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Walnuts

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Walnut (genus *Juglans*) is known for the nuts and timber it produces. There are many species but it is the Persian walnut *(Juglans regia)* which is best known and grown most extensively in the world as a food crop. It is also commonly known as the "English" walnut but the name "Persian" is preferred because it indicates the area extending from Eastern Europe to the Himalayas where the species is native. It is widely cultivated with commercial production in France, Italy, Turkey, China, India, and the United States, the leading producer. Practically all of the U.S. production is in California (mostly in the interior valleys) which now has about 178,000 bearing acres with an average yield of around one and one-third short tons (in-shell basis) per acre. Many orchards produce over two tons per acre and yields of three tons are common in some of the recent plantings.

Walnuts have two major outlets, the in-shell and shelled markets. In recent years, the amount of the crop sold as shelled product has been increasing and now represents about 68% of the crop. Most of this is sold domestically since the export market which is around 25 to 30% of the total supply consists almost entirely of in-shell sales. Sun Diamond Growers, a coop-

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Fig. 1. Lateral bearing habit in walnut as shown by nuts borne on current season's growth from lateral buds of one-year-old shoot.

erative marketing grower organization, handles a little over half of California's total walnut production. The remainder of the crop is sold through independent handlers dealing directly with producers.

Climatic Adaption

Walnut cultivars in California are sensitive to both low and high temperatures. High summer temperatures can result in sunburning of the hull and dark shriveled kernels. Some damage to exposed nuts occurs at 100°F and severe damage at 105 to 110°F or higher, particularly when the trees are under moisture stress. In the spring, once growth begins, walnut leaves, shoots, blossoms, and nuts are easily killed if temperatures drop below freezing. For this reason, late leafing cultivars are grown in mountain areas where spring frosts are a hazard. Young vigorous Persian walnut trees which continue to grow into late fall are subject to killing of the new shoots by fall frost. In the winter when the trees are dormant, cultivars grown in California can tolerate 12-15°F without serious injury. Some strains grown in colder parts of the world (carpathian walnuts) can tolerate much colder temperatures when the trees are dormant but they are not as productive. The amount of winter chilling needed to break the rest or dormancy is an important climatic factor that determines where walnuts may be grown satisfactorily. Most walnut cultivars require some temperatures below 45°F during the winter months. If this condition is not met, the results can be seriously delayed bud opening, poor crops, and dieback

of branches. Franquette and other late leafing cultivars are so severely delayed that it is not practical to grow them in warm winter areas like Southern California.

Soil Requirements

Walnuts do best on soils where roots can develop uniformly to a depth of 9 to 12 feet or more. This requires soil of medium texture free of hardpan or layers of high clay content. Soils of this type are typically associated with alluvial fans of rivers and streams. Under these conditions both of the commonly used rootstocks, North California Black walnut *(J. hindsii)* and Paradox hybrid *(J. Regia* x *J. hindsii)* seem to perform equally well. Under less than ideal conditions, however, Paradox is preferred because it is more vigorous and more resistant to Phytophthora root and crown rot diseases.

Water Requirements

A mature walnut orchard requires 4 to 4.5 acre-feet of water per acre per year if the trees are to produce the maximum number of high quality nuts possible. The period of irrigation is from late spring to late summer prior to harvest. However, late fall or winter irrigation may be necessary in areas of low average rainfall or in very dry years. Good quality water is also essential. Water that contains excess quantities of boron, chloride, carbonates, bicarbonates, or other salts is not suitable for walnut production. Paradox hybrid rootstock is particularly sensitive to excessive soil salinity and boron.

Yield Factors

Bearing habit is an important factor in determining the yield potential of young trees . Cultivars with high (80 to 90%) lateral bud fruitfulness are called Payne-type cultivars and they will bear more heavily during the early years than cultivars with low (0 to 5%) lateral bearing habit (Fig. 1). Lateral bearing is less important to the yielding ability of a mature orchard where the crop is being borne primarily on spurs rather than laterally on one-year-old shoots. However, there does appear to be some relationship between degree of lateral bearing and yield at maturity. Lateral-bearing cultivars need much more pruning than less fruitful ones.

Bearing surface is an important consideration in maximizing early yields. Most growers are utilizing higher tree densities with precocious cultivars to attain earlier economic production (Fig. 2). Tree spacings of 24 to 30 feet are common in orchards planted over the past 15 to 20 years and there is now interest in hedgerow planting of walnuts to even further increase the number of bearing units per acre.

Flower initiation is dependent on availability of sunlight. Maximum nut production is normally reached in close plantings (30′ x 30′ or less) by about 10 years of age. By this time the trees have grown together and have about as much leaf surface as can be exposed to good light. It is at this stage that shading and loss of the lower fruit wood starts to become a serious problem. The problem is avoided by anticipating a crowded tree condition and maintaining good light penetration to lower spurs through regular pruning or the removal of trees.

Fruit set in walnut is normally very high, but can be significantly affected by spring weather and pollination conditions. Late spring frost or rain which spreads walnut blight may cause damage to foliage and flowers. This means that leafing and bloom dates are very important factors in the performance of walnut cultivars. Early cultivars are more prone to damage by codling moth in addition to walnut blight. The dates of pollen shedding and pistillate flower recep-

Fig. 2. Young bearing Ashley Walnut Orchard (30′ x 30′) typical of recent plantings in California.

tivity are very important to pollination and productivity. Pollen shedding must coincide with pistillate bloom for the production of consistently heavy crops. In many cultivars, pollen is released too early (protandry) for effective pollination of the last pistillate bloom. Because of this, it is often suggested that a second cultivar be planted which will shed pollen at the end of pistillate receptivity of the first cultivar.

Nut size is an important factor in in-shell sales and may be a factor in total yield ability of the cultivar. Nut size is a varietal characteristic but can be greatly influenced by pruning and soil moisture availability, particularly in late spring and early summer when most fruit growth occurs.

Kernel percentage is of importance primarily to cultivars sold as kernels rather than in-shell. A low shelling percentage results in more wasted shell. On the other hand, too high a shelling percentage may indicate that the shell is thin and weak, and that insect damage may be more prevalent than with a moderate (48 to 55%) shelling variety. Kernel percentage is largely a characteristic of the particular cultivar (Fig. 3).

Kernel quality is a very important marketing characteristic. A premium price has traditionally been paid for light-colored kernels. Cultivars vary somewhat in kernel color, but darkening is often associated with heat damage to nuts directly exposed to the sun. Sunburn can be especially severe

where trees are deficient of adequate soil moisture in the summer. Off-grade, primarily shrivel, mold and insect damage, directly reduces the edible kernel yield. Consistently low off-grade is a very desirable varietal characteristic. However, prompt harvest is also important in avoiding damage by navel orangeworm or mold.

Cultivars

Payne is an old cultivar which originated as a seedling in the George Payne orchard in Santa Clara County many years ago and was first planted in the San Joaquin Valley in about 1920. It was the first cultivar in California with lateral bud fruitfulness and is still being planted in the coastal areas and the northern part of the San Joaquin Valley. It represents 16% of the total bearing acreage. Yield potential is high. Approximately 80 to 90% of the lateral buds on shoots are fruitful. The leafing date is in mid to late March in the Central Valley. The leafing date of Payne is the standard by which other varieties are compared. The pollen shedding period on Payne coincides quite well with the period of pistillate flower receptivity. This partially explains why solid Payne blocks are often very productive.

Payne is an early harvesting variety, maturing in mid-September. Nut size is considered medium to small and kernel percentage averages 49% with fair color.

Payne tree size is moderate with a rounded shape and good vigor. Moderate to heavy pruning is required when the trees are young to avoid overbearing. A good pruning program must be practiced in the mature orchard to maintain vigor. Spacing should be about 30′ under the best growing conditions. Payne is very susceptible to both codling moth and blight.

Hartley is a seedling of French parentage selected by John Hartley in the Napa Valley. It was introduced into the central valley in 1932 and has become the most widely planted cultivar with 28% of the bearing acreage. It continues to be popular in many areas today. Yield potential is moderately high. Hartley is the principal cultivar used for the in-shell market because of its excellent kernel color, lack of problems with codling moth and blight in most of California, large size and good shell characteristics. It is susceptible to deep bark canker. Under conditions of moisture stress or poor soil conditions, deep bark canker can be a limiting factor in Hartley production. For this reason, Hartley requires fertile, deep, well-drained soil and an adequate water supply for good production.

Hartley has up to 10% lateral buds which are fruitful. This means Hartleys are somewhat slow to come into bearing, but bear good crops at maturity. The leafing date of Hartley is approximately 15 days after Payne. Since Hartley is a late blooming variety, the only acceptable pollenizer at the present time is the very late blooming Scharsch-Franquette. Harvest timing for Hartley is mid-season. The Hartley nut is generally large and has a broad, flat base and a more or less pointed tip. It is thought of as being somewhat heart-shaped. Kernel percentage is approximately 46%.

The Hartley is a moderate to large tree which is moderately spreading, with good vigor on fertile soil. Hartley needs 40 to 45′ spacing for a mature tree.

Franquette, an old French cultivar, was the most important one grown in California until 1960 and still retains 15% of the bearing acreage. In recent years it has been planted in very limited numbers because of lack of lateral bud fruitfulness, large tree size and

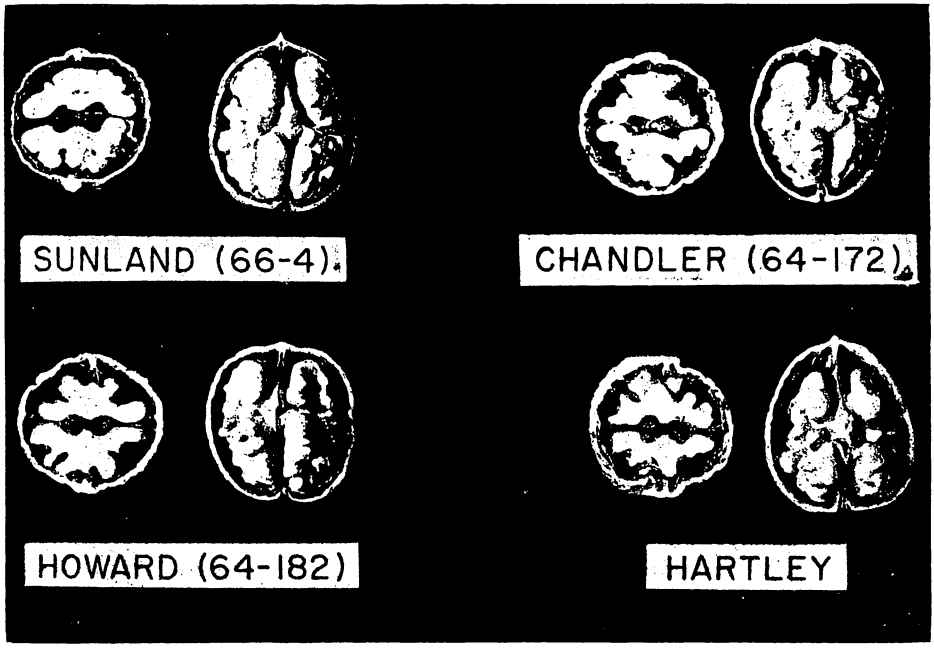

Fig. 3. Nuts of Hartley and the new cultivars Sunland, Chandler and Howard showing cross section and nut with half the shell removed.

relatively low yields. Of current interest is the Scharsch-Franquette selection, which is used as a pollenizer for medium to late blooming cultivars such as Hartley. The leafing date on Scharsch-Franquette is 29 days after Payne. None of the lateral buds are fruitful. Harvest timing is late. Nut size tends to be small. Kernel percentage is 46% and color is generally very good. Scharsch-Franquette trees are large and require 40 to 50′ spacing. Vigor is moderate to high and tree shape is upright.

Serr (UC59-129) was a cross of Payne x PI-159568. Serr is low to moderately heavy yielding, depending on the location and orchard conditions. Yields have been very disappointing in some locations, especially where cultural and soil conditions were exceptionally good, resulting in excessive tree growth. In some cases, Serrs planted on shallower, heavier, or less fertile soil seem to bear better. Serr has exhibited the problem of pistillate flower abscission. This is not exclusively a Serr problem, but Serr is notably prone to dropping its flowers. Serr only has 30-50% lateral buds which are fruitful. Leafing date is approximately one day ahead of Payne. Pollenizers include Chico and Tehama. Harvest timing is early to midseason.

Serr nut size is large. Kernel percentage is high at 59% and color is good. Serr tree size is large and requires a spacing of at least 40′ on good soils. Shape is moderately spreading and vigor is good to extreme. Serr is susceptible to codling moth and blight damage.

Ashley is a highly fruitful variety with 80 to 90% fruitful lateral buds which has been widely planted since 1960. Leafing date is similar to Payne to a day earlier than Payne. Many of the Ashley characteristics are very similar to Payne, including its susceptibility to codling moth and blight. Very good pruning is required to keep Ashley vigorous.

Sunland (UC66-4) is a cross of Lompoc x PI-159568. This is a new University patented release which is not yet well established or well proven, but it has the potential of high productivity. Sunland has 80 to 90% lateral bud fruitfulness. It leafs out one day after Payne. Varieties such as Chico and Tehama can serve as pollenizers. Harvest timing is mid to late. Sunland nut size is very large with high kernel yield (59%) and good color. Tree size appears to ultimately be similar to Payne, even though it exhibits extreme vigor in the early life of the tree.

Trinta is a variety whose popularity seems to be waning to some extent at this time. Trinta is a very heavy producer and has 80 to 90% lateral buds which are fruitful. Leafing date is three days after Payne. The harvest period is in mid-season. Nut size is large but kernel color is only fair and kernel yield is 47%.

Chico (UC56-206) is a cross of Sharkey x Marchetti. Chico is very highly fruitful with 90 to 100% of the lateral buds fruitful. Leafing date is three days after Payne. Chico blooms early and sheds pollen late (protogeny). Therefore, it crosses very well with early blooming varieties such as Payne and Serr. Chico has been planted primarily as a pollenizer for early leafing varieties, but it yields very heavy crops and may be an excellent variety on its own. The harvest period is early. Chico nut size is small and heavy pruning is required to maintain good size. However, kernel color is very good with 48% crackout. Tree size is small with a shape similar to Payne, but more upright. Chico seems well adapted to a hedgerow planting or to a closely spaced planting of 22′ to 28′.

Vina (UC49-49) is a cross of Franquette x Payne. Vina's fruitfulness is high with 80 to 90% of the lateral buds fruitful and yields are very heavy. Vina leafs 7 days after Payne. Pollenizers would include those varieties which shed pollen in mid-season such as Chico, Tehama, and some of the newer varieties such as Howard and Chandler. Vina harvests in the early to mid-season. Nut size is medium and the shape is pointed, somewhat similar to Hartley, but less flattened on the base. Vina's kernel color is very good with a yield of 47% kernel. Tree size is small to medium and shape is similar to Payne. Vigor is moderate to good. A good pruning program is very important to maintain nut size and tree vigor. Vina seems to exhibit less blight compared to varieties such as Ashley. However, under poor conditions blight can be a problem with Vina.

Tehama (UC58-11) is a cross of Waterloo x Payne. Fruitfulness is moderately high with 70 to 80% lateral bud fruitfulness. Leafing date is 12 days after Payne. Tehama harvests in mid-season. Nut size is large. In some years, particularly with delayed harvest, the nuts tend to crack, exposing the kernel to possible damage and contamination. Kernel percentage is 49% and color is good. Tehama trees are large and require 35 to 40′ spacing. Shape is somewhat upright and vigor is good. Tehama was primarily used in the past as a pollenizer variety but many growers have planted Tehama as a primary variety with very satisfactory results.

Amigo (UC56-226) is a cross of Sharkey x Marchetti. It has high fruitfulness, with 80 to 90% lateral bud fruitfulness. Leafing date is 12 days after Payne. Amigo is similar to Chico

in that pistillate bloom receptivity begins prior to pollen shedding. Harvest timing is early. Nut size is large and kernel color is excellent with 52% crackout.

Howard (UC64-182) is a cross of Pedro x 56-224. It is a newly released patented variety which is potentially very productive with 80 to 90% lateral buds being fruitful. Leafing date is quite late, 14 days after Payne. Scharsch-Franquette is used as a late pollen source. Harvest timing is slightly ahead of Hartley in mid-season. Nut size is large and kernel color has been excellent and kernel percentage is 50%. Tree size is small to medium and semi-upright with moderate vigor. Howard is smaller than Vina and Chandler. Howard seems to exhibit less blight due to its late leafing.

Pedro (UC53-113) is a cross of Conway Mayette x Payne introduced primarily as a pollenizer for the early blooming varieties. Pedro is late leafing at 16 days after Payne. It is highly fruitful with 80 to 90% lateral bud fruitfulness. The nut is large and averages 49% kernel with fair color. Harvest period is mid to late season. In the hotter districts shell and kernel quality may suffer.

Chandler (UC64-172) is a cross of Pedro x 56-224. It is a new patented release that has potentially high fruitfulness with 80 to 90% of lateral buds fruitful. Chandler leafs 18 days after Payne. Scharsch-Franquette is used as a pollenizer. Chandler harvests in mid-season a few days after Hartley. This variety seems to have good potential for an in-shell variety to supplement Hartley as nut size is large and it has outstanding kernel color. Kernel percentage is 49%. Chandler tree size is larger than Howard. The tree is moderately vigorous, semi-upright and similar to Vina in characteristics. Chandler may have less blight due to its late leafing.

New Directions in Walnut Improvement

A new breeding program for walnuts was initiated in 1982 at U.C. Davis in cooperation with the USDA. Blackline susceptibility in the *J. regia* scion varieties and *Phytophthora* susceptibility in the rootstock have been identified as the primary genetic traits limiting increased yield and have been targeted for improvement.

Blackline

Several approaches to the blackline problem are being investigated. Currently available commercial varieties of Persian walnut are tolerant of the virus. The common rootstocks Northern California Black (*J. hindsii*) and Paradox (*J. hindsii* x *J. regia*) as well as other related species are resistant. Thus, the virus can enter the Persian scion through the flowers during pollination and can travel down the stem, presumably without causing symptoms until it reaches the resistant rootstock. The rootstock resists the virus by means of a "hypersensitive" reaction in which the virus and a thin layer of rootstock cells die causing a lethal girdle at the union.

Backcross breeding is being evaluated as a means of developing commercial varieties which will resist the virus. A first backcross generation, (*J. hindsii* x *J. regia*) x *J. regia*, is mature and disease screening and nut evaluations are underway. Although several selections are potentially high yielding with lateral bud fruitfulness, the shell thickness limits their commercial potential. At least two more generations at a minimum of six years per generation will be required to obtain a disease resistant replacement for the current tolerant varieties.

Other approaches to blackline being investigated include the mass screening of *J. regia* introductions and the development of an acceptable tolerant rootstock. The latter approach may

provide a short term solution to the blackline problem; however, inoculum buildup and potential tree decline due to the virus limit its usefulness.

Phytophthora

Several species of *Phytophthora* cause severe crown and/or root rot on walnut rootstocks. Of the common rootstocks, Paradox is more resistant to *Phytophthora* than *J. hindsii* or *J. regia* and Wingnut *(Pterocarya stenoptera)* is most resistant. Through mass screening of *J. hindsii, J. regia* and Paradox it is expected that adequate levels of resistance can be identified that will provide selections which are commercially valuable. Selection and screening of rootstocks which have survived in areas of severe *Phytophthora* infestation is also being used to increase the levels of resistance available.

Wingnut has shown some potential as rootstock for *Juglans;* however, graft incompatibility has been reported in the past. To overcome this problem intergeneric hybridization is under investigation as well as introduction of Wingnut from China where it is used as a rootstock.

New varieties of Persian walnut and release of improved rootstock is not expected in the near future due to the long generation time; however, several additional selections developed toward the end of the old breeding program (1970-77) for improved yield and quality and later leafing may be released if they prove to be superior to existing cultivars. Of particular interest is their suitability as late pollenizers to replace Franquette.

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