Since the expression of the constant-variant trait is influenced by environment-genotype interaction, these classifications are arbitrary. Although cultivars like Fuyu and Jiro are categorized as pollination-constant and non-astringent (PCNA), they nonetheless retain an astringent flavour when cultivated in regions with brief seasons. Even when exposed to ethanol fumes, the tannins in the harvested fruits do not polymerize (Ryugo, 1988).

In the eastern and southern United States, cultivars of the native American persimmon, D. virginiana (2n-90), including Early Golden, Ruby, and Miller, are grown as accidental seedlings for local consumption[13].

Area and Distribution

China, Korea, Japan, Brazil, Italy, Israel, Australia, and India are the top producers of persimmons. Indian states like HP, J&K, TN, Uttarakhand, and others grow persimmons. China was where the fruit was initially grown, and it is still where 75% of all persimmons are produced today. India only contributes a relatively minor amount to the world's total persimmon production, and its output is insufficient for domestic use alone, let alone exports. With over 10,000 Farmers growing persimmon on a total of less than 500 hectares of land, Himachal Pradesh accounts for the majority of persimmon farming worldwide. Comparatively speaking, it has a much lower producing area than other fruits[14].
Persimmons are grown in the following locations in India:

Himachal Pradesh: Shimla, Solan, and Sirmaur districts are well known for their persimmon farming. Persimmons are successfully grown in these places thanks to the favourable environment and suitable soil.
Persimmon cultivation is well known in Arunachal Pradesh's hilly areas, especially in the districts of Itanagar, Papum Pare, and Lower Subansiri. Persimmon trees can grow well due to the cool environment and high altitude.
Sikkim: Persimmons are also grown there, mostly in the East Sikkim and West Sikkim areas. These areas are best suited for growing persimmons due to their moderate climate and well-drained soil.
Uttarakhand: Persimmons are grown in Uttarakhand in places like Pithoragarh, Almora, and Nainital. These regions are suited for persimmon production due to their cool climate and hilly topography.
Jammu and Kashmir: The districts of Kishtwar, Doda, and Rajouri are particularly well-known for their persimmon production. The growing of this fruit is made easier by the favourable soil conditions and moderate climate.
Meghalaya: East Khasi Hills, West Khasi Hills, and Ri-Bhoi are some of the areas in Meghalaya where persimmons are grown. These regions' cool, humid weather is suitable for persimmon farming.

Soil Requirement

Loamy soils are ideal for persimmon growth. Sandy, light soil is not good for growing persimmons. If there is excellent drainage, this fruit growing can also be done on thick clay soil. For the growing of this fruit, a pH range of 5.5 to 6.5 is optimal[15].

Climate Requirement

The following general parameters are needed for persimmon cultivation in India since persimmons require particular weather conditions in order to thrive:

Temperature: Temperate or subtropical climates are preferable to persimmons. For growing persimmons, the ideal temperature range is between 10°C and 30°C (50°F and 86°F).

Nevertheless, throughout the growing season, persimmons may handle a little bit higher temperature, although extreme heat may reduce fruit quality[16].
Frost: Persimmon trees must be protected from cold temperatures since they are vulnerable to frost. Frosty weather can harm early fruit and flower buds, reducing the overall output. As a result, regions with little or no frost are better suited for persimmon farming[17].
Rainfall: Persimmons need a fair quantity of precipitation, usually between 800 and 1200 millimeters (31 and 47 inches) per year. However, as long as adequate irrigation is offered during dry spells, they can typically adapt to diverse rainfall patterns[18].
Sunlight: Persimmons grow best where there is plenty of it. For optimum growth and fruit development, they need at least 6 to 8 hours of direct sunlight every day.
Height: Persimmons can be cultivated at a variety of heights, although they typically thrive in areas that are 500 to 2000 meters (1640 to 6560 feet) above sea level in elevation[20].

Plant Genetic Resource management and Varieties

Fig.2 Plant Genetic Resource Management and Varieties

Persimmons can be divided into two groups: astringent and non-astringent. Sometimes, all astringent fruits are referred to as "Hachiya," whereas all non-astringent fruits are referred to as "Fuyu."
Non-astringent kinds are sweet even when still firm and not quite ripe, whereas astringent varieties don't become sweet until they are fully ripe[21].
Another classification is connected to pollination. Pollination-constant and pollination-variant are two terms used to describe these categories.
Pollination-constant cultivars yield fruits that are uniform in colour and consistency whether or not they get pollination.
Pollination-variant varieties often yield fruit with brown meat after pollination and light flesh when they are not pollinated (and seedless).
Pollination-constant astringent (PCA), pollination-constant non-astringent (PCNA), pollination-variant astringent (PVA), and pollination-variant non-astringent (PVCA) fruits are all classed together[22].

Leading Cultivars of *D. kaki*

- **Chocolate**: The reason "Chocolate" got its name is that its exterior resembles a typical persimmon with brilliant orange flesh. The flesh, however, is brown like chocolate jelly

when you bite into it, as if a magician had somehow changed it into a chocolate-based treat.Unfortunately, it doesn't taste chocolatey. But this "fruit of the gods" comes close to matching it. It is extremely juicy and sweet with a hint of nutty spiciness. It's obvious this type is unique even before you take a mouthful. The medium-sized fruit has a bowl-worthy appearance when placed on your table and has vibrant red skin. The fruit's lack of seeds is even better. One of the last types to ripen, this pollination-variant astringent variety is ready for harvest in late October or early November[23].

- **Eureka**: The pollination-reliable astringent cultivar "Eureka" is well-liked in both the US and Asia. The medium-sized fruits are available to be picked from late October to early November. The skin is a lovely shade of red. However, the main factor making this type one of the more popular types is the texture, which keeps its shape while remaining stable on the shelf.While many Asian persimmon varieties lack seeds, this particular variety does.

- **Fuyu**: There's a solid reason why "Fuyu" is one of the most popular non-astringent cultivars in the world. There are many advantages to this tree. the fruit's orange exterior matches its pumpkin-orange interior, and it lacks a core and seeds. The squat fruit is topped with a tiny green cap that isn't as large as some other varieties, which makes it just about picture-perfect for a fall display. You can bite into the medium to large fruits right off the tree, even when they are still solid, because it is non-astringent. They have a rich texture that can be crisp and apple-like when they are young or soften as they get older. As it continues to ripen, the flavour becomes sweeter and creamier with a tinge of clove. One of the best things about this kind of fruit is that it hardly ever has flaws, so if you sell it at a farmers' market, you'll probably have a lot of fruit that can be sold. Later in the year, "Fuyu" is ready for harvesting. From the middle of November through the middle of December, picking season normally begins.

- **Giobo**: Giombo is another pollination-variant astringent cultivar that bears large, conical-shaped fruits. When it's young, this variety produces fruit every other year, unlike some others. It produces fruit each year after reaching maturity. When fully ripe, the orange meat is covered in a lovely, almost translucent skin. But what distinguishes it is the flavour. It has a sweet-spicy flavour that only gets better as it ripens. Giombo is harvested between mid-September and mid-October. But be cautious. Early leaf emergence makes it vulnerable to late frosts. If a late frost should occur, cover the tree with a sheet or blanket to keep it safe. When the temperature rises above 34°F, remove the covering.

- **Great wall**: When plant explorer J. Russell Smith discovered one growing close to the Great Wall of China in the 1920s and brought it back to the US, it gave the pollination-constant cultivar its name. In order to increase its resistance to lower temperatures, some farmers have since grafted it onto American persimmon rootstock. The flesh of the 'Great Wall' fruit matures to a cinnamon-orange hue and is an astringent variety that grows to a maximum height of 20 feet. It has medium orange skin. From late September to late October, this variety ripens.

- **Hachiya**: Beautiful fruit with an acorn-like form and an orange peel is produced by the "Hachiya" plant. In California, it is one of the most extensively produced varieties. You need to let this one develops extensively before you'll get a good flavour out of it because the flesh can be really astringent inside. Overripe fruit eventually becomes even sweeter than non-astringent varieties like Fuyu. A pollination-constant variety, the harvest may last into mid-December. Ripe fruits can be picked from the tree starting in mid-November.

- **Izu**: This variety is also very common, maybe as a result of being one of the earliest to ripen. By the time it is fully grown, you can begin picking fruits from the tree in mid-September, and harvests may continue into mid-November. The fruits range in size from medium to giant. 'Izu' is a non-astringent pollination-constant variety with a compact growth habit and highly sweet fruit. Although young trees take a little longer to get going, once they are established, they are dependable performers.

- **Jiro**: Another common variety is called "Jiro," but its disadvantage is that while the tree is young, its yields are inconsistent and unpredictable. Harvests are more regular as the tree ages. Medium to huge in size, the fruit is available to be picked from mid-October until mid-November. Beware of tip cracking.If exposed to strong, lashing wind or intense heat, this cultivar is prone to splitting at the end. You can't stop it, so if you notice fruits cracking, pluck them if they are ripe enough, and use them immediately away.A non-astringent cultivar with continual pollination is called "Jiro." It can tolerate low temperatures of 0°F and is more cold-resistant than the majority of Asian persimmons.

- **Midia**: The 'Midia' fruit can weigh up to 12 ounces (0.75 pounds) per when mature, which is rather huge for a non-astringent pollination-constant type, although the trees aren't particularly robust. In addition, you might need to thin the fruits in order to get a good harvest; this practice is optional for most Asian varieties, with the exception of "Fuyu." Don't be deterred by that. The wonderfully tasty fruits stand out thanks to their indented ring and gorgeous orange skin. Fruit harvesting typically occurs between late October and late November.

- **Saijo**: The flesh is virtually seedless, very sweet, and luscious. This astringent pollination-constant variety's fruit is conical in shape and has medium orange flesh. This is a wonderful option if you want to dry your persimmon. From mid-September until mid-October fruit is available.

- **Sheng**: This cultivar produces medium to large, clearly gelatinous fruit that is available to harvest from mid-September to mid-October. The fruits, which are fairly squat and like tomatoes that someone (gently) sat on. This pollination-constant astringent variety is exceptionally sweet when mature and has a distinctive nutty flavour.

- **Triumph**: This variety stands out because, unlike some persimmons, it blooms without a period of cool hours below 45°F. 'Triumph' is a pollination-constant astringent variety that bears small, squarish, incredibly delicious fruit with few or no seeds. The harvest

season lasts a long time, from September through November. Unlike some other types, it has firm skin even when it is fully ripe. This facilitates handling and storing. In Israel, where it is frequently produced, this type is known as "Sharon fruit."

- **Suruga**: Medium-to-large, very sweet fruits are produced by Suruga 'Suruga'. The extremely sweet and spicy, non-astringent fruits that are pollination-constant keep their flavour off the tree for a very long time. between general, this variety is ready for harvesting between October and November.

- **Tanenashi:** it is a pollination-constant astringent cultivar with yellow-orange flesh and skin that ranges in colour from light orange to red. In Japan, this fruit variety with a cone-like shape is well-liked for drying. The fruit normally ripens from September to October, and when it is fresh and fully ripe, it has a sweet and rich flavour.

Leading cultivar of *D. virginiana*

- **Goldener**: originated as a fortuitous seedling of a native American species in Olney, Illinois, USA. Fruit has tender flesh and a flavorful flavour. When mature, fruits separate from the calyx. It ripens too soon. Even if grafted, it is too late to start bearing fruit.

- **Owens**: It features a medium-sized, oblate-shaped fruit and is an Indiana native. It features seeds-free fruits with a good flavour. Late September to early November is when it ripens. A grafted tree takes longer to begin yielding fruit. The native tree, which has an 85-foot height, a spread of around 60 feet, and a circumference of 13 feet, is thought to be the largest native persimmon tree in the United States.

Fig. 3 **Leading cultivars of *D. virginiana***

<u>Plant Propagation and NurseryManagement</u>

All three *D. Kaki* species—the *D. Kaki, D. lotus, and D. virginiana*—can have their trees grafted or budded onto their saplings. Cutting a 15 to 20 cm long branch with both cut ends sealed is another method of propagation. Due to the fact that many cultivars have a tendency to set parthenocarpically, *D. Kaki* seeds are scarce. However, seeds can be easily found in the fruits of other species. Trees with D. Kaki rootstocks are typically smaller than those with D. lotus or D. virginiana rootstocks[24]. Due to their vigour and graft compatibility with the majority of D. Kaki scions, lotus seedlings are recommended. Some lotus seedling strains cannot be grafted

onto Fuyu. The lengthy tap and sparse fibrous roots, which are readily snapped and severely de topped when transferred, make seedlings challenging to transplant.

Stem cutting:

- One to two days prior to making the stem cutting, water the persimmon tree. Cuttings from trees that lack sufficient moisture in their tissues will not take root as quickly as those from recently irrigated plants.
- Before the first frost in the fall, cut a 5- to 6-inch stem from the persimmon tree using sharp pruning shears or a clean, sharp knife. The cutting can be obtained from side shoots, root suckers, or 1-year-old shoots. Generally speaking, the stems from which the cuttings are made should be firm, semi-hardwood or hardwood, as softwood dries out much more quickly and may not perform well during the rooting process.
- Make a 1- to 2-inch vertical cut on each side of the stem's base. This may encourage roots and improve the stem's capacity to take up water and rooting agents. To stop the cutting from losing moisture, put it inside a container right away, like a plastic bag.
- Rooting medium should be poured into a pot or a propagation container. Sand, perlite, vermiculite, and peat mixtures are a few examples of rooting mediums.
- Before inserting the persimmon stem into the container, make a hole in the middle of the rooting medium. After completely wetting the cut, cover it with a transparent or translucent material. As a result, the air becomes more humidified, which keeps it moist and stops the cutting from drying out.
- To complement the light, they receive during the day, place the plants under a fluorescent or incandescent light bulb for two to four hours each night. The plants require more illumination or roughly 12 hours of sunlight each day.
- After the persimmon cutting has grown roots, plant it in a 4- to 8-inch pot filled with potting soil. Maintain consistent moisture levels while properly watering. Start hardening the young plant by leaving it outside in a shady location for a few hours each day once the threat of frost has passed. Bring the plant gradually into direct sunshine. The young persimmon plant can be placed in its permanent placement in the garden after it can withstand full sunshine and has sturdy roots[25].

Fig. 4 **Stem cutting method**

By seed:

Rootstocks are multiplied by mature seeds. Persimmon seedlings can be grown from fresh seeds. Seeds should be stratified for 60 to 90 days at a temperature of roughly 45 °C for improved germination. These seeds can now be grown in boxes. When the soil temperature is 55°F or greater in the spring, seedlings are laid out. Seedlings should be transplanted when they are 6 to 8 inches tall for optimal lateral root development. When the rootstock and scion are quiescent at the conclusion of one season's development, seedlings can be grafted. Best germination occurs at 28 °C[26].

Fig. 5 Rootstocks

Planting

The planting distance varies according on the climate, cultivars, and orchard management techniques. Additionally, the planting position relies on the mature trees' eventual sizes. The best distance is 5×5 meters of distance. This can accommodate around 400 plants per hectare.
There are two times of year to plant: in the spring and the autumn. Autumn planting is advised for kaki trees to ensure strong roots and recovery of development. However, April planting is advised in colder climates to reduce the risk of winter damage[27].
Although planting a tree is a straight forward process, if done incorrectly, the tree may grow slowly or not at all. The planting hole should be 100 cm wide and 90 cm deep. Each planting hole has 20 kg of manure-mixed soil placed to the bottom, 50 cm deep. Above that point, a tree stump is placed in the center of the pit, and 10 kilograms of top soil mixed with 2 kg of lime and fully rotted manure is then added. The mound in the pit is covered by roots, and then the hole is gradually filled with top soil[28]. A small basin is created, and the tree is immediately irrigated to help the soil surrounding its roots settle. A week or ten days after planting, extra dirt is piled up around the trunk just above the soil's surface to encourage rainwater runoff. Mulching improves survival rates by preventing moisture evaporation because the root of kaki is a tap root.


Fig.6 **Planting**

Training and Pruning

Kaki trees can be trained and pruned in one of two ways. One is the open center natural form, and the other is the modified central leader form. The former is a good strategy for cultivars that grow erect, whilst the latter is better for cultivars that spread out. Recently, it has been proposed that the best tree shape for high density planting be thought of as a spindle bush form similar to apple trees. Kaki trees have a lengthy economic bearing period. Young trees have a tendency to grow straight, but as they age, they start to spread out. The majority of buds in the shoot's base go blind and eventually produce very weak branches, whereas the lateral bud near the shoot's apex produces a very powerful side shoot[29].

As a result, only the perimeter of the canopy has blooms that are easily moving upward. The blind buds grow and create a robust shoot if turning around is accomplished. throughout the juvenile stage. Because of the wood's extreme hardness and lack of suppleness, the primary branch is readily broken. As a result, the branch's angle should be large. In the curved areas of the branch, numerous strong sprouts might be created. The primary branch needs to continue growing straight. Kaki trees have a propensity of bearing. Only the top 2-3 buds of a branch that is a year old will develop compound flower-buds. If the tree is pruned, it stops producing fruits. Thus, spreading out is done more often than turning around and going back[30].

In Fruit thinned out, Fruit size is influenced by cell size and quantity. Up to 30 days after anthesis, the number of cells grows. The time frame for cell differentiation is extended if reserve nutrients have accumulated in the tree to a sufficient amount. Therefore, fruit thinning is less efficient than bloom thinning. If thinning is also carried out prior to anthesis, reserve nutrients are moved to the remaining blossoms, resulting in fruit that is of a decent size. Fruit thinning should start once physiological decline has stopped. The conclusion of cell differentiation should occur at this time[31].

Therefore, fruit thinning should have no effect on cell growth, yet it can cause cell enlargement to result in larger fruit. The best time for fruit thinning is as soon as possible after the end of the physiological drop period, which typically occurs in early July in Korea. The best time for bloom thinning is 10 days before anthesis. Typically, 1-3 blossom of the core flower are kept after blossom thinning. The type of bearing branch determines the extent of fruit thinning.

One fruit is permitted in the center of each cluster on heavy fruiting cultivars, while two fruits are permitted in the center of each cluster on tiny fruiting cultivars. If a branch is weak while bearing fruit, all of the fruits are thinned out. According to Watanabe (1970), NAA 10 ppm

sprays applied three days after full bloom were an efficient agent for fruit thinning. When fruit setting was poor, he claimed that the concentration of NAA could be reduced to 5 ppm[32].

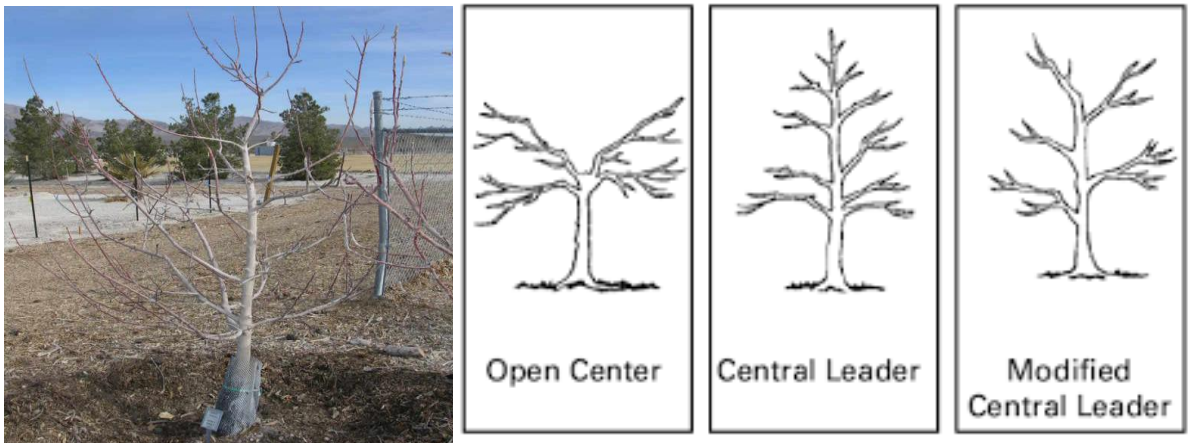

Fig. 7 **Training and Pruning**

Nutrient Management

Manures help soils become more fertile and aerated. However, as trees mature, alternating bearing and poor yield are observed in the orchard without fertilization. The kaki tree's roots are dispersed extremely deeply in fertile soil; therefore, it is common to display strong tree vitality even without use of artificial fertilizers. Because of their deep spreading roots and slowly developing roots, persimmon trees react slowly to fertilizer application. Due to these factors, it takes longer to restore the tree's vigor, which can only be done by using chemical fertilizers. In order to maintain healthy trees, productive soil, and good crop production, manuring is crucial. For young trees, it is advised to apply 1,000 kg of barnyard manure per 10a, but mature trees require 1,800 kg of barnyard manure per 10a[33].

The amount of fertilizer used is determined by the yields, planting density, cultivar, and vigour of the trees. Although determining the necessary number of fertilizers can be challenging, the suggested quantities are listed in table based on the amount of typical supply, the pace at which trees absorb nutrients, and run-off on the soil surface[34].

Water Management

Roots of persimmons develop slowly. Regular irrigation is necessary for optimum growth and fruit of the highest caliber. In the spring and summer, give your persimmon tree a watering once or twice a week. Trees that produce persimmons may endure brief droughts[35].

For newly planted trees to thrive, sufficient water is necessary. After planting, frequent irrigation is needed 2 to 4 times per week. Rainfall, soil type, and evapo-transpiration are only a few of the variables that affect irrigation volume. Fruit become more tolerant of drought as they mature. Having access to water is crucial during the primary growth phase in the first few months of the season. Water accessibility is crucial for flowering and fruit set, though. Irrigation is used in July and August when natural precipitation is unable to satisfy a plant's need for water (tropical areas)[36].

Orchard Floor Management

Kaki buds are compound buds that extend basal laterals on bearing branches as well as new shoots. The shoot apex of a flowering bud enlarges and flattens into a dome-shaped structure. Depending on the species and local customs, this takes place from mid-July to August. C/N ratio, level of training, moisture in the soil, amount of light, and length of sunshine are all factors that affect flower bud differentiation. In comparison to other deciduous fruit trees, the development of flowers in kaki trees is slower after flower bud differentiation. The petal primordia develop and grow in size by the middle of March the following year in tropical areas. Early in April, the anther stamens develop, followed immediately by the pistil[37].

Fig .8 **Orchard Floor Management**

Kaki trees are dioecious in nature. Nevertheless, some female trees may have some staminate flowers, while some male trees may have a few flowers with pistils that may bear a few fruits. Although the female tree has a lovely blossom, the stamen is terminated, signifying no pollen production. The female tree furthermore bears a gorgeous blossom with an aborted pistil. Most economically viable cultivars exclusively produce female flowers. For good seed laying and bearing, cultivars with weak parthenocarpy habits, like Fuyu, must thus be pollinized sufficiently by either insect pollinators or manual pollination. The greenish yellow blossoms bloom in the late spring when the threat of a late frost has passed[38].

Typically, staminate blooms are smaller than pistillate flowers. The latter are typically borne in groups of three to eight, whereas the former is also borne alone. Particularly in the case of persimmons of the PVNA type, seed production is crucial for removing an astringent flavour and enhancing fruit set. To eliminate astringency in Nishimurawase, more than four seeds must develop[39].

Some kaki cultivars, like Hiratanenashi, yield fruits that initially carry seeds but eventually become parthenorcarpic seedless. Cultivars affect parthenocarpic capacity and seed formation capacity. For instance, Hachiya, Nishimurawase, and Fuyu have relatively poor parthenocarpy ability, yet they have great seed production ability with sufficient pollination. While Tsuruga, Hiratanenashi, Sagoksi, and Cheong-dobansi have modest seed production abilities, they have strong parthenocarpic abilities[40].

Kaki fruit physiological decline is divided into two groups: early drop, which happens from anthesis to early July, and late drop, which happens from mid-August to September. In the first drop, there are two waves. The most serious harm is caused by the first drop-wave, which

happens between 10 and 20 days after anthesis. Early in July, the second drop-wave appears. Astringent persimmons experience the late drop more severely than sweet persimmons, notably in Hachiya, Hiratanenashi, and Yokono. In warm areas with little day-to-night temperature variation, the late drop also gets worse[41].

Fig .9 Kaki fruit

The physiological drop's mechanisms. The abscission layer is created between the fruit stalk and the bearing mother branch when early drop occurs. However, in a late drop, a layer of abscission forms between the fruit stalk and the flesh. All types of physiological drop occur for the following reasons: (1) no seed formation due to insufficient pollination; (2) inadequate assimilate accumulation for low intensity sunlight and excessive rainfall; (3) low root activity under excess soil moisture; (4) lack of reserve food cannot supply; inadequate nutrition to every fruit when the fruit set is great; and (5) prolonged blooming period or poor fruit development[42].

Controlling the physiological decrease by cultural practices. The drop can be decreased by providing enough pollination with appropriate pollinizer interplanting. Additionally, fruit and flower thinning, appropriate manuring, and summer pruning are other helpful methods to reduce physiological declines. Applying plant growth regulators like GA or Tomatoton is another option for reducing the decline. But in other cultivars, incorrect handling of the plant growth regulator results in uneven fruit morphology[43].

Disease Management

Crown gall

Disease signs observed around the crown, huge galls (swellings) form, and the bigger roots grow smaller marble-sized galls. Plants get infected by bacteria through wounds in the soil. The plant will turn yellow, grow stunted, and sickly if the condition worsens. Infected crop debris and the soil both harbor bacterial life. Warm temperatures and high humidity encourage the growth of illness.


Fig. 10 **Crown gall disease**

Root rot

The crown, foot, and root rot are caused by the Phytophthora fungus. On the trunk, dark spots of sunken bark known as cankers appear; these cankers release a dark sap that causes stains or streaks. The tree limbs and twigs eventually wither, the leaves turn colour and fall from the tree, and the tree eventually fails as a whole. The pathogens can persist in agricultural waste and soil. This illness can be brought on by the tree's surrounding waterlogged region[44].


Fig. 11**Root rot disease**

Cercospora leaf spot

On both leaf surfaces, there are tiny dark brown dots. The dots are constrained by the veins and take on an angular shape as a result. severely impacted leaves readily fall.The injured plant sections may allow the disease to spread. At temperature of 25 °C and a relative humidity of about 70%favours growth of spot[45].

Fig.12 **Cercospora leaf spot disease**

Circular leaf spot

Leaf spot causes black spots to form on the surface of leaves and occasionally may even impair fruit, although not being fatal to adult trees. It might also cause early leaf fall. When it rains, the fungus spreads. Through the infected leaf, spread. This disease is favoured by temperatures between 25.5 and 30.5 °C and relative humidity levels between 86 and 92%[46].

Fig.13 **Circular leaf spot disease**

Bitter rot

Spot also appears on the surface of fruit and foliage. Additionally, it may cause the early loss of leaves and fruits. It could spread via infected areas. Continual rain, temperatures between 28 and 30 °C, and excessive humidity encourage the growth of disease.

Fig 14 **Bitter rot disease**

Post harvest fruit rot

The fruit calyx (stem-end) was the principal site for the disease's irregular brownish, soft lesions, which spread quickly at room temperature before turning dark brown or black and forming obvious, and occasionally numerous, white to grey mycelium. spreading through fruit that is infected. Fruits are subject to chilling harm, temperature changes, and long-term storage[47].

Fig 15 Post harvest fruit rot disease

Pest Management

Scale

While plant and stink bugs may damage the fruit, scale, persimmon psylla, twig girdlers, and borers attack the tree or foliage. Scales attack the wood on the branches and trunk, primarily white peach scale. Pruning can get rid of small infestations, but bigger infestations need to be treated with a conventional pesticide during the growing season that is directed at the crawler stage of the scale. Large infestations might require two sprays spaced 7–14 days apart. Pruning is a good way to get rid of small infestations[48].


Fig 16 **Pest Management**

Persimmon psylla (*Triozadiospyri)*
The main pest of leaves is the persimmon psylla, which attacks freshly emerging leaves in the spring. Crinkled and deformed leaves indicate an infestation. Control is challenging since the black-bodied adults and white-powder-covered nymphs are found eating inside the deformed leaves. Psylla infestations prevent young trees' shoots from growing normally. It is best to timing the application of conventional pesticides to the bloom stage[49].


Fig 17 **Persimmon psylla** (*Triozadiospyri)*

Persimmon clearwing borer (*Sanninauroceriformis* Walker)
The only known host of the persimmon borer, Sanninauroceriformis Walker (Lepidoptera: Sesiidae), is the American persimmon, Diospyros virginiana. The native American persimmon is employed as the rootstock for the fruit-producing scions of the Japanese persimmon, D. kaki, making the persimmon borer a pest. The native persimmon is attacked by this clearwing moth along the Atlantic Coast from New Jersey to Florida and farther west to Texas, Oklahoma, Missouri, Kansas, Ohio, and Indian[50].
The roots, trunk, and branches of persimmons may be attacked by a variety of wood-boring insect species. The American rootstock is naturally attacked by the persimmon clearwing borer. The adult moth only has one generation per year, which happens in the early spring.

Twig girdlers (*Oncideres cingulate)*
Twig girdlers prey on persimmons as well as a number of different tree species, particularly hickory and pecan. The mature female lays her eggs between September and October by making a hole in the bark underneath the buds on terminal twigs. The female girdles the stem after oviposition, which may eventually fall to the ground. The beetle may spread the wilt illness

Cephalosporiumdiospyri in this way. Twigs that are infested need to be collected and removed[51].

Fig 18 **Persimmon clearwing borer** (*Sanninaurocerifformis* Walker)

Flowering, Fruiting and Yield

Young kaki fruit contains sucrose, glucose, and fructose in addition to a trace amount of sorbitol and inositol. As plants mature, sucrose content rises in the sucrose-type Fuyu, Jiro, Atago, and Hanaogosho while reducing sugar (fructose and glucose) rises in the reduced sugar-type Hiratanenashi. However, following August, reducing sugars are rapidly accumulated in all cultivars of these 2 substances. In contrast to cultivars of the reduced sugar type, cultivars of the sucrose type continue to collect reducing sugars beyond August, peaking in the ripening stage, whereas only sucrose is continually accumulated up to that point[52].

Starch content peaks during the first blooming phase. Starch quickly decreases following anthesis till ripening. The starch almost completely vanishes at maturity. Citric and malic acids are prevalent in mature fruit. Malic acid in Fuyu increases dramatically from the blooming stage until maturity, but citric acid increases in Hiratanenashi. Persimmons are picked when they are nearly completely coloured, ripe, and firm[53].

Beginning in the middle of March, flowering lasts until the second week of April. Fruits develop in September and October and are flat-globose, conical-globose, orange, reddish orange, and orangish red in colour. Orange-colored flesh has a pulpy, fibrous texture. By cutting or splitting the stems, the fruit is freed from the tree while still having its calyx lobes attached. Fruit can weigh anywhere between 50 and 300 g. When fully mature, the tree produces 150–200 kg of fruit per year. The fruits turn visually appealing when they reach maturity and are yellow to orange in colour.[54].

Post-harvestManagement

It's crucial to get rid of the astringency in persimmons since the taste is caused by tannin ($Cl_4H_2O_9$). In order to eliminate astringency, tannins must be polymerized rather than converted to sugar. Persimmons can be produced using a variety of techniques to reduce the astringency. By exposing the fruits of parthenocarpy and partially seeded PCNA and PCA cultivars to ethanol fumes, astringency can be eliminated. Fruits can be made more astringent by packing them in airtight containers with a small amount of whisky or ethanol on the calyx lobes or the wrapping paper that covers the majority of the box[55]. This will induce the tannin to polymerize. The following is how alcohol removes astringency. Alcoholdehydrogenase which is present in fruits, converts alcohol consumed with fruit into acetaldehyde. Fruit tannins are polymerized by this acetaldehyde. Typically, to make 18 lit of stock ethanol (92% ethanol 200 lit including 5 kg ethylacelate), 30.7 lit of water must be added[56].

Fruits with hard nesh and complete pigmentation are used. 1 kg of fruit is treated with 4-5 ml of alcohol. After that, 0.02-0.03 mm P.E. film is used to air tighten the treated box. After 10 days at a room temperature range of 10-15°C, astringency will disappear. One issue with this alcohol treatment is that fruit might get spotted or alcohol-damaged, and the fruit's shelf life (after astringency reduction) is only 1-2 days[57].

CO_2 treatment (short-duration constant temperature approach). In order to prevent heat exchange, the air-tightened room must be sealed with 0.2–0.3 mm P.E. film sheet, and a fan must be used to circulate the air. When fruit is heated or cooled to a temperature of up to 25°C, 300 kg of fruits are treated with 1.3-1.6 kg/m3/'CO, (95-98%). Keep the temperature between 23 and 25 °C. The treatment lasts 20–24 hours. After treatment, the vinyl curtain or ethylene is removed to allow the fruits' CO, gas and heat to escape. This technique may cause CO, gas damage in some cultivars, such as Hachiya, but it has the advantage of extending shelf life and preventing spotted fruit in other cultivars[58].

20 kg of fruits require 240 g of dry ice for the elimination of astringency. Astringency will vanish after five days. Additionally, this approach has a one-day shelf-life issue and is chilling damage by dry ice.

Fruits that have been harvested keep well at 0°C and 85% relative humidity. Persimmons are quickly softened if they are stored with apple and onion, both of which release ethylene gas. Three to ten days prior to harvest, 50 ppm of GA can be sprayed on the leaves to increase storability. Fruits of the Fuyu cultivar can be stored for up to 42 days using these treatments. A polyethylene layer that is 0.06 mm thick can also be helpful for extending storage because it has a similar impact as CA storage conditions[59].

Processing and Value Addition

Fresh persimmons can be consumed after they stop being astringent. The fruits of PCA species with melting flesh, like as Hachiya, Saijo, and Hiratanenashi, are dried whole. Peeling and hanging up the firm, completely developed fruits to dry.

Fruits must be present during the drying process to prevent them from becoming brittle and woody. According to some research, peeling or slicing fruits seems to encourage the generation of ethylene, which causes tannins to polymerize and causes the fruits to lose their astringency quickly[60]. The surface of the dried product develops a fine layer of powdery sugar if it is kept in a cool, dark environment. This is sometimes misinterpreted as fungus infection-produced powder. Fruits with firm flesh and no astringency can be thinly sliced and heated in the oven until the pieces are chewable. When frozen, ripe Hachiya fruit can be consumed as a dessert. Also made with the soft pulp are bread, biscuits, and puddings. Additionally, astringent persimmons are used to make vinegar and pickles. Young persimmon leaves, which are rich in vitamin C and A, can be brewed into a tea[61].

Fig 19 value added products

Future Research Needs

The persimmon fruit market has been strong recently. Compared to barely a decade ago, this fruit is now quite well-known because to significant government promotion and exposure to international markets. The persimmon farming sector still needs organized planting, appropriate planting materials, supported training, uniformity, and education, despite all the marketing. Based on the traditional wisdom they have accumulated through the years; farmers are farming persimmons now. In Himachal Pradesh, very few farmers have the necessary expertise to grow persimmons. Traditional methods are frequently impractical for commercial persimmon farming because many new techniques and practices have emerged over time, making their revival seem a bit far-fetched.

Persimmon production requires standardization, much like any commercial fruit farming. It is important to give adequate instruction and planting supplies. Based on tests and the soil and weather conditions, the ideal variety should be chosen. The majority of these are done by the farmers themselves, and the current stage is more trial and error with little good documentation. Farmers today deal with a variety of issues, including poor fruit setting, large young fruit drop, astringent fruit character, and insufficient understanding of fruit maturity. To top it all off, neither the fruit nor the techniques of eating are known to consumers.

Conclusion

In conclusion, persimmon cultivation stands as a promising venture with a myriad of benefits. This resilient fruit, known for its sweet and vibrant flavor, not only offers a lucrative market but also proves adaptable to diverse climates. Its low maintenance requirements and resistance to pests make it an attractive option for farmers seeking sustainable and profitable crops. Moreover, persimmons boast numerous health benefits, adding an extra layer of appeal to consumers. As global demand for exotic fruits continues to rise, investing in persimmon cultivation emerges as a strategic choice, promising both economic prosperity for farmers and a delicious, nutritious treat for consumers worldwide.

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