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Cultural practices for persimmon production

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SUMMARY – Persimmon is a species easy to grow in the Mediterranean basin and at present there are no limiting factors, apart from water supply for some areas and low spring temperatures in others, that seriously condition its cultivation. Propagation techniques are not advanced, since seedlings from *Diospyros lotus*, and sometimes of *D. virginiana* and *D. kaki*, are used as rootstocks especially in Italy. Planting density is not high, since at present no dwarfing rootstock is massively propagated for persimmon. The most common training systems adopted are palmette and the vase, while centre leader has lost its importance and can be found in old Italian orchards. Pruning consists of the elimination of the branches which have already produced fruits, and with the shortening of long shoots. The root system is deep and very active in water absorption, nevertheless in the Mediterranean climate, with long dry summer seasons, and namely in coastal areas, trees can undergo stress for water deficiency. As for fertilization, persimmon shows a low demand in comparison to other fruit tree species of temperate climates. Fruit set and productivity are positively correlated to pollination, while fruit drop in early stages is associated mostly with seedless fruits in most persimmon cultivars, and namely in PCNA ones. On the contrary, 'Kaki Tipo' and 'Rojo Brillante', the most widely used cultivars in Italy and Spain, respectively, show a very high parthenocarpic fruit set. Persimmon is still a hardy species in Europe, not being an appetizing host for very deleterious pests and diseases: among insects, the Mediterranean fruit fly and the currant clear-wing are the most dangerous.

Key words: Persimmon, propagation, cultural practices.

RESUME – *"Pratiques culturales pour la production de plaqueminiers". Le plaqueminier est une espèce facile à cultiver dans le bassin méditerranéen et il n'y a actuellement pas de facteurs limitants, à part l'apport en eau dans certaines zones et les faibles températures de printemps dans d'autres, qui conditionnent sérieusement sa culture. Les techniques de propagation ne sont pas très avancées, puisque des plants de* Diospyros lotus*, et plus rarement de* D. virginiana *et* D. kaki*, sont utilisés comme porte-greffes spécialement en Italie. La densité de plantation n'est pas élevée, car actuellement il n'y a pas de porte-greffe nain qui soit massivement propagé pour le plaqueminier. Les systèmes le plus couramment adoptés pour la formation de l'arbre sont la palmette et le vase, tandis que l'axe central a perdu de son importance et peut être trouvé dans les vieux vergers italiens. La taille permet d'éliminer les branches qui ont déjà produit des fruits, et d'écourter les tiges très longues. Le système racinaire est profond et très actif pour absorber l'eau, mais dans les climats méditerranéens, aux étés longs et secs, et en particulier dans les zones côtières, les arbres peuvent subir un stress dû au manque d'eau. Concernant la fertilisation, le plaqueminier montre une faible demande comparé à d'autres espèces fruitières des climats tempérés. La fructification et la productivité sont corrélées positivement à la pollinisation, tandis que la coulure des fruits pendant les stades précoces est associée principalement aux fruits sans semences chez la plupart des cultivars de plaqueminier, et en particulier chez ceux de type PCNA. Au contraire, 'Kaki Tipo' et 'Rojo Brillante', les cultivars les plus utilisés en Italie et en Espagne, respectivement, montrent une très forte fructification parthénocarpique. Le plaqueminier est encore une espèce à rusticité en Europe, et n'est pas un hôte très appétissant pour les ravageurs et maladies très délétères : parmi les insectes, la mouche méditerranéenne des fruits et la sésie tipuliforme sont les plus dangereux.*

Mots-clés : *Plaqueminier, propagation, pratiques culturales.*

Introduction

Persimmon (*Diospyros kaki* L.f. = *D. kaki* Thunb.) is originally from China, and from there it spread to Korea and Japan. Its cultivation has recent traditions in western countries where it is present only since the second half of the 19th century. In recent years, the cultivation of persimmon has found renewed interest in various countries of the Mediterranean basin as well as in some American fruit-growing zones and the Australian hemisphere. The reasons for this phenomenon can be attributed to both the favourable marketing prospects which the fruit seems able to guarantee and the hardiness and adaptability of the crop, which, in contrast to many other widely cultivated fruit trees in western countries, requires only minimal care and intervention.

Propagation

The propagation techniques for persimmon do not greatly vary from those employed for other fruit trees and are: reproduction from seed, propagation by grafting, from cuttings and by micropropagation.

Reproduction from seed is employed for the production of rootstocks. In autumn seed are collected when the fruits are ripe. Once they are separated from the flesh, the seeds are dried and layered in constantly moist sand. Planting can take place in winter in containers in a greenhouse at 22°C. When external temperatures are higher, night-time temperatures do not fall below 5°C and soil temperature is not lower than 10°C, the young rootstocks are placed directly in the nursery of young trees at a spacing of 20 cm in the row and 100 cm between rows.

Some nurserymen plant directly in the soil of the young tree nursery at the end of winter, but generally they prefer to permit the seeds to germinate in soft soil (1/2 sand, 1/2 soil) which is carefully shaded since young seedlings are very sensitive to being burned by the sun. In this case, transplanting of the young rootstocks in the young tree nursery takes place when they have reached a height of approximately 20 cm, making sure to trim the tap-root in order to favour greater development of the lateral roots. Special care is given to transplanting so as to avoid breaking the fragile roots and young plants are kept constantly moist.

Generally shading is also employed in this phase in order to favour more rapid rooting of the plantlets and to limit losses as much as possible. The rootstocks usually reach sufficient size for grafting at the end of the year when they were planted.

To favour rooting, studies have been conducted on the effects of mycorrhiza on the growth of young persimmon seedlings. The plants were inoculated with: *Gigaspora margarita*, *Glomus aggregatum*, *Glomus fasciculatum*, *Glomus mosseae* and *Glomus* sp. *R-10*. Various effects where found depending on the fungal species utilized. From the obtained results, it emerged that 15 weeks after inoculation the plants showed an increase in height. In addition, there was an increase in the number of leaves, and thus leaf area; shoots and roots had greater dry weight. The fungi increased the concentration of P both in the principal and lateral roots in nearly all the inoculated plants (Matsubara and Hosokawa, 1999).

The production of rootstocks can be obtained also by cuttings. The best starting material comes from root cuttings. It has been pointed out that the best method to obtain self-rooted plantlets is to remove large sized roots from young plants and put them to root in greenhouse under mist and in controlled environment, and then place them in the young tree nursery in spring. With this method it is possible to obtain rootstocks of a calibre able to support the graft of a single year.

It is known that micropropagation makes it possible to obtain self-rooted plantlets on a large scale and this propagation system is in development for persimmon. Micropropagated trees, compared to grafted trees, do not demonstrate significant differences with regard to productive efficiency, and there is no effect on the quality of the fruit. Moreover, with this technique the plants do not undergo shock from transplanting and there is an increase in the length and number of shoots, whereas there are scarce effects on the number of female flowers and no effects on the number of male flowers. It should be mentioned that micropropagated plants have a rate of growth in the first years of life which is greater and thus could bring advantages for commercial nurseries where vigorous vegetative growth is preferable and for orchards in poorly fertile soils or cold areas.

In most cases, nurserymen graft persimmon plants when they are still in dormancy or at the beginning of vegetative growth. The most common type of graft is by scion (wedge graft, wip and tongue graft and seldom crown graft) in that it guarantees a greater percentage of rooting, in contrast to bud grafts.

Generally the graft is applied at about 20 cm from the collar or, in areas which are more exposed to winter chill, at 70-100 cm in order to attenuate possible damage, using the notoriously more resistant rootstock *Diospyros lotus*. The scions are removed from healthy and well lignified plants during winter dormancy and kept under refrigeration until the time of grafting. The thinner seedlings are grafted by whip and tongue, while those with a larger diameter are cleft or wedge grafted. The diameter of the scions used is from about 6 to 10 mm.

Some nurserymen have obtained good results also with under-bark graft, which is also done at the end of winter or the beginning of vegetative growth and with wood that has been kept under refrigeration for one year. Good results are obtained using chip budding.

As for the graft, it should be mentioned that persimmon is sensitive to temperatures of the grafting waxes (used to avoid fungal infections) which are too high.

The rootstocks used belong essentially to four species of *Diospyros*: *lotus*, *virginiana*, *kaki* and *rhombifolia*.

Diospyros lotus: currently the most commonly used rootstock in Italian persimmon orchards. It has notable resistance to low winter temperatures and drought, and it is able to impart to the scion elevated vigour and uniformity of development; it has a root apparatus which is not tap-rooted and does not produce suckers; it has excellent affinity with pollination variant (PV) and pollination constant astringent (PCA) cultivars (except for a slight delay in entering into production and an accentuation of fruit drop in combination with cv. 'Hachiya'); it has total or partial incompatibility with many pollination constant non astringent (PCNA) cultivars, including 'Fuyu'; another negative aspect of this rootstock is its susceptibility to cancer of the crown (*Agrobacterium tumefaciens*).

Diospyros virginiana: recently suggested for new plantings. It is of American origin, easily propagated, of elevated vigour and resistance to heavy and moist soils, but excessively misshapen (for the heterogeneity of seedlings which are obtained) and used to produce suckers. Up to now, it has been particularly common in Sicilian orchards where the graft in the field is still widely practised: rooted two-year-old seedlings of *D. virginiana* are wedge grafted the year after planting.

Diospyros kaki: the oldest existing rootstock, of Japanese origin. Seedlings of this rootstock produce tap-roots with few lateral roots but, trimming the tap-roots of young seedlings at the time of transplant in the young tree nursery, these develop a good root apparatus. The roots are rather fine and easily broken and this creates some difficulty for the nurseries with regard to packing and for farmers for with regard to rooting. The affinity with all cultivars grafted onto it is excellent. It is considerably less resistant than *D. virginiana* and *D. lotus* to excesses of moisture in the soil, but as compensation it is not very susceptible to cancer of the crown. For its hardiness and uniformity of plants, both in the nursery and in the orchard, it is by far the most commonly used rootstock in Japan, China, New Zealand and California. *D. kaki* has scarce resistance to cold and for this reason it is used in southern Italy and wherever there are not problems of low winter temperatures.

Diospyros rhombifolia: created to obtain dwarf rootstocks but it exhibits problems of incompatibility; for example with the cultivar 'Fuyu', the plants are too weak and some die after four to six years.

Plantations

Soil management, both before planting and during plant growth, is rather simple, not requiring any special technology. The root system of persimmon, and its most common rootstock used in Europe (*Diospyros lotus* L.) is similar to other fruit tree species hence soil tillage should be shallow.

Planting and spacing

Persimmon presents some difficulties in rooting, above all due to the roots' ease and rapidity for dehydration. One-year whips are sold either with or without root-ball. The one-year whip with root-ball is definitely better because there are not problems with dehydration and shock from transplanting is less. To resolve dehydration problems in one-year whips without root-ball, fruit-growers position the plants immediately after uprooting from the nursery, sometimes adopting soaking in dung (Bellini, 1982a). In both cases, once planting has taken place it is best to irrigate the plants immediately, both to maintain the rooting apparatus turgid and to assure good contact between the soil and roots. Trees are planted from autumn to spring and each plant is provided with a supporting pole which rises approximately 150 cm above soil level.

Currently in specialized plantations, there is a tendency to increase planting density in order to reach a quantitative production increase in a short time. This makes it possible to reduce plant development, making culture operations easier as well as containing overall costs.

The spacing employed in persimmon orchards depends on various factors: cultivar vigour, soil fertility and training system used (Table 1). Presently there are not dwarf rootstocks for persimmon, thus arrangements which are too close and also training systems associated with high and very high planting densities are to be excluded.

Table 1. Planting distances (in meters between rows and along the row) for modern persimmon orchards in relation to tree vigour, soil fertility and training system (from Bellini, 1991)

Vigour of cultivars	Soil fertility	Training systems		
		Vase	Centre leader	Palmette
Medium	Medium	5.0 × 4.0	5.5 × 4.5	4.5 × 3.0
	High	5.0 × 4.5	5.5 × 5.0	4.5 × 3.5
High	Medium	5.0 × 4.5	5.5 × 5.0	4.5 × 3.5
	High	5.0 × 5.0	5.5 × 5.5	4.5 × 4.0
Very high	Medium	5.0 × 5.0	5.5 × 5.5	4.5 × 4.0
	High	5.5 × 5.5	6.0 × 6.0	4.5 × 4.5

In shallow or poorly fertile soils and with cultivars characterized by average or scarce vigour, spacing can be 4.5 × 4.5 m. When there are very vigorous cultivars with broad crown (e.g. 'Hachiya' and 'Tamopan'), for planting in fertile, deep soils with good drainage, wide spacing is employed: up to and at times greater than 7 × 7 m. Closer spacing is instead employed with less vigorous cultivars: 'Yakume' needs spacing around 5 to 6 m both between and along rows; 'Fuyu' prefers spacing of 6 × 6 m.

Attempts have been made (Lunati *et al*., 1988) to reduce the distance along rows to 3 m and between rows to 4.5 m with palmette training. On one hand, this spacing allows rapid formation of the fructifying wall, early productivity of the plantation, good economic productivity until the eighth or ninth year, however on the other, it is necessary to deal with the need to thin the trees along the rows because of the elevated vigour and vegetative density. A cultural intensification of this type can only be temporary and requires greater costs.

Tillage

Tillage is advised essentially in two periods: in autumn, when relatively deep tilling (15-20 cm) is carried out to permit rainwater to be stored in the deep layers of the soil, and in spring, when one or more superficial tillings (5-10 cm) are carried out, depending on the case, in order to impede water evaporation, eliminate weeds and favour microbial activity.

Periodic superficial tillage must be applied keeping in mind the characteristics of the root apparatus, which has a configuration similar to that of other fruit trees, with roots that develop prevalently in the superficial layers of the soil (40-45 cm) (Bargioni, 1962). Only in soils with excellent structure do a part of the roots (about one-third) reach the deeper layers.

In the most fertile soils and where there is greater possibility to intervene with irrigation, it is possible to introduce, after the first years of vegetation, grassing. It is necessary to consider that the heaviest interventions in a persimmon orchard are those tied to the harvest, which is carried out in a period frequently characterized by continual rain (especially in northern regions): problems emerge with tilled soils with regard to compacting of the soil and difficulties with the movement of machines, problems which do not exist or are nearly negligible when grassing is present.

Training system and pruning

Training systems

Persimmon tends to spontaneously assume a dome or pyramidal behaviour, with a rather expanded crown and high ramification. Therefore training systems which are more similar to the natural one are those of volume, such as centre leader and vase, while modern Italian persimmon cultivation has mainly employed palmette (Bellini, 1982b).

(i) *Centre leader* (pyramid) is the shape persimmon naturally assumes and it is widespread in old plantings. It is essentially not employed in more recently plantations in that it is particularly difficult to mechanize principal operations such as pruning and harvest, requiring long periods. In order to create centre leader at the end of the first year, shoots destined to form the extension and the first tier of branches at about 1.30 m above soil level are chosen and it is made up of three shoots opportunely distant one from the other. The extension is instead cut at about 70 cm from the first tier. The next year, at the site of the cut, shoots will appear, and from these the extension and three new shoots destined to form the second tier will be chosen. This type of pruning is continued until the desired number of tiers is reached.

(ii) *Palmette* (oblique-branch-palmette) is instead the training system used in Italy in new plantations. It permits mechanization of the principal operations. It is realized by creating three to four tiers of branches at a distance of 80-100 cm from each other. In order to favour the formation of the tiers, it is necessary to always cut the central extension at winter pruning. The branches must be inclined at about 60° with respect to the central axis since branches with a more upward trend tend to become bare in the basal part. The branches should be cut when they cross with those of the neighbouring plant. It is necessary to favour the formation of numerous suitably spaced small branches able to assure vegetative renewal along all the branch.

(iii) *Vase* (open centre) is found only in old Italian plantations, while it is still in use in new plantations in the area of Valencia (Spain). Vase, normally with three principal branches, is obtained by choosing three vigorous shoots at 80-100 cm from the soil. These branches will later be shortened in order to favour the formation of fruit-bearing shoot and the extension of those branches. In very productive cultivars, such as 'Rojo Brillante' and 'Kaki Tipo', the breaking of branches can occur.

Production pruning

Production pruning is aimed at maintaining well balanced plant vegetation and at having a homogeneous distribution of fructification in the crown, thus permitting quality production. Although persimmon has the capacity to self-regulate the fruit load through fruit drop, production pruning is an operation which must be carried out every year. The absence of pruning interventions causes a shift in the productive zone toward the exterior of the crown and progressive stripping of the basal portion of the branches. Moreover, leaving the plants unpruned strongly reduces illumination into the internal parts of the crown, and the shading thus leads to greater fruit drop (Costa and Spada, 1988).

Persimmon bears fruit on branches of the same year, above all in the basal and median portions. It does not tolerate well intense pruning cuts, which provoke the emission of suckers and woody branches without fertile buds; while less intense cuts, which leaves an elevated load of buds and thus fruits, stimulates production alternation, which leads to a worsening of qualitative characteristics and smaller size of the fruits.

The vigour of the plant must be considered in pruning: in young plants and in vigorous adult plants pruning must be very light and generally limited to small cuts. In weak plants, generally, the thinnest branches and those in shade are eliminated. While in plants which are too vigorous the aim is to control their excessive growth, limiting nitrous fertilization and reducing pruning to a minimum.

Pruning is carried out by eliminating or shortening the productive branches and thinning those which are one-year-old. Trimming of one-year-old branches can be carried out either to shorten those which are too long (more than 40 cm), and whose fructification in the terminal portions can be subjected to friction, or to favour the emission of shoots able to insure production the following year, maintaining production near the skeleton structure of the tree. In the first case, the cut is carried out above several mixed buds leaving the branch about 30-40 cm long so that it is able produce. In the second case, the cut can be carried out immediately above several vegetative buds leaving a spur approximately 5-10 cm in length.

Pruning operations can be carried out during the entire winter dormant period, but in areas where there is danger of returning cold, it is advisable to postpone pruning until the end of vegetative dormancy or to anticipate it to the period following harvest. In young plants which are in formation, it can be useful to concentrate pruning in the summer.

Irrigation

Although persimmon is a plant which can support drought rather well, studies conducted on irrigation reveal that good water availability is important above all during flowering and fruit set in that it brings out the vegetative activity which is manifested principally with shoot growth. This is most intense in the first days of May and declines rapidly in the second half of the month, and then falls to minimum values after fruit set. Water transfer is important also during fruit growth in that it favours a normal development of the fruits, inducing larger size and leading to a lowering of their sugar content (Natali and Bignami, 1988).

Where natural precipitation does not satisfy hydric needs, irrigation is applied in July and August, but the irrigation season can be prolonged until as late as September.

The employed irrigation method depends on water availability and tradition. For example in the Faenza area, infiltration from furrows is employed: irrigation is begun in July with three interventions. Localized irrigation is also used: six interventions are applied in July and August and three in September, administering a total of 2-2.5 m^3 per plant. Furthermore, it has been determined that, with a daily evapotranspiration of 4-6 mm, a localized supply of 20-40 l/tree (333 plants/ha), for 70 days (corresponding to approximately 700 m^3), realization of elevated size and nearly contemporary maturation of fruits is possible (Ragazzini, 1978).

In the Naples area, irrigation is carried out by submersion of beds or depressions created around the plant in such a way as to not block superficial tilling between rows. Two or three waterings are administered between August and September. These long irrigation time-table are tied to the irrigation method and are in part justified by the elevated quantity of water available (Bellini, 1979).

Bellini (1979) reports that in California, generally from 150 to 200 mm of water are administered monthly in different irrigation time-tables, depending on the method employed (lateral infiltration, sprinkling or drip). The susceptibility of persimmon to pooling of water which, while it is not elevated can lead to problems of root asphyxiation, should not however be overlooked.

Fertilization

With regard to fertilization of persimmon, the extreme variability in culture environments of this species does not permit a valid generalization of the employed techniques.

The nutritive needs of persimmon vary in the different periods of the life cycle. During production, the plant’s need for nutrients varies over the course of the year, above all as a function of the various vegetative and productive phases: sprouting, growth of buds and leaves, flowering, fruit set, fruit development, flower induction, ripening, accumulation of reserves, entry into dormancy.

The phase of bud growth is, from a nutritional point of view, particularly critical. This phase has an intense pace and for such a brief period of time, and at the beginning it takes place exclusively thanks to the nutritional reserves accumulated the previous year since persimmon has a late foliation and begins good photosynthetic activity only after about 15 days from sprouting (Hino *et al.*, 1974). Also the productive phase requires an adequate availability of nutritional substances in order to allow fruit development which, with a different rhythm, begins in June and finishes at the beginning of October.

Absorption of nitrogen increases progressively until July and then rapidly decreases in the following months; the period of maximum consumption is between May and August when the plant assumes 68% of the annual total.

The peak of P absorption occurs in July, while between June and August 70% of the annual total is absorbed of this element. For K and Ca maximum absorption takes place is June; between May and July approximately 78% and 70% of the annual consumption of K and Ca, respectively, occurs. Approximately 90% of the total Mg assumption takes place from May to August, with a peak between July and August.

Observation of the seasonal variations of leaf concentration of nutritive elements gives indications about the nutritional status of the plant. Research conducted in New Zealand on cv. 'Fuyu' (Clark and Smith, 1986) reveals that the leaf content of N, P and S decreases progressively over the course of the season. This probably occurs due to the effect of leaf growth rate, which is much greater than the absorption of these elements. These three elements continue to be accumulated in the leaf until August, before they are directed to other organs such as fruits, bark or wood. Also Cu, Fe and Zn decrease until August, and then increase later since, being scarcely mobile in the plant, they are accumulated in the leaves until leaf drop. The concentrations of B and Ca increase progressively over the course of the vegetative season, due to the fact that these two elements are not transferred, which in turn renders their continual availability in the soil important. It has been found that distributing boron (B_2O_3) on the soil leads to an increase in fruit size and anticipation of maturation (Granelli *et al.*, 1988). It was noted that, while having distributed elevated amounts of B_2O_3, symptoms of phytotoxicity were not found in the crop, which induces a certain tranquility in the use of this microelement at least for brief periods (one to two years).

For K, an accumulation in the leaves is observed until August, after which time it decreases because of its transfer toward other parts of the plant to constitute reserves, or probably also to satisfy the needs of the fruits which in September and October present their maximum accumulation following development and intensification of the processes of maturation.

Evaluation of annual extirpation by the plant can direct the fertilization technique by indicating the quantities to be returned to the soil (Table 2). It is known that young plants need good availability of nitrogen, while they require only limited quantities of P and K. Over time, the relationship among these macroelements modifies for the increased need of P and K. For plants in full production it is important to have a balanced supply of N, P and K able to maintain a good equilibrium between vegetative and productive activity.

Table 2. Year removal of some mineral elements by persimmon trees in full production (from: Ragazzini, 1983)

Element	N	P_2O_5	K_2O	CaO	MgO
g/tree	501.7	103.63	436.31	508.81	95.41

Studies on fertilization have been carried out to determine the effects of nitrogen, phosphorous and potassium on fruit quality and productivity of persimmon orchards (da Silva *et al.*, 1992). It was noted that a good level of phosphorous increases average fruit weight and also colouring, thus guaranteeing greater appreciation on the market. However, an elevated concentration of phosphorous (more than 235 kg/ha) can cause a reduction in fruit production due to a nutritional imbalance in the plant, principally causing problems with the absorption of zinc, a lack of which provokes dropping of the young fruits (Costa and Spada, 1988). Phosphatic fertilization does not have effects on the soluble sugars content.

Potassium, like all nutritive elements, has both positive and negative effects. The negative effects are: (i) antagonism of absorption and transfer of calcium and magnesium which causes deficiency of these nutrients; (ii) decrease of the average fruit weight (Basso *et al*., 1985); and (iii) decrease in fruit acidity and reducing sugars content. Among the positive effects, it has been verified that soluble sugars increase in a directly proportional way with increasing doses of potassium.

Nitrogen does not have an effect on average fruit weight, while it causes negative effects on solid soluble sugars concentration. Therefore, it is in contrast to K. Furthermore, it has been verified that increasing doses of nitrogen increase titratable acidity of the fruit while potassium, as mentioned above, decreases this acidity.

It is necessary to keep in mind the physiologic needs of the plant and environmental characteristics when planning the time of fertilization. In this regard, a fractionated distribution of nitrogenous fertilizers from the end of vegetative dormancy (February), when presumably there is a return of development and root activity, to spring (April-May), when there is maximum growth of shoots and flowering, seems sufficiently in accordance with the Italian cultivated areas. A limited supply of slow-release nitrogen, together with P and K, at the beginning of autumn is efficacious for favouring the final growth phase of the fruit and accumulation in the tree of nutritional reserves; growth of the plant in the initial phases of vegetative development in following year depends largely on the amount of reserves.

In practice, fertilization is carried out from February to April, depending on the farm, with medium release nitrogenous fertilizers, or with complex fertilizers in order to assure good availability of P and K as well as N. Administration in autumn is avoided: at the beginning of autumn due to the risks of an excessive prolongation of vegetative activity; in late autumn due to the risk of loss through leaching.

As a general rule, it can be assumed that in soil which contains sufficient nutritive substances and has undergone good basic fertilization, annual doses of 100-150 kg of N, 50-70 kg P_2O_5, and 70-100 kg of K_2O are able to supply an adequate nutritional support for persimmon. In order to avoid a lack of Mg, 40 units of MgO can be supplied every two years.

Organic substance is very important, above all for basic fertilization in a plantation's first years. Generally, it is supplied by administering manure or green manure.

Pollination, fruit set and drop

The flowering and fructification biology of persimmon is rather complex in that the flowers can be female, male or hermaphrodite. Moreover, the species can be monoecious, dioecious and polygamous-dioecious. Generally, the cultivars of agro-pomologic and commercial value have only female flowers, preferring to produce seedless fruits. The fruit is a berry that can develop either after pollination or trough parthenocarpy.

Fructification by parthenocarpic methods, characterizes most of the agronomically interesting cultivars and determines the formation of seedless fruits. Fecundation guarantees a more regular development of the fruit and exercises notable influence on the organoleptic qualities, with various effects depending on the cultivar; in addition it contributes to reducing the amount of drop, both of flowers and fruit, assuring greater production (Bargioni *et al*., 1976; Bellini *et al*., 1991).

The effects of pollination have been studied above all in Japan, where manual pollination trials effectuated on the same day of anthesis and the day after, led to an elevated rate of fruit set (Yasunobu and Akiyama, 1979).

Pollination trials conducted in Sicily (Caruso and di Marco, 1984) highlighted how parthenocarpy leads to a fruit drop of more than 90% in 'Hana Fuyu' and 55% in 'Cal Fuyu', whereas with pollination it is reduced to 72% in 'Hana Fuyu' and 30% in 'Cal Fuyu'. The same authors underline the greater production obtained by a plantation of 'Hana Fuyu' subjected to controlled pollination by 'Cal Fuyu' and 'Mandarino', compared to the production of plantations left to free pollination. Furthermore, Yamada *et al*. (1987) demonstrated that the production from non pollinated plants is variable over the years. In order to guarantee a good pollination, in New Zealand the presence of at least two pollinating cultivars and a ratio between pollinators and plants to be pollinated of 1:8 is advised (Kitagawa and Glucina, 1984).

The role of bees and other pollinating insects has also been studied to evaluate the incidence of their activity on the production of cultivars which seem to benefit from pollination. From these studies it has emerged that the persimmon flower is very attractive to bees while it is scarcely visited by other insects (Piazza and Intoppa, 1996).

Keeping in mind the that receptivity of the stigma very brief and at its maximum immediately after the closing of flowers and on the following day (Yasunobu and Akiyama, 1979), in order to guarantee pollination it is necessary that there is an elevated presence of beehives in the orchard. The number varies depending on the climatic conditions (temperature and rainfall) and the presence or lack of other crops and competing spontaneous flowers.

Fruit drop can be due to a lack of ovary development which provokes an accumulation of abscisic and salicylic acids the gynoecium when there in not pollination (Lu *et al*., 1982). In Korea, the effect of various types of pollinators on fruit drop in the cultivar 'Fuyu' was studied. The percentage of drop in 'Fuyu', pollinated by *D. lotus*, wild persimmon, 'Nishimura Wase', 'Mikado', 'Bang Gosho', 'Zenjimaru', and free pollination, was 77.3, 17.1, 22.9, 32.0, 34.0, 13.4, and 65.9% respectively. Therefore, the cultivar 'Fuyu' requires a pollinator in order to reduce the percentage of drop, and wild persimmon is considered the most suitable for this purpose (Lee *et al*., 1998).

In some cases an excessive fruit set can cause alternating phenomena. In order to avoid that an elevated number of fruits negatively influences flowering induction, thinning of the immature within 30 days of full flowering seems efficacious (Matsumoto and Kuroda, 1982), unless, as often happens, natural drop of the newly-formed fruits occurs early on, i.e. immediately after flowering.

In the Australian subtropical zone, studies have been carried out on the effect of the active ingredient paclobutrazol on thinning and fruit dimension. Paclobutrazol does not influence fruit set but it increases the fresh weight of fruits, compared with the control, by 7% while reducing the number and weight of seeds (George *et al*., 1995).

Also in Australia, the effect that the position of buds in the crown can have on fruit set and quality and quantity of fruit produced has been studied. From the investigation, it was found that the position in the crown has little influence on quality while it plays a role in fruit set, which progressively increase from the bottom toward the top (George *et al*., 1996).

Adversities

Persimmon, compared to other fruit-producing plants, is affected by a small number of adversities, among which only a few can cause damage of economic importance. Notwithstanding this fact, it was considered useful to include, here below, a brief report of the most serious ones which can have direct influence on persimmon growers in Mediterranean countries.

Abiotic adversities

Persimmon is a plant which tolerates rather well low temperatures when it is in dormancy, but the buds and young shoots are sensitive to spring frost (Nakagawa and Sumita, 1969; Hong and Wang, 1980; Leng *et al*., 1993). In winter, temperatures below –15°C can notably damage branches, in particular in CFNA cultivars, however spring frost is more dangerous due to frequent recurrence. Under normal conditions, spring frost causes various levels of damage in relation to both the species belonging to the genus *Diospyros* and the single persimmon cultivars.

Kang *et al*. (1998) have conducted trials on resistance to spring frost damage in five *Diospyros kaki* cultivars ('Fuyu', 'Hiratanenashi', 'Hokikoshi', 'Jiro' and 'Tamopan') and four different *Diospyros* species (*D. lotus*, *D. oleifera*, *D. rhombifolia*, *D. virginiana*). Cold damage was examined one month after frost events on 13 and 14 April 1996. The plants in group 1 did not reveal damage. Plants were categorized into four groups: undamaged plants, slightly damaged plants, damaged plants, heavily damaged plants (Fig. 1; Table 3).

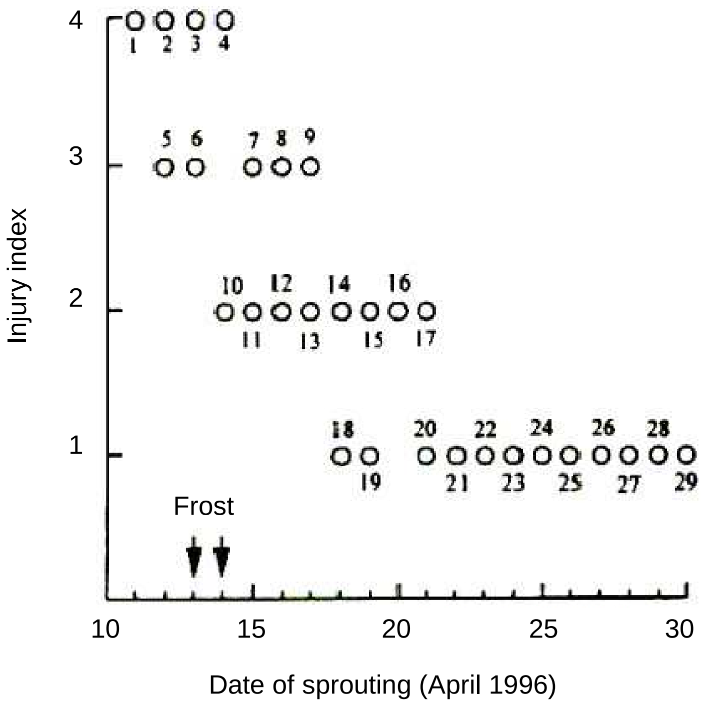

Fig. 1. Response to spring frost of persimmon cultivars and some *Diospyros* species. Injury was examined about 1 month after the frost of 13 and 14 April 1996 (1 no injury-4 heavy injury; numbers indicate the cultivars reported in Table 3) (from: Kang *et al.*, 1998).

Table 3. Spring frost injury on different cultivars and *Diospyros* species induced by late spring frost in 1996 (from: Kang *et al.*, 1998)

Injury index†	Cultivar and species
4	1 Tonewase; 2 Meotogaki; 3 Hiratanenashi; 4 Nishimurawase
3	5 Shiroutodamashi; 6 Hiratanenashi; 7 Hokisushi; 8 Mizushima; 9 Gionbo
2	10 Johonshi; 11 Tamopan; 12 Jiro, Toyooka; 13 Aizumishirazu, Pansu; 14 Tenjin Gosho, Toshi, Wasemyotan, *D. oleifera*; 15 Okumyotan, Seihakuji, Tenryubo; 16 Dojohahachiya, Karasumi; 17 Miyazakitanenashi, Yashima
1	18 Shozaemon; 19 Yamato; 20 Hokikoshi, Taywankoshi, Taywanshoshi; 21 Zenjimaru; 22 Fuyu, Shibumyotan, Yokono; 23 Hazegosho; 24 Mikado; 25 Amayotsumizo; 26 Benigosho, *D. lotus*; 27 Ogosho; 28 Hanagosho, *D. rhombifolia*; 29 Kyara, *D. virginiana*

†1: no injury-4: heavy injury.

Application of Prohexadione Ca to plants retards sprouting, thus making it possible to efficiently reduce damage from future spring frosts (Matsumura *et al.*, 1992).

Persistent rainfall during flowering impedes pollination and, together with cloudiness (which reduces solar radiation), leads to a slowing down of the photosynthetic process. This causes not only the drop of flowers as soon as they are set, but also the onset of phytopathologies, leaf drop and fungal attack.

Persimmon, compared to other fruit trees, is less demanding with regard to light. When there is sufficient light, the leaves are more active and resistant, the branches are stronger and the fruit is of better quality; however when there is little light, there is an inferior assimilative capacity, and thus a dropping of fruits, thin and long branches, and weak leaves. On the other hand, an elevated exposure of the fruits to direct irradiation can provoke quite pronounced lesions on their skin.

Persimmon trees are rather fragile and can face the breaking off of branches when the fruit load is excessive. When subjected to wind, the shoots break off easily if they are not well lignified, the leaves can be lacerated, and lesions or scratches can appear on the fruits. Therefore, persimmon cultivation should be avoided in areas of strong and persistent winds.

While persimmon is quite resistant to pooled water, in cases of excessive moisture superficial rooting occurs which leads to negative influence on fruit development.

Biotic adversities

In Mediterranean countries involved in persimmon production, biotic adversities sufficient to impede its cultivation have not been noted, although several phytophagous (Mediterranean fly, currant clear-wing, and greenhouse white flies) in many cases require efficient methods to control their danger (Ferrari *et al*., 1992).

Among bacteria, *Agrobacterium tumefaciens* should be mentioned. It causes tumours of the rooting apparatus and on the collar of the plant, often provoking vegetative withering and sometimes death of young plants.

Among fungi, *Armillaria mellea* is one of the principal agents that cause vegetative withering, and at times death of plants where there is pooling of water, and in plantations where other fruit trees have been grown previously. Symptoms are seen in adult plants when the roots come in contact with contaminated remains from previous crops and are thus attacked by the pathogen. Another serious fungal disease is *Phomopsis mali* which over the course of a few years leads to complete desiccation of the epigeal parts of effected plants, while below the collar the rootstock can remain vital for several more years and give rise to apparently healthy suckers. *Phomopsis dispyri* is a pathogen which can attack all woody organs of the aerial portion, causing cortical necrosis. Stricken plants face withering with leaf and fruit drop as well as progressive loss of vitality and desiccation of branches.

Among afflictions which strike the fruits, several fungal diseases due to *Botrytis cinerea*, *Penicillium* spp. and *Rhizopus nigricans* should be mentioned. These pathogens develop on fruits with lesions subjected to conservation or which remain on the plant until maturation. Rotting (*Botrytis cinerea*) can afflict both young plants in the nursery and persistent calyx leaves which transmit the infection to the fruits.

Apex cracking ("kachorekka") and calyx separation ("hetasuki"), typical of the PCNA cultivars, are serious alteration which cause fruits to be unmarketable, also because the above mentioned infections take hold in the fissures. These alterations are found most frequently in young plants where a vegetative imbalance tends to produce very large fruits with very rapid growth. The cultivars characterized by large-sized fruits and calyx which is reduced in size are more greatly subjected to "hetasuki", like those with flattened fruits compared to those with round fruits. Studies conducted in Japan have demonstrated that the susceptibility to these two alterations is transmitted genetically. The entire PCNA cultivar group is effected by these alterations; the difficulty to remove this tendency through genetic improvement is considerable given the scarce genetic variability present in this group. Excessive fertility of the soil and accentuated rainfall contribute to increasing these serious alterations of the fruit.

Among nematodes, some species belonging to the genera *Meloidogyne*, *Criconemoides*, *Longidorus*, *Xiphinema* and *Tylenchulus* cause slow deterioration of persimmon orchards but to such a degree as to normally not require particular steps.

As for phytophagous, there are about thirty living species involved. Among the most worrisome for persimmon is the Mediterranean fruit fly (*Ceratitis capitata*), above all when climatic conditions are favourable and there is availability for much of the year of fruits from various host plants. Thus, the insect is able to develop almost uninterruptedly throughout the year. In these areas, the fruit fly also attacks persimmon fruit, particularly the varieties with late maturation. Instead, varieties with an early harvest are less effected by the attack of fly while damage to them is essentially is due to the traces from stings due to egg deposition in that the laid eggs are not able to hatch because they are devitalized by the high tannic content of the still immature fruit. In Emilia-Romagna, the fly rarely appears, it has a fewer number of generations and it involves restricted areas where particularly favourable microenvironments are present for the fly development.

Eulecanium corni and *Eulecanium persicae* are two polyphagous species which can occasionally be observed on the branches, leaves and fruit bracts, without however causing significant damage. *Planococcus citri* and *Pseudococcus longispinus* (*adonidum*) are rather common and cause sporadic infestations in almost all plantings, above all toward the end of summer. They live under the calyx bracts and produce a sticky honeydew which, in cases of serious infestation, stain the fruits and these are then sites where mould easily develops (Tranfaglia, 1973).

Among moths, the species which attack persimmon are: *Cossus cossus*, *Symnoca signatella* and *Synanthedon tipuliformis*. The coat moth (*Cossus cossus*) is a polyfagous species which attacks also persimmon but its infestations are much less frequent than those of other fruit trees. The larvae of *Symnoco signatella* live off of the cortical tissue of adult plants and only rarely damage also the cambium layer. Their damage is of scarce economic interest, even if they sometimes favour attacks by the currant clear wing (*Synanthedon tipuliformis*) (Zuccherelli, 1970, 1974; Ragazzini and Briolini, 1980). This latter species is considered the most feared phytophagous of persimmon. Its larvae cause notable damage to both nursery plants and those in production, positioning themselves in the area of the graft and fork of the principal branches and causing erosions of varying lengths and depths. This causes damage to lymphatic vessels, yellowing and reduction of vigour, and thus a loss of productivity. Very often branches break and in the most severe cases the entire plant breaks of under the effect of wind.

Dialeurodes citri, which gives rise to occasional infestations, lives on the underside of leaves and produces honeydew which stains also the fruits, constituting the substrate for the development of mould fungal agents; the same problems derive from *Metcalfa pruinosa*, which in attacks also persimmon.

There are occasional attacks by *Heliothrips haemorrhoidalis*, a thrips which is present in late summer or autumn on the underside of leaves. It effectuates numerous stings, causing yellowing of the blade, producing blackish excremental drops which stain the vegetation and fruits.

The presence of *Cydia pomonella* and other species of leaf rollers (*Argyrotaenia pulchellana*, *Cacoecimorpha pronubana*, *Clepsis semialbana*) is exceptional (Ciampolini and Fanti, 1971). The chemical fight against these pests, in the few cases in which it may be necessary, is very difficult due to a lack of registered products for this crop.

The fight against currant clear wing is principally of a mechanical-chemical type (Lugaresi, 1998). Therefore to protect plantations, once the infestations have been identified it is necessary to react in a manual way. At the time of winter pruning, the bark is removed, using appropriate cutting tools, to expose the nutritional gallery of the insect; steel brushes are useful for assisting in the elimination of the phytophagous hidden in the wrinkles. After having brushed the area, chemical attack can be undertaken with specific treatments for the infested woody organs using oils together with phosphorganic compounds. During the period of maximum emerging from the cocoon or birth of larvae, it is possible to carry out some treatments using phosphorganic compounds. Integrated control can be realized through the use of irrigation of suspensions containing parasitic nematodes.

In order to fight against *Ceratitis capitata* it is possible to use various active ingredients, including: dimetoate, fenitrothion, trichlorfon, diazinon, etc.

Finally, with regards to anti-cryptogamic defense against *Phomopsis diospyri*, it is necessary to surgically remove the effected parts and then use, in autumn and winter treatments, copper products (Giunchi *et al*., 1988).

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