

## Walnut Timeline

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### **Introduction**

This timeline has been created to give a general overview of crop production, worker activities, pesticide use, and key pests in walnuts. The timeline is intended to describe the activities and their relationships to pesticide applications, which take place in the orchard throughout the year. This information will be used in worker risk assessments and in the assessment of pesticide benefits. The timing of events described may vary due to such factors as geography, climate, and weather. Pesticide use information is current as of the last update.

Table 2 is a timeline of crop events, which have been divided into three sections to show the duration of crop stages, the timing of worker activities, and pest activity periods with typical pesticide application timings. Please refer to Table 2 to view the relationship between the various crop events that take place in the orchard.

### **Crop Production**

The United States produces 38% of the world's walnuts, production second only to China. Ninety-nine percent of the United States walnut production occurs in California. In 1999, California produced 283,000 tons of walnuts on 191,000 bearing acres with a value of about \$251 million (Crop Profile for Walnuts in CA, 1998; USDA-NASS, 2001).

The majority of U.S. walnuts, *Juglans regia*, are grown in the San Joaquin and Sacramento valleys of California. The Central Coast and other areas of California also produce walnuts. Typical orchard sizes range from 20 to 40 acres. In a mature orchard, trees are spaced from 40 x 40 feet, with 27 trees per acre, to 28 x 28 feet, with 56 trees per acre. Within the last decade, many orchards have been planted with up to 75 trees per acre. In some instances, young orchards may be densely planted to maximize production, with trees thinned after about 10 years to achieve mature orchard density. However, walnuts are rarely thinned because growers often choose an orchard density that will give them yields when the trees are developing while avoiding crowding problems with mature trees. Selection of walnut cultivars influences tree spacing. Mature trees can grow to a height of 50 feet (Walnut Production Manual, 1998, 10, 93-95; Grant, 2001; Markle, et al., 1998, 277).

Walnut trees are dormant during the winter. Foliage emerges in early March to mid-April. Walnuts are monoecious and most commercial cultivars are dichogamous, meaning that the male (staminate) and female (pistillate) flowers open at different times. The female flowers bloom in April and May and are wind pollinated. The pollinated female flowers will develop into nuts. The nuts develop for about seven weeks after pollination before they become full size. The shell begins to harden around the middle of May and continues through June, with kernel growth following from mid June until late July. The husk, also known as the hull, is the outer fleshy material covering the shell of the nut, and splits between August and September, and can occur even into early October. Harvest begins after husk split (IPM Walnuts, 1987, 10-11; Walnut Production Manual, 1998, 139, 273; Ludwig, 2001).

Crop events, including crop stages, worker activities, pest development, and pesticide applications, may vary in timing from the northern and southern growing regions due to climatic differences. For example, walnut blight is a more serious problem in the wetter northern region, which begins receiving rain in October, and may receive 26 inches by the end of the rainy season in May. The southern region receives rain from December to April, with as little as 6 inches per year in some areas. Due to the increased water availability, flood irrigation is more likely to be used in the northern growing region. Other areas are more likely to use low-volume irrigation systems.

## Worker Activities

Irrigation is necessary in California walnut orchards to be economically feasible. Surface irrigation, typically flood or furrow, requires a relatively flat or slightly sloped orchard floor and an adequate water supply. However, this type of irrigation may increase the incidence of certain diseases, such as *Phytophthora* rots, and spread weed seeds. Sprinkler irrigation is most frequently used in areas of limited water supply, such as the southern part of the state, or where the terrain is uneven. Low-angle sprinklers minimize leaf burn from saline water. Low-volume irrigation, such as micro-sprinkler and drip, may also be used in areas of low water supply or uneven terrain, and in addition to saving water, is largely automated. Low-volume irrigation is increasing in use across California because of its efficiency in directing water to the crop (Crop Profile for Walnuts in CA, 1998; Walnut Production Manual, 1998, 65-70).

Harvest takes place starting in late August and occurs through mid-November. The timing can be influenced by the use of growth regulators. Because an early harvest is a key component to controlling certain pests, some growers use ethephon, a growth regulator that may be used by the grower to promote an early harvest, which can minimize navel orangeworm and mold damage. Use of ethephon, which may weaken stressed trees, allows harvesting 7 to 10 days earlier than normal, with a second harvest occurring later. Another use of ethephon is to apply it about 10 days before the harvest, which synchronizes nut maturity, often making a second harvest unnecessary. Nuts are removed from the trees with a mechanical shaker, which is an apparatus that is driven into the orchard, clasps a trunk or limb and shakes, causing the nuts to fall off the tree. The shaker has a cab to prevent injury to the driver, and newer shakers have closed cabs that are air conditioned and air filtered. After the nuts drop, they are swept into windrows by a mechanical sweeper, a small piece of equipment that is not closed-cab. The sweeper has a rotating rake to bring the nuts into windrows, and a blower in back to move the nuts from the tree row into the middle of the adjacent windrow. Workers may enter the orchard to remove sticks from the nuts to make pick up easier. The pickup machine, or harvester, is not typically closed-cab. As the equipment picks up the nuts, debris and dust are blown out. The air is directed toward the ground, which may also create dust. Once the nuts drop, all harvest operations are completed within a day because nut quality decreases if left on the ground. Hand harvesting with poles may be used for walnut trees that are younger than eight years old. However, most growers wait until enough nuts are on the tree (approximately year 5) to justify mechanical harvesting. For photographs of a shaker, sweeper, and pickup machine, see the Almond Production Manual, 1996, pages 260 and 261 (Walnut Production Manual, 1998, 273-275; Reiger, 2001; Grant, 2001; Van Steenwyk, 2001).

Walnut trees are hand pruned in the dormant season. Trees up to three years old are pruned from the ground, while older trees are pruned every two to three years by hand with a person standing on a hydraulic tower to reach the limbs of the tree. A small percentage of growers may use mechanized pruning, using mechanical hedgers. These hedgers are a mobile unit with circular saws attached. The trees may be trained into hedgerows, a row of trees grown close together as a unit, but this is not a common practice. Young trees, up to three years old, are pruned in the summer to train them. A photograph of hand pruning is on page 152 of the Walnut Production Manual, 1998. For a picture of a mechanical hedger, see the Walnut Production Manual, 1998, page 157 (Grant, 2001; Walnut Production Manual, 1998, 99, 151-158).

Other activities requiring hand labor also occur in the orchard. In late March, insect traps, used to determine the level of pest infestation, are placed in the orchard, usually by a commercial company. Hand hoeing weeds may occur in young orchards throughout the season as needed (Grant, 2001).

Mummy nuts, walnuts that remain on the tree after harvest, are removed in the winter for navel orangeworm control. This practice is particularly important for the southern San Joaquin Valley, where there is a higher incidence of navel orangeworm than in other walnut producing areas. The nuts are removed with mechanical shakers, the same equipment used for harvest, which enter the field to shake the trees after a heavy fog or light rain has made the walnuts overly heavy. Some areas rely on wind and rain throughout the winter to remove the nuts. The nuts are mowed to destroy them. Equipment operators are the only people in the orchard during this process (Van Steenwyk, 2001; Grant, 2001).

Although the use of tillage has declined in recent years, many growers still use tillage in the orchards. Growers using flood or furrow irrigation are more likely to disc in order to achieve an even slope. Tillage is also useful to increase water penetration into the soil. Even in orchards that are typically not cultivated growers may occasionally use tillage to improve water penetration (Grant, 2001).

Pesticides are applied from the ground or air. Ground applications, which are more common in part because they are less expensive and coverage of the trees is better, are usually done with an air blast sprayer, although herbicides are applied with a ground boom sprayer. The sprayers may be self-powered or pulled by a tractor, which may or may not have a closed cab. Typically between 24 and 60 acres can be sprayed in a day, but the number of acres may vary from this range for several reasons. Walnut husk fly sprays only need to be applied to every other row, increasing the number of acres that can be treated per day. Variations in ground speed, coverage, and the number of gallons of pesticide used per acre will also affect the number of acres that can be sprayed in a day. Usually about 100 to 200 gallons of solution are applied per acre, with loads of about 500 gallons per sprayer, although the number of gallons may vary depending on the type of spray used. Aerial applications, using fixed-wing aircraft or helicopters, are not used as frequently. Aerial applications are useful if soil conditions prohibit ground machinery from entering the field, and aerial applications are able to cover a large area more quickly than ground sprayers. Aerial applications may also be necessary if the trees are too large to be completely covered from a ground application. In this case, both ground and aerial applications would be made to fully cover the trees. In 1999, approximately ten percent of total pesticide applications were applied aerially. Ten to thirty gallons of product per acre are usually applied using aerial application. In Tulare county, approximately 41 percent of pesticide applications are made by commercial applicators, whereas about 59 percent of pesticide applications are made by the growers or workers in the orchard. However, BEAD cannot assure that these percentages are representative of the entire walnut growing region (Grant, 2001; Walnut Production Manual, 1998, 254-265; Van Steenwyk, 200; Bonds, 2001; Cal-DPR, 1999; Buchner, 2001; Holcomb; 2001).

**Pesticides**

Pesticides typically applied to walnuts during 1999 are listed in Table 1.

**Table 1. Pesticides Typically Used in Walnuts, 1999<sup>1</sup>.**

<b>Herbicides</b>	<b>Insecticides</b>	<b>Fungicides</b>
Diuron	Chlorpyrifos	Copper hydroxide
Glyphosate	Esfenvalerate	Copper oxide
Oxyfluorfen	Methyl parathion	Maneb
Paraquat	Permethrin	
Simazine	Phosmet	
	Propargite	

**Source:** USDA Agricultural Chemical Usage, 1999 Fruit and Nut Summary. July 2000.

<sup>1</sup> 216,000 acres of walnuts, including bearing and non-bearing acres, were grown in 1999.

**Insects**

Codling moth (*Cydia pomonella*) infests walnuts from mid-April until late September. There are two (cooler coastal districts) to four (hot inland areas) generations of codling moth each year. Early season cultivars are the most affected because the nuts develop earlier than other cultivars, enabling them to support first generation larvae. Larvae feed on the nuts, leaving behind frass, and leaving the nuts open to navel orangeworm damage. Damage from larvae of the first generation cause the nuts to drop, whereas damaged nuts from subsequent generations remain on the tree and cannot be sold. No cultural controls were identified. *Trichogramma platneri*, a parasitic wasp, is available for codling moth management but does not provide adequate control. Pheromone mating disruption programs may be available in the near future. Essentially, there are currently no biological controls that

are feasible or effective to the level needed. Chemical control is used on 60 percent of the acreage for this pest, up to three times a year. Typically an organophosphate or pyrethroid is applied, but other chemicals may also be applied for codling moth management. The applications occur in either mid to late April or early to mid May, in mid June, and mid August (IPM Walnuts, 1987, 34, 36-41; Crop Profile for Walnuts in CA, 1998; Walnut Production Manual, 1998, 247-248, Van Steenwyk, 2001).

Navel orangeworm (*Amyelois transitella*) overwinters in mummy nuts and then enters the nut after husk-split or into damaged kernels, caused by codling moth, walnut blight, or sunburn injury. Navel orangeworm larvae consume entire nut meat, leaving behind frass and webbing. Also, fungal aflatoxin production is associated with navel orangeworm infestation. Cultural practices available for management of navel orangeworm include managing codling moth and walnut blight, mummy nut removal, early harvest, and good sanitation (removing trash nuts) of equipment and buildings where nuts have been handled. Ethepon may be used to facilitate early harvest. Biological control measures consist of two wasps, *Goniozus legneri* and *Pentalitomatix plethricus*, but they are not effective. Insecticides, typically organophosphates or a pyrethroid, are applied before or at husk split, usually somewhere between late August and September, although carbaryl may also be used late in the season. Chemical control alone will not completely control the navel orangeworm (Crop Profile for Walnuts in CA, 1998; IPM Walnuts, 1987, 42-44; Walnut Production Manual, 1998, 248-249; Van Steenwyk, 2001).

Walnut husk fly (*Rhagoletis completa*) causes damage largely to mid- and late-season walnuts from June through mid-October. One generation occurs each year. The female fly lays eggs beneath the husk, also known as the hull, in the summer. The larvae feed on the inner, fleshy part of the husks for 3 to 5 weeks, causing decay. When the larvae are mature, they fall to the ground where they will pupate in the soil. The decay stains the shell, reducing quality, and hampers harvest. Navel orangeworm may overwinter in husk fly damaged walnuts remaining in the orchard. Parasites have not been effective in managing walnut husk fly. Removing black walnut and other walnut trees, hosts of the walnut husk fly, from roadsides helps reduce walnut husk fly. A protein hydrolysate bait with an organophosphate or pyrethroid is applied in July or August. This treatment, used on eighty percent of the chemically treated acreage, can be applied to alternate rows, reducing the amount of pesticide used but the efficacy is adequate (IPM Walnuts, 1987, 44-46; Walnut Production Manual, 1998, 249; Crop Profile for Walnuts in CA, 1998).

Aphids, specifically the walnut aphid (*Chromaphis juglandicola*) and dusky-veined aphid (*Callaphis juglandis*), may damage walnut trees in the spring and summer. Aphids consume cell contents in the leaves, causing damage to the leaves and nuts. Honeydew produced by the aphids may harm the husks or allow sooty mold to develop. Defoliation or sunburn to the nuts may also occur. Aphids cause quality and yield losses to walnuts. Females are able to produce live young asexually, with many generations possible each year resulting in a rapid increase in the population. No cultural controls were identified. The walnut aphid may be biologically controlled through a parasitic wasp, *Trioxys palladus*. There are several generalist predators that may manage the dusky-veined aphid, though nuts are often damaged by honeydew sooty mold accumulation before dusky-veined aphids are brought under control by predators. Chemical controls are applied post-bloom by ground to a small percentage of total walnut acreage (IPM Walnuts, 1987, 34, 47-49; Crop Profile for Walnuts in CA, 1998; Walnut Production Manual, 1998, 249-250).

Mites can cause damage to walnut trees from June through August. Mites that typically infest walnut orchards are twospotted mites (*Tetranychus urticae*), Pacific mites (*Tetranychus pacificus*), and European red mites (*Panonychus ulmi*). Mites feed on the leaves and produce webbing. Defoliation may occur, leading yield and quality losses of the nuts. Nuts may also become sunburned and cracked once defoliation has occurred, allowing navel orangeworm to enter. Reducing dust, which interferes with mite predators and parasites, by oiling or watering dirt roads and managing the ground cover is a cultural control method. Growers may also irrigate the trees to keep them from water stress. Mites have many predators, including the Western orchard predator mite, *Metaseiulus occidentalis*. Acaricides are applied post bloom if needed (Crop Profile for Walnuts in CA, 1998, IPM Walnuts, 1987, 56-59).

Redhumped caterpillar (*Schizura concinna*) may damage walnuts during the summer. Groups of the caterpillar feed on the leaves and can cause defoliation, which may cause small or sunburned nuts. The redhumped caterpillar has several predators, including two parasitic wasps, *Hypersoter sp.* and *Apanteles conglomerates*. *Bacillus thuringiensis* may be applied to larvae. Organophosphates may be applied post bloom by ground or by air. Codling moth controls may keep redhumped caterpillar numbers down. No cultural controls were identified (IPM Walnuts, 1987, 34, 59-60; Crop Profile for Walnuts in CA, 1998).

## Diseases

Walnut blight (caused by *Xanthomonas campestris p.v. juglandis*) is a bacterial disease that attacks walnuts beginning in early spring, when moisture is available to the bacteria. The northern walnut growing areas tend to have a higher incidence and severity of walnut blight than areas to the south due to more rain in the spring. Early blooming walnut cultivars are more susceptible than those that bloom later. The bacteria enter through natural openings in the tree, contacting them through pollen or water drops from rain or sprinklers. Walnut blight causes flower and nut drop. Lesions also form on nuts, leading to shriveled and/or moldy kernels or to navel orangeworm infestation. Copper compounds are applied beginning in April and May, with multiple applications possible (IPM Walnuts, 1987, 63-65; Crop Profile for Walnuts in CA, 1998; Walnut Production Manual, 1998, 242-243; Buchner, 2001).

Armillaria root and crown rot (caused by *Armillaria mellea*) is a fungal disease that damages walnut trees after wet conditions in the spring or fall. The fungus spreads by rhizomorphs, allowing it to spread along the roots to nearby trees. The disease damages the roots, causes a decline in leaf growth, and eventually causes the tree to die. Before planting, fumigation in late summer to early fall can control Armillaria rot. Other management methods include using a resistant rootstock and removing nearby infected trees (IPM Walnuts, 1987, 67-68; Crop Profile for Walnuts in CA, 1998; UC IPM Guidelines: Walnuts, 2000).

Crown gall (caused by *Agrobacterium tumefaciens*) is a bacterial disease that may become a problem anytime during the year. Wounds must be present in order for the bacteria to enter the tree. Young trees, typically when two or three years old, are more likely than older trees to suffer from crown gall. Galls that form below ground may not be noticed and remain untreated. The trees experience stunted growth or wood rot, leading to losses in yield. Cultural controls consist of avoiding injury to roots, planting a less susceptible rootstock, and practicing good sanitation. A biological control agent, *Agrobacterium radiobacter-84*, is used before trees are planted to prevent crown gall. After the disease has developed, chemical treatment is available but it is expensive and most effective on younger trees (Crop Profile for Walnuts in CA, 1998; UC IPM Guidelines: Walnuts, 2000; IPM Walnuts, 1987, 68-69; Buchner, 2001).

Phytophthora root and crown rot (caused by *Phytophthora* spp.) occurs in cool, wet conditions. Phytophthora penetrates the tree at the roots or at the crown. Leaves become small and sparse. The tree declines and may eventually die. Water management and use of a less susceptible rootstock is important. Very little of the acreage is treated chemically, although there are fungicides used to treat the disease (Crop Profile for Walnuts, 1998; IPM Walnuts, 1987, 65-67).

## Weeds

Weeds may aggravate pest problems and compete with the trees for nutrients and water. Weeds can also interfere with sprinkler irrigation and, when dry, create fire hazards. Young trees are more sensitive than mature trees to weed competition and control measures.

Weeds should be monitored at least twice during the year. Winter weed species should be surveyed between January and February, and summer species surveyed between May and June.

Weed management often consists of strip weed control. Weeds are mowed or tilled between the tree rows and an herbicide is applied in the tree rows. This practice reduces physical injury to the trees and decreases the amount of herbicides used in the orchard. A flail or rotary mower is used in mowing, which begins before bloom and occurs every 4 to 6 weeks, with eight mowings possible each year. A sprayer with a short boom is used for spraying herbicides along the tree rows in the fall or winter for pre-emergent activity. Spot treatments may occur throughout the season as necessary (Crop Profile for Walnuts in CA, 1998; UC IPM Guidelines: Walnuts, 2000).

### **Vertebrate Pests**

Ground squirrels can cause major damage to the walnut orchard. Ground squirrels are active in the spring, early summer and in the fall, with inactive periods during the summer and winter. Young squirrels may remain active throughout the year. Ground squirrels cause damage by feeding on buds, blossoms, and nuts, gnawing on bark and irrigation lines, girdling the tree, and by creating burrows that interfere with orchard operations, such as irrigation and harvest. Monitoring for ground squirrels occurs about once a month. Flood irrigation may help keep squirrels from burrowing in the orchard and thus keep populations at lower levels in the orchard, although the squirrels may simply move to nearby areas. Trapping may be effective if the population of squirrels is small. Bait traps and fumigation may be used in late winter to early summer. An anticoagulant poison is typically used in toxic bait. No biological controls were identified (IPM Walnuts, 1987, 25-28).

### **Post Harvest**

Several pests can damage walnuts after harvest, including navel orangeworm and codling moth. Fumigation is used to control these pests and to meet export market requirements. Fumigants currently used are phosphine and methyl bromide. Research to find methyl bromide replacements is currently underway (Crop Profile for Walnuts in CA, 1998).

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	Jan				Feb				March				April				May				June				July				August				Sept				Oct				Nov				Dec						
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<b>Insect Pests</b>																																																			
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<b>Vertebrate Pests</b> Ground squirrels					■																																											
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<sup>1</sup> The horizontal bars represent the usual range of time when the events occur for the entire crop. These times are variable depending on variability in geography, climate, and weather.

<sup>2</sup> Additional fungicide applications may need to be applied every two weeks under wet conditions.

<sup>3</sup> Post-emergent spot sprays are not represented, and may need to be applied intermittently during the season.