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The pecan is native to North America. The earliest orchards were established in the mid 1800s and resulted in an extensive expansion of the pecan industry into the southeastern US. Pecan trees have a productive life of 100-200 years.

Pecan scab is the most significant disease affecting the trees. The fungus was first found on a tree in 1882. The scab fungus survives the winter in masses of cells in lesions on twigs. During the spring, spores are abundantly produced. Infection by the fungal spores occurs during periods when rains, high humidity, and dew periods are frequent and spores are ejected. These conditions are very common in the Southeast. Within 10 days of infection, the fungus erupts back through the plant surface ejecting additional spores. This cycle repeats itself many times during a growing season [1]. The nuts may have so many infections on them that practically the entire surface of the nut appears black. Nuts remaining on the tree are usually of very poor quality because the kernels do not develop [2].

In the absence of control programs, widespread losses approaching 100 percent can occur in wet years while losses of 50-70 percent can occur in dry years [3]. Tests in the early 1900s showed that spray applications of copper and lime controlled scab. However, the copper-lime mixture also damaged the leaves on the pecan tree. The mixture was used for many years despite periodic losses due to tree damage and failure of the sprays in years with very wet springs [4]. Several highly effective scab control chemical fungicides were introduced in the 1960s. Growers switched to the synthetic chemicals because they were more effective in controlling scab and did not damage the pecan trees [5]. Research in the 1960s indicated that the chemical fungicides increased the yield of pecan trees by almost 100 percent in comparison to the copper-lime mixture [6].

Two of the main reasons for the tripling of pecan production per tree in the U.S. (Figure 1) are the introduction of chemical fungicides for scab control and the development of airblast sprayers for dispersing the fungicides throughout an orchard [7].

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The Ogallala Aquifer stretches across eight states from South Dakota in the north to Texas in the south. Ogallala groundwater is largely non-renewable because its sources in the Rocky Mountains were cut off thousands of years ago. The aquifer contains enough water to fill Lake Erie nine times [1]. However, at the current withdrawal rate, the Ogallala will be completely drained in 200 years.

Irrigation water from the Ogallala Aquifer supports nearly one-fifth of the wheat, corn, cotton, and cattle produced in the US. Depletion of the groundwater threatens the long-term sustainability of irrigated agriculture in major parts of the Southern High Plains, with the most critical depletion area occurring in the Texas High Plains.

Tillage to control weeds has been practiced in the region for many years. Tillage results in increased need for irrigation because of considerable water loss from the soil due to evaporation from each tillage operation.

Although the potential for increased water conservation with no-till farming was illustrated by research in the late 1930s, no-tillage was impractical at that time because of weed control and equipment limitations. Major improvements in herbicides were made during the late 1950s and 60s which led to widespread interest in developing no-tillage systems. The use of herbicides eliminated the need for 3-4 tillage operations [2]. Soil water content at planting is 50 percent higher in the herbicide plots versus the tillage plots [3].

The target goal of Texas groundwater management districts in 50 years is to have 50 percent of the Ogallala groundwater remaining for future generations. Recently, seven water management strategies were evaluated for their potential water-savings in North Texas [4]. A water savings of 1.75 inches per acre per year was estimated from shifting an acre from conventional to conservation tillage with herbicide applications substituting for tillage operations. Increasing conservation tillage from 50 percent of all irrigated acres in 2000 to 72 percent by 2060 was estimated to lead to a cumulative water savings over the 60-year period of 2.1 million acre-feet (682 billion gallons) [4]. Of the seven technologies, conservation tillage was the least costly in terms of increased cost per acre-foot of water saved. It is 80 times less costly than making changes to irrigation equipment.

References
Herbicide Use Increases Maine Blueberries by 60 Million Pounds Yearly

U.S. Pesticide Benefits Case Study No. 3, May 2011
Leonard Gianessi and Ashley Williams

Maine’s 60,000 acres of wild blueberries grow naturally in fields and barrens that stretch from Downeast to the state’s southwest corner. Native Americans were the first to use the tiny blue berries, both fresh and dried; it was not until the 1840s that wild blueberries were first harvested commercially.

Through management of this wild acreage, commercial blueberry production reached 10 million pounds annually in 1927. Weeds were identified as a major factor that limited yield in 1946 and were still a major concern in a 1974 survey [1]. Weed growth not only lowered blueberry yield through competition but also made harvesting difficult, with 10 to 30 percent of the crop left behind [2]. The inability to control weeds also resulted in growers’ unwillingness to fertilize blueberries, since the fertilizer resulted in denser growth of weeds [2].

The registration of the herbicide terbacil in the 1970s provided effective control of grasses and sedges, and resulted in significant yield increases when combined with increased fertilizer use [3],[4]. The subsequent registration of hexazinone in 1983 provided effective control of grasses and herbaceous and woody weed species in low bush blueberry fields [4]. As a result of improved weed control, research demonstrated that use of hexazinone increased blueberry yields by 56 percent [4],[5]. Since the introduction of hexazinone, blueberry production in Maine has more than tripled, from an average of 20 million pounds per year to over 80 million pounds per year (Figure 1). In addition to reduced weed competition, hexazinone has facilitated increased use of fertilizer. Approximately 95 percent of Maine’s wild blueberry crop is treated with herbicides [5].

In 2007, direct and indirect economic impact of the wild blueberry industry in Maine totaled $250 million, making wild blueberries a major contributor to Maine’s economy.

References
Herbicides are Key to Sustainable Great Plains Dryland Farming

U.S. Pesticide Benefits Case Study No. 4, May 2011
Leonard Gianessi and Ashley Williams

Dryland farming is crop production without irrigation in semiarid regions. The Central Great Plains comprise about 20 million acres of dryland farms in parts of Colorado, Wyoming, South Dakota, Nebraska and Kansas. One of the practices that evolved for dryland crop production was the use of summer fallow wherein no crop is grown in order to store water for the following crop.

To maximize the amount of stored water, weeds must be controlled throughout the fallow season. Undisturbed weeds remove 2 to 6 inches of soil water per year [1]. Tillage systems developed to remove weeds during the fallow season involve 7 to 10 operations per season. Although the system kills weeds, soil dries out to the depth that is tilled. The maximum tillage system resulted in soil water storage of only 19 percent of precipitation [2].

Frequent tillage of fallow fields made the soils of the Great Plains extremely vulnerable to wind erosion, which reached its peak in the 1930s when periods of record-setting drought combined with extensive tillage resulted in the “Dust Bowl”[3].

Experimentation with herbicides to remove weeds during the fallow period began during 1948-55. The use of herbicides during the fallow period reduced the need for tillage operations to 2 to 4 per season and resulted in storage of 33 percent of precipitation [2]. The extra soil water stored with the use of herbicides was reflected in an average 21 percent increase in winter wheat grain yield over conventional tillage fallow [4].

Fallow acreage in the US has declined significantly in recent decades [5] (Figure 1). In dryland areas of the Great Plains, there has been an expansion of summer corn and sorghum acreage. Improved herbicide options have eliminated the need for fallow in all but the driest areas of the Great Plains [6]. Research demonstrated that by using herbicides to remove weeds without any tillage, soil water storage improved to 40 percent [2].

References
Insecticides Protect Soybeans from New Invasive Aphid

U.S. Pesticide Benefits Case Study No. 5, May 2011

Leonard Gianessi and Ashley Williams

Traditionally, only about 2% of U.S. soybean acres received insecticide treatment. However, with the introduction of the soybean aphid to the Midwest, approximately 16% of U.S. soybean acres (12 million acres) are currently treated with insecticides (Figure 1) [1],[2].

The soybean aphid is native to Asia where it is the main pest in soybean fields. In 2000, the soybean aphid was first detected in Wisconsin. Subsequent surveys detected the pest in 20 states.

Thousands of aphids have been observed on the leaves of plants in some fields. Aphids remove plant sap from soybean leaves with piercing-sucking mouthparts. Even at low densities, feeding by soybean aphid can greatly impair photosynthetic processes in soybeans. High soybean aphid densities cause damage by reducing plant height, pod number, and total yield. Heavy infestations of the soybean aphid have caused economic yield losses up to 45% in some untreated fields [3]. In Michigan, 13,000 aphids per plant and 40% loss in seed yield were recorded [4].

Soybean aphids reproduce asexually increasing their numbers rapidly. In the summer, the population in soybeans is comprised of females that essentially clone themselves and give birth at rates of 3 to 8 aphids per day for about a month. The soybean aphid population doubles every two to three days.

Research trials in the Midwestern U.S. show that insecticide sprays reduce the number of aphids per plant by 95% [5]. Insecticide treatments to control soybean aphid have prevented soybean yield losses of 30-50% [6].

References

Figure 1: U.S. Soybean Acreage Treated with Insecticides (% Acres Treated)
Wild rice originated in Minnesota and the surrounding Great Lakes. It is the only cereal native to North America that was domesticated from a wild plant. Before commercial wild rice production began, Native Americans hand harvested it from wild stands. The first commercial field of wild rice was planted in 1950 in Minnesota using seed from natural stands. After one successful season, fungal brown spot destroyed the second crop in this field. Over the next decade, fungal brown spot destroyed many other wild rice crops. Epidemics in 1973 and 1974 resulted in complete crop loss in many Minnesota paddies and contributed to the demise of several large wild rice farms [1].

Fungal brown spot disease inoculum comes mainly from infected crop debris. When paddies are flooded in the spring, infected crop debris floats to the surface and disease organisms infect the leaves and stems of wild rice as it emerges from the water. Brown spot forms brown lesions on the leaves and stems, interrupting photosynthesis and preventing seed formation. Infected panicles can become covered by a dense mat of fungus that generates massive amounts of fungal spores that disperse above the wild rice canopy [1]. After infection, leaves may shrink and die and stems may become girdled and break, causing the panicle to fall and seed to be lost. Growers report that the brown spot pathogen infects up to 100 percent of wild rice acreage in most, if not all, years [2].

Growers and experts estimate that wild rice losses from fungal brown spot can reach 75 to 100 percent without fungicide use but are typically reduced to 5 to 30 percent with the use of fungicides [2]. The use of fungicides was one of the key factors accounting for significant increases in Minnesota wild rice production beginning during the mid-1970s (Figure 1). USDA recently concluded that without fungicides, a severe outbreak of fungal brown spot could destroy the entire Minnesota wild rice crop [2].

References
Florida’s Sweet Corn Flourishes with Help from Insecticides

U.S. Pesticide Benefits Case Study No. 7, May 2011
Leonard Gianessi and Ashley Williams

Florida ranks number one nationally in the production and value of fresh market sweet corn, typically accounting for 25 percent of national sweet corn production. More than 500 million pounds of fresh sweet corn are produced annually in Florida. Yet the American Farm Bureau has estimated that without the use of insecticides, no commercial sweet corn production would exist in Florida because of the severe insect damage to the ears [1].

Florida’s warm humid climate is ideal for the development of pest populations. Corn earworm and fall armyworm are two of the most important insect pests of sweet corn in Florida. Damage occurs when the larvae of these two pests eat the kernels. Corn earworm initially feeds on the silk, then tunnels downward, leaving a trail of damage and waste that often ruins the entire ear. Fall armyworm causes similar damage, though larvae may enter ears by burrowing through the husks on the side [2].

Sweet corn is grown in Florida in successive overlapping crops from late August to mid June. Female earworm moths are attracted to the silks for egg laying. Each female earworm lays 500 to 3,000 eggs and each armyworm moth may lay more than 1,000 eggs.

Prior to the development of synthetic chemical insecticides in the 1940s, Florida was considered an unlikely place for growing sweet corn. Control of insects was economically prohibitive. The first commercial production of sweet corn in Florida was reported in the 1947-48 season after the introduction of chemical insecticides. Research determined that the insecticide sprays would result in 96 percent worm-free ears in comparison to only 2 percent worm-free ears in untreated plots [3]. A great expansion in sweet corn production occurred in Florida in the 1950s after the introduction of chemical insecticides (Figure 1) [4]. The establishment of sweet corn in Florida is attributed largely to successful control of insects with the new insecticides [3].

Between 98 and 99 percent of Florida’s sweet corn acreage is treated annually with insecticides, with 10 to 12 sprays made to each acre. Repeated sprayings are necessary due to the short time period for incubation of earworm eggs (24 to 36 hours) and due to the rapid rate of silk elongation.

References
Without Fungicides, Northeastern Cranberries Would Succumb to Rots

U.S. Pesticide Benefits Case Study No. 8, May 2011
Leonard Gianessi and Ashley Williams

The American cranberry industry began in Massachusetts with the hand harvest of native populations of plants. Today, growers in Massachusetts and New Jersey produce 200 million pounds of cranberries which represents 33% of U.S. production.

Cranberry growers must control at least eight and as many as fifteen fungal pathogens that can cause significant crop loss. In Massachusetts and New Jersey, early rot infects all cranberry beds and can cause 100% losses if not controlled [1]. The fungi that cause fruit rots in cranberries overwinter on infected living and dead vine leaves and stems and on rotted fruit left in the field [2]. Wind and wind-driven rain disperse fungal spores from their overwintering hosts. These spores land on blossoms or small, developing fruit and will penetrate the plant tissue if there is a suitable layer of moisture present for 6-8 hours. Early rot first appears as a small light-colored watery spot, which enlarges rapidly until the whole berry becomes soft. Cranberries with end rot are often distended by gas produced by the rotting process and may burst from the increased pressure [2].

Soon after the establishment of the first cranberry beds in New Jersey, a severe fruit disease eliminated most of the crop [3]. Prior to the use of fungicides, cranberry fruit rot was responsible for up to 100% crop loss in worst-case scenarios and routinely reduced the New Jersey crop by 33% [3]. With the development of Bordeaux mixture (copper plus lime sulfur) in the late 1800s, cranberry fruit rot could be reduced by as much as 10 to 50% [4]. The spraying of cranberry beds for disease control has been a general practice of New Jersey and Massachusetts cranberry growers since about 1900 [4]. Cranberry growers stopped using Bordeaux in response to the greater effectiveness of synthetic chemical fungicides and research that showed vine thinning and damage resulted from repeated annual sprays of Bordeaux [5]. Currently, cranberry fruit rot losses range from less than 1% to 15% annually [3]. However, the loss of registered fungicides for cranberry disease control could lead to nearly complete crop loss within 5 years [3].

References
The pistachio is a native plant of Asia Minor. California entered the world pistachio market in 1976. Within a decade, the California industry grew to become the second largest producer in the world, second only to Iran.

Panicle and shoot blight (Botryosphaeria) was first discovered in a commercial orchard in the Sacramento Valley in 1984. In the orchard, as well as a few other orchards in Butte and Tehama counties, yield losses from 40 to 100 percent were not uncommon [1]. Since its initial discovery in 1984, panicle and shoot blight has become a disease of major importance for pistachios grown in California. Surveys demonstrated that over the five-year period of 1994 through 1999, orchards with panicle and shoot blight produced an average of 23 percent less than orchards without the disease [2]. The disease was particularly damaging in 1998 when the average yield was reduced by 54 percent in orchards with the disease. Total production loss in 1998 was estimated at 20 million pounds.

When buds are infected by the fungus, they either will not emerge (total blight) or emerge but the resulting flower or shoot eventually dies. Symptoms appear as dark lesions. Shoots originating from heavily infested buds grow to a short length, become black, and die. Infected leaves begin to drop in July and severe defoliation can occur by late summer. Infections on current season shoots develop into cankers. These cankers are the major source of spores that are released in the winter and spring when rains occur. Cankers produce viable spores for at least six years [1].

Growers have reported that fungicide use reduced panicle and shoot blight incidence from 75 to 100 percent among untreated trees to less than 1 percent among treated trees.

References
Hops are a specialty crop used for bittering and flavoring beer. U.S. hop production is centered in the Northwestern states of Washington, Idaho, and Oregon. The U.S. produces enough hops annually to flavor approximately nine billion gallons of beer.

Hops in the Pacific Northwest are attacked by two key pests: the hop aphid and the two-spotted spider mite. If left uncontrolled, each pest can cause complete crop loss annually [1],[2]. 100% of the commercial hop acreage in the Northwest is treated with insecticides for these two pests [2].

Aphids feed directly on hop plants, extracting cell sap and nutrients with their sucking mouthparts. Hop aphids excrete prolific amounts of honeydew. Sooty mold grows on the honeydew and can destroy a crop’s value, as mold renders hop cones unacceptable for brewing [2]. Spider mites puncture leaf tissue and destroy leaf cells while sucking plant juices from the leaves. Mites feed on and damage cones, reducing yields and producing off-flavors. Injured hop cones dry, turn red and shatter. Discolored hops may be rejected by customers. Research demonstrated that insecticides reduce the percentage of hop leaves infested with aphids and mites from 50-76% to 3% [3].

Nearly 100% of U.S. hop acreage is treated with fungicides targeted at downy mildew and powdery mildew. The downy mildew fungus overwinters in infected hop crowns and first appears in the spring as an infected shoot. The under surface of the leaves becomes blackened with millions of spores which spread the disease to other shoots. If infection occurs later in cone development, a portion of the cone becomes blackened and is unacceptable to brewers, or cones may shatter in harvest, resulting in yield loss. The fungus causing hop powdery mildew is known as *Podosphaera macularis* and only attacks hops. The fungus overwinters in infected buds. In the spring, the infected buds produce mildew covered shoots. Spores from the infected shoots disperse causing secondary infections. Powdery mildew infections lead to browning of hop cones, which may change the aroma of the cones making them unusable for brewers [4]. The hop industry estimates that without fungicide application 69% yield and quality losses would occur, with losses reaching 100% in many varieties [4].

**References**
Without Fungicides, 50% Less Orange Juice from Florida

U.S. Pesticide Benefits Case Study No. 11, May 2011
Leonard Gianessi and Ashley Williams

Florida growers produce 11.6 billion pounds of oranges. Up to 95% of the Florida orange crop is delivered to the processed market primarily for orange juice.

The first mention of greasy spot on citrus leaves was from Cuba and Florida in 1915. Greasy spot is important only in areas where nearly 100% relative humidity and high temperatures occur simultaneously for prolonged periods [1]. The disease affects leaves of all commercial plantings. The most serious consequence is defoliation. In Florida, losses of up to 45% of fruit yield have been caused by defoliation induced by greasy spot [1].

Spores of the fungus are produced in decaying leaf litter on the orchard floor. The fungus swells and ejects numerous microscopic spores. Spores are airborne and are deposited on the underside of leaves where they germinate. After extensive growth on the surface of leaves, the fungus penetrates leaf tissue. The plant cells die and become impregnated with gum. The blisters later become swollen and darkened and resemble dirty blotches of grease. Heavily infected leaves fall off prematurely. Excessive defoliation of citrus causes a reduction in the following spring’s growth flush and a subsequent yield reduction in the following crop year [2].

Greasy spot can often be adequately controlled with only one fungicide spray per year [3]. Copper fungicides have proven to be the most reliable materials for controlling greasy spot [1]. Spray oil is also used to control greasy spot. Oil is not chemically fungicidal, but it does interfere with the mechanical penetration of the leaf surface by the fungus [1]. Research has demonstrated that a single application of oil plus copper can reduce defoliation from 59% to 2% [4]. It has been estimated that without fungicide use, Florida citrus yield on currently treated acres would decline by 50% [5].

References
Insecticides Keep Processed Spinach Free of Insects

U.S. Pesticide Benefits Case Study No. 12, May 2011
Leonard Gianessi and Ashley Williams

The green peach aphid feeds by sucking juice from the spinach plant. Aphid populations seldom reach sufficient levels to reduce spinach yield [1],[2]. The principal concern surfaces when aphids are detected in the processed spinach product. The broad and crinkled leaves of spinach make removal of aphids by washing at processing plants extremely difficult [2].

In the 1930s the FDA was made aware of consumer complaints regarding the presence of aphids in canned spinach and adopted a standard of 500 aphids per pound of spinach. In 1972 the FDA adopted the current standard which is set at 250 aphids per pound of spinach [3]. Canned or frozen spinach that exceed this standard are subject to seizure due to adulteration of a food product. It is believed that processor standards are more stringent than the FDA’s and that processors strive for no aphids in the can. As a result, entire spinach fields may be rejected by the processor if aphids are detected at harvest [2].

In the 1940s, surveys indicated that approximately 20 percent of the spinach acres in the Arkansas/Oklahoma region were not harvested due to aphid infestations at harvest time [4]. The spinach pack in Arkansas in 1950 was reduced from an estimated 3 million to 100,000 cases due to the presence of insects [5].

Insecticide spraying is initiated when numbers reach 1-2 aphids per leaf. As harvest nears, the threshold for spraying is reduced. Research with insecticides for green peach aphid control showed a reduction from 33 aphids per plant untreated to 3 aphids per plant with the insecticide treatment [6].

References
Magnified downy mildew on spinach leaf

Fungicides Needed to Protect Spinach After Failure of Plant Resistance to Mildew

U.S. Pesticide Benefits Case Study No. 13, May 2011

Leonard Gianessi and Ashley Williams

Downy mildew, also know as blue mold, is probably the most widespread and potentially destructive disease of spinach worldwide [1]. The disease first appears on leaves as small pale or yellow spots that enlarge rapidly. The spots, yellow on top and gray beneath, later die producing light brown areas on the leaves [2]. A fuzzy bluish gray growth appears on the underside of the leaves (hence the common name ‘blue mold’). Spores are transported by wind to other sites [3]. When environmental conditions are favorable, epidemics can progress very rapidly and an entire crop may be lost in a short period [4].

Until the late 1950’s the U.S. spinach industry was not highly viable. Cultivars were susceptible to downy mildew, which caused severe reductions in quality and in some cases complete loss of the crop [3]. Control by fungicide spray was not practical. Because there were no effective controls, a search for resistance to downy mildew was begun in 1946. As a result of cross breeding with commercial varieties, new commercial hybrids with immunity to downy mildew were released in the mid 1950s. At this time, there were only two races of the organism causing downy mildew on spinach worldwide and the hybrid plants had immunity to both races [3].

For twenty years, downy mildew was unknown on spinach in the U.S. In the late 1970s a new race of the downy mildew fungus appeared and spread rapidly in U.S. spinach fields causing heavy losses [3],[5]. A gene for resistance to race three was used in spinach cultivars as early as 1982 and provided resistance to downy mildew on spinach in the U.S. until 1989 when race 4 became established [4]. As a result, spinach cultivars with resistance to races 1,2 and 3 became infected with downy mildew [6]. Since then, downy mildew races 5-10 have been discovered.

Little or no work had been done with fungicides on spinach because the resistance had been so effective. Research revealed that certain fungicides were highly effective in controlling downy mildew; whereas untreated plots incurred a 43 percent reduction in yield, the treatments reduced the yield loss to 1 percent [7]. Downy mildew is relatively rare in spinach fields because of the use of fungicides [8].

References
Leaf spot is the most important fungal disease of cherry in the eastern U.S. where it is estimated to infect 80 percent of the orchards and has the potential to reduce yields by 100 percent if not controlled [1]. The disease is caused by a fungus known as *Coccomyces hiemalis*, which overwinters in old leaves on the ground. The first infection of new foliage in the early summer is caused by spores which are discharged from these old leaves. After the fungus develops on the new leaves, more spores are produced that may cause further spread of the disease. On leaves, infections appear as small reddish to purple spots. The individual spots never become large, but they may be so numerous that they coalesce and thus kill large areas of the leaf. The appearance of numerous spots on the leaf is usually followed by rapid yellowing and dropping [2]. Infection of fruit is rare. However, fruit on severely defoliated trees fail to mature normally, and they are light colored, low in soluble solids, soft, and watery [3]. Defoliation from leaf spot reduces the number of flower buds and subsequent fruit set for the following year. Defoliated trees are less cold-hardy and may be killed by low temperatures in winter.

In southern Pennsylvania, early defoliation in 1945 was followed by the death of more than 25,000 trees, which represented 10 percent of the total cherry acreage [2]. All sprayed trees survived. The yield in 1946 averaged 36 pounds per tree on unsprayed trees and 107 pounds per tree on sprayed trees [2]. In experiments in the 1940s, it was demonstrated that poor control of leaf spot could result in 72 percent of the tree branches dying during the winter months. Growers who spray fungicides regularly and thoroughly every year seldom suffer any serious loss from leaf spot. Research has shown that fungicide applications reduced defoliation of cherry trees from 80 to 0.3 percent and from 98 to 3 percent [4],[5].

**References**

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Insecticides are Necessary for Maggot-free Cherries

U.S. Pesticide Benefits Case Study No. 15, May 2011
Leonard Gianessi and Ashley Williams

The cherry fruit fly (also called the cherry maggot) is a native fly that feeds exclusively on cherries. The earliest records of eastern cherries being attacked by fruit flies dates from 1883 [1]. The flies infest mature or maturing cherries one to three weeks before harvest by depositing individual eggs inside the fruit. Eggs hatch in 3-7 days and young maggots feed on cherry flesh, mainly around the pit. Larval tunnels extend throughout the infested fruit.

Mature larvae make breathing holes and eventually drop to the ground and penetrate to a depth of 1 to 6 inches for pupation. Pupae spend 9-10 months in the soil and emerge as adults the following spring. 4,000-5,000 adult flies can emerge from the soil under each tree [2]. Each female may deposit 100 to 300 eggs under the fruit skin over a period of thirty days. Maggots and their frass within the fruit render the product unfit for sale [3]. If left untreated, nearly 100% fruit damage can occur [4].

Truckload quantities and even entire blocks of fruit may be rejected if any larvae from fruit fly are found. In the 1930s, the standard for No. 1 cherries allowed up to seven larvae in a 30-pound tin. Additional larvae meant a reduction to No. 2 grade. Now, there is zero tolerance for cherry fruit fly mandated by state and federal law and by the marketplace [5]. The zero tolerance for fruit flies has required that growers maintain intensive insecticide control programs to achieve perfect control [6]. Control of cherry fruit flies with insecticides must be preventative in nature. Once eggs hatch and larvae bore into the cherry, the damage is irreversible.

Without effective insecticides for cherry fruit fly control, the eastern cherry region would likely not be able to produce and market maggot free fruit within just a few years. The overall result of not having or using effective insecticides for cherry insect pests would be a rapid demise of the cherry industry in the eastern U.S. because of the inability to produce market acceptable, maggot-free fruit [7].

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Fumigation Makes California the #1 Producer of Strawberries in the World

U.S. Pesticide Benefits Case Study No. 16, May 2011
Leonard Gianessi and Ashley Williams

The United States is the world’s leading producer and consumer of strawberries. The U.S. accounts for 28% of the world supply of strawberries. California is the top strawberry growing state, accounting for more than 90% of U.S. production and 20% of world production.

Soil fumigation has been an integral part of strawberry cultivation in California since about 1960 [1]. Starting in 1950, strawberries in California were produced almost entirely from cultivars developed by the University of California and Driscoll Strawberry Associates. Although the yields of these cultivars occasionally reached 40,000 or even 60,000 lbs/acre, the state average for the period from 1950 to 1960 ranged from 10,000 to 12,000 lbs/acre [1]. The yield potential of the new cultivars was far from being realized.

One source of strawberry yield losses was verticillium wilt, a disease caused by the fungal pathogen *Verticillium dahliae*, which attacks the water-conducting tissue of the plant called the xylem. The infections extend into the plant’s xylem from where they spread throughout the plant. Infected plants wilt and outer leaves dry and turn brown. Infected plants often collapse during the peak of the first year’s growth [2]. Eventually the entire plant wilts and dies. The fungus has been known to remain in the soil for 25 years [3]. In the period before fumigation became a common practice, growers constantly searched for new land in order to avoid plant diseases.

Since about 1965, approximately 90% of strawberry acres in California have been fumigated before each crop is planted [1]. Statewide average strawberry yields tripled following the adoption of fumigation and now average about 50,000 lbs/acre (Figure 1). In addition, soil fumigation made available lands that had previously been avoided for strawberry cultivation. These were the rich, fertile, alluvial lands with long crop histories and fungal infestations [4]. Generally, the increase in strawberry yield is credited to effective control of verticillium wilt with fumigation [1].

USDA has estimated that without the use of soil fumigants in California, strawberry yield would decline by 70% [5].

References

Figure 1: California Strawberry Yields (Tons/Acre)
Fungicides Protect High-Yielding Sugarbeets from Disease

U.S. Pesticide Benefits Case Study No. 17, May 2011
Leonard Gianessi and Ashley Williams

Sugar produced from sugarbeets totals approximately eight billion pounds annually in the U.S. More than half of the sugar produced in the U.S. comes from sugarbeets. The crop produces large storage roots that are harvested for sugar extraction. Sugarbeets are known for their abundant foliage; sugar content is proportional to the size and development of leaf surface.

The fungus causing Cercospora leaf spot of sugarbeets overwinters on infected beet residue in the soil. During humid weather, spores are formed and are spread by wind, water and insects. An individual spot on a beet leaf results from the invasion of a germ tube from a spore and the subsequent fungal growth in the tissues of the plant. The fungus produces a toxin called cercosporin, which produces molecules that attack the fatty acids that make up plant membranes. Eventually, the membranes rupture and the plant cells die. As the disease progresses, numerous individual spots coalesce to form large areas of dead tissue. Severely infected leaves wither and die. The entire plant can be defoliated. Under conditions of severe leaf spot attack, every green leaf may dry up, causing the field to appear as if it had been scorched [1].

Cercospora leaf spot was not economically important to the sugarbeet crop produced in the Red River Valley and southern Minnesota before 1980. In the late 1970s growers began switching the varieties they planted from cultivars that were highly resistant to Cercospora to ones that were highly susceptible but had higher yield potentials [2]. Favorable weather conditions in 1980 resulted in an epidemic of Cercospora affecting 80% of the crop with loss estimated at 4,000 to 6,000 lbs/acre [2]. Starting with the 1981 crop, sugar cooperatives instituted an aggressive calendar spray schedule policy to control Cercospora [3]. Most currently approved sugarbeet varieties in North Dakota and Minnesota are considered moderately resistant to moderately susceptible to Cercospora, but yield well. Varieties that are more resistant have lower sugar yield [4].

Cercospora leaf spot control relies on the use of fungicides. Recent research demonstrated that fungicide treatments increased the amount of extractable sucrose by 30% in comparison to plots untreated for Cercospora [3]. Cercospora now infects about half of all U.S. sugarbeet acreage [5].

References
Herbicides Saved Louisiana Sugarcane Production Following Shortages of Laborers for Weeding

U.S. Pesticide Benefits Case Study No. 18, May 2011
Leonard Gianessi and Ashley Williams

Prior to 1940, a great deal of labor was available for sugarcane production in Louisiana. Johnsongrass and other weeds were held in check by continuous hoeing and digging [1]. Approximately 40 to 70 hours of hand labor were required to weed an acre of sugarcane [2]. Impacts of the Second World War resulted in a shortage of labor for hand weeding with a consequential buildup of johnsongrass infestations. In 1949, at least one-third of the sugarcane acreage of Louisiana was so badly infested that the yield of cane was materially reduced, and one-sixth of the acreage was so thoroughly infested with johnsongrass that sugarcane production was marginal [3]. Reported sugarcane yield losses to johnsongrass were 23-50% [4]. Some fields were so besieged that farmers believed the only recourse was to replace sugarcane with pasture [5].

As herbicide programs were put into practice to control johnsongrass, it was found that nearly all the other grasses and broad leaf weeds were also being eliminated [5]. Herbicide use is one of the factors that led to a significant increase in Louisiana sugarcane yields in the 1950s and ‘60s (Figure 1). Herbicide use led to increased yields as a result of more effective weed control, which also facilitated higher sugarcane plant populations and increased efficiency of fertilizers [3].

References
The Romans Prayed, U.S. Farmers Spray Fungicides to Save Wheat from Rust

U.S. Pesticide Benefits Case Study No. 19, May 2011
Leonard Gianessi and Ashley Williams

Wheat rust was particularly troublesome around the Mediterranean basin; Roman wheat farmers were plagued by rusts. For over 1,700 years, the Romans honored a god, Robigus the rust god, in the Robigalia, a religious ceremony held on April 25. There was a temple to Robigus three miles from Rome; the priest at this temple offered prayers and annually sacrificed a red animal (usually a dog) to appease the rust god in an attempt to spare their grain and avoid rust infections. Climate change in the first century A.D. produced wetter and cooler conditions that led to frequent, severe outbreaks of wheat rust. Crop failure followed leading to famine and social disruption that contributed to the decline of the Roman Empire.

Three different rust diseases affect wheat in the U.S.: stripe rust, leaf rust, and stem rust. Each is caused by a different fungal species but all have similar life cycles. Large spore populations build up in the southern wheat areas in the winter. The spores produced on these hosts can be carried for hundreds of miles on air currents [1]. Spores that land on wheat plants germinate and infect the plant through stomata, the natural breathing pores on the surface of leaves and stems. The rust fungus grows between host cells just under the surface. Tiny tubes penetrate host cells to withdraw nutrients. Fungus tissue proliferates beneath the epidermis and, as masses of spores are formed, the epidermis bursts and pustules erupt through the plant surface. Each pustule contains tens of thousands of spores that can be carried by the wind to infect other plants. Photosynthetic output is reduced by loss of leaf area and water loss is increased due to the cracks in the epidermis. Grain yield is reduced by interference with grain filling, which results in a reduction in the number and size of kernels and the formation of shrunken kernels [1]. Under severe disease pressure, yield can be reduced as much as 50%, although losses of 10-15% are probably more typical [2]. The first commercial use of foliar sprays for cereal rust control in the U.S. occurred in 1981 in the Pacific Northwest. That year, the use of fungicides prevented the loss of more than 52 million pounds of wheat in Washington. Similar losses were prevented in Oregon and Idaho [3]. Since then, foliar fungicides have become a part of rust control programs.

References
Herbicides Help Keep U.S. Chile Producers Competitive with Foreign Suppliers

U.S. Pesticide Benefits Case Study No. 20, May 2011

Leonard Gianessi and Ashley Williams

New Mexico, eastern Arizona, and far west Texas produce 90% of U.S. chiles. In New Mexico, chiles generate more than $400 million in economic activity in the state each year. The chile pepper industry in the southwest is facing increasing pressure from foreign competition. Other countries, such as Mexico, have access to lower-cost labor. Reduced production costs are essential for the southwestern chile industry to survive.

Chiles grow slowly at the beginning of the season, giving rapidly growing weeds a competitive advantage. Uncontrolled weeds have been documented to reduce chile yields by up to 76% [1].

Mechanical cultivation can effectively control weeds only between the rows. Weeds in the rows can significantly reduce chile yields. Research has shown that chile yields are reduced 33% when only cultivation is used for weed control [2]. A combination of herbicides is widely used to control a broad spectrum of weeds in chiles. A two-year research study demonstrated that chile yields could be equivalent between fields treated with herbicides and fields that were hand weeded [3]. However, an extra 42-79 hours of hand weeding was required. The hand weeding program would be 5-10 times more costly than the herbicide program.

References
Fungicides Protect Potatoes from a Disease that Caused the Death of Millions

U.S. Pesticide Benefits Case Study No. 21, May 2011

Leonard Gianessi and Ashley Williams

The pathogen *Phytophthora infestans* causes a disease known as “late blight,” so named because in most sections of the country it attacks potato plants at or after the blossoming stage [1].

Following infection, the fungus grows within plant tissues, breaking down cell walls so that it can use the nutrients found within them. In the field, severely affected plants have an acrid odor which is the result of dying potato tissue. The disease spreads rapidly, with the result that all the plants in a field may be killed in a few days [1]. On a tuber, the fungus spreads irregularly from the surface through the flesh like the diffusion of a brown stain. An effect of the disease in storage is the wet rot phase, which is due to the invasion of secondary bacteria following late blight development. This phase develops rapidly and causes a very wet, soft, or slimy and foul smelling rot [2].

Late blight was first reported in the United States in Philadelphia in 1843, and subsequently spread throughout the country [3]. Late blight was reported in Europe in 1845 where it had spread to Belgium, England, and Ireland. Irish peasants subsisted almost entirely on potatoes. 40% of the Irish potato crop was destroyed by late blight in 1845 and almost 100% destruction occurred in 1846 [4]. An estimated 1.5 million Irish died of famine and disease during the late blight epidemic, and a similar number of people emigrated, mainly to North America [5].

Late blight continued to be a devastating disease until the 1880s when the first fungicide was discovered. A summary of twenty years of experimental data in Vermont (1890-1910) showed an average increase in potato yield of 64% with the use of copper-lime fungicides [6]. Research with synthetic chemical fungicides in the 1940s showed potato yield increases of 23% and 35% in comparison to the copper-lime fungicides for control of late blight [7],[8]

References
It has been estimated that brown rot fungi infect 100% of U.S. acres of peaches with the potential to reduce yield by 75% [1],[2]. The first symptom of the disease on the fruit is the appearance of a tiny brown speck that rapidly develops into a large spot beneath which the flesh is deeply invaded [3]. The invasion of the fruit by the fungus is quite rapid; the entire fruit may become completely rotten and soft within a few days as a result of a rapidly spreading brown decay [4]. Appearing on the surface of the fruit are ash colored masses of millions of spores, which serve in turn to spread the disease further [5]. The invaded fruit that remains attached to the tree slowly becomes dried and shriveled, harboring 40,000 spores that can infect fruit the following year [6]. Spores are also released from fruit that falls to the ground.

Brown rot caused substantial fruit loss in field and during transport before the development of fungicides. In 1852, it was estimated that Georgia peach growers expected to lose 50% to 75% of the crop [7]. Southeastern peach growers began widespread spraying to control brown rot in 1912 with the development of finely powdered sulfur [3]. The average yield on the sprayed trees was two and one half times higher than on the unsprayed trees [8]. While unsprayed trees showed 95% brown rot incidence, sprayed orchards demonstrated 25% incidence [8]. Peach losses due to brown rot averaged 13% in Georgia in the 1920s [9].

More effective brown rot control became possible after introduction of synthetic chemical fungicides in the 1950s [10]. Experiments have shown reductions in the incidence of brown rot from 69% to 1% [11]. The use of synthetic fungicides has virtually eliminated losses due to brown rot [12].

References
Herbicides Reduce Peach Tree Death in the Southeast

U.S. Pesticide Benefits Case Study No. 23, May 2011

Leonard Gianessi and Ashley Williams

Until the 1960s, the predominant weed control system in Southeast peach orchards was bare ground culture, maintained by cross-disking until midsummer. In the 1960s, growers began to realize herbicides could reduce the need for disking. By utilizing herbicides, the need to maintain wide row spacing of trees to accommodate cross cultivation was reduced, and growers were able to plant a higher density of trees per acre. It was also determined that cultivation is detrimental to tree growth due to root pruning, and it contributed to soil erosion in peach orchards located on slopes. As a way of reducing the incidence of peach tree short life (PTSL), many growers adopted the use of herbicides in peach orchards.

Research demonstrated that a 19% peach tree mortality rate occurred in four years of disc weed control, while the chemical weed control system resulted in no loss [1]. Pythium root rot was much more prevalent in orchards where roots had been damaged by disking. Research demonstrated that the total number of peach tree roots in the top 20 cm of soil surface was 435 higher in the herbicide treated plots in comparison to the mechanically cultivated plots [2]. After two years, peach tree diameters were 27% greater in plots treated with herbicides in comparison to trees in cultivated plots [3]. Peach yield in the herbicide plots was 167% higher than in the cultivation plots [3]. Although the cultivated plots were tilled seven times during the season, there was rapid regeneration of weeds after each tillage operation [3]. In contrast, the residual herbicides provided season-long control of most broadleaf and grass weed species [4]. Now, the most common method of weed control in Southeastern peach orchards is to use herbicides in a strip down the tree row and to maintain a weed sod between the rows.

References
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Insecticides Protect Alfalfa in Regions Where Parasites are Ineffective

U.S. Pesticide Benefits Case Study No. 24, May 2011
Leonard Gianessi and Ashley Williams

Alfalfa is grown on 21 million acres in 42 states and is the predominant forage of choice for high producing dairy cows.

Although the alfalfa weevil was distributed throughout Europe and Asia, it was not in the U.S. until the early 1900s. The alfalfa weevil is now in all the contiguous 48 states. The Egyptian alfalfa weevil was first discovered in 1939 and has remained confined to California and Arizona. Adult weevils emerge from a summer resting state in fall and begin to migrate to alfalfa fields to feed, mate and lay eggs. Females deposit an average of 50 eggs per day for up to 80 days [1]. The females deposit the eggs in holes they chew in alfalfa stems. The tiny larvae crawl up the stems to feed on young leaves. Older larvae are voracious feeders. Plants may be stripped of all foliage. The alfalfa weevil is capable of defoliating an entire untreated alfalfa field [2].

Because the alfalfa weevil is an invasive species, Asian and European parasites were imported for control beginning in the early 1900s. From 1980 to 1990, USDA distributed 16 million parasites of the alfalfa weevil throughout 38 states [1]. In northeastern and mid-Atlantic states, parasites maintain the alfalfa weevil below economic threshold on the majority of acres [3]. Biological control of alfalfa weevil is now taken for granted in most of the north central states [4]. One parasite particularly suited to the northeast is the wasp Microtonus aethiopoides. After mating, the female pursues the alfalfa weevil adults aggressively. When it catches a weevil, it inserts its egglayer through the anus and lays an egg in the body cavity. The parasite larva feeds on the organs of the alfalfa weevil. Eventually, the weevil is killed. It is estimated that this parasite kills up to 90% of adult weevils.

However, the level of biological control reached in the northeastern and north central states has not been achieved in other regions of the U.S., probably due to higher temperatures in these regions. Consequently, much of the alfalfa acreage in these other states continues to be treated annually with insecticides to control alfalfa weevil and Egyptian alfalfa weevil.

References
Insecticides Required to Meet Consumer Demands for Sunflower Seeds

U.S. Pesticide Benefits Case Study No. 25, May 2011
Leonard Gianessi and Ashley Williams

North Dakota, South Dakota and Minnesota account for two-thirds of U.S. acreage of commercial sunflowers. Approximately 209,000 acres are grown for confection food uses, producing a volume of 273 million pounds. A set of trade standards have been developed for non-oil sunflower kernels that stipulate there should be no more than 2% insect damage [1].

The NDSU budget for confectionery sunflowers includes a spray targeted at head feeding insects: red seed weevil, lygus bug and banded sunflower moth [2]. The NDSU Extension Service recommends that sunflowers grown for the confectionery market be treated a minimum of two times for these three pests [3]. Growers who do not spray at all invariably have insect damage above 10%, which renders the entire crop unfit for human consumption [4].

The red sunflower seed weevil deposits eggs in sunflower seeds and the larvae feed in the developing sunflower kernels destroying a portion of the kernel. A single female red sunflower seed weevil lays enough eggs to damage an average of 20 seeds. Insecticide treatments reduced seed weevil damage by 93-96% [5]. Sunflower leaves contain a combination of chemicals, volatiles, and moisture that stimulates egg-laying by the banded sunflower moth [6]. Larvae penetrate and consume the contents of seeds. Kernel brown spot was observed for the first time in 1998. The spot is superficial with little or no tissue degradation. Processors are allowed only 0.5% brown spot damage in their finished product [7]. Feeding by the lygus bug was identified as the source of kernel brown spot. Though lygus bugs don’t eat much, they inject plant tissues with digestive enzymes and extract nutrients [8]. Lygus insert their mouthparts into the host, start a pre-digestion pump to inject saliva and start digestion, then suck the fluids into the stomach. The saliva is toxic to plant tissue, helping reduce the plant fluid into a digestible source. Research has shown that lygus are controlled by the same insecticide sprays that control banded sunflower moth and seed weevils [7].

References
Herbicides Replaced Backbreaking Hand Weeding in California Vegetable Fields

U.S. Pesticide Benefits Case Study No. 26, May 2011
Leonard Gianessi and Ashley Williams

Use of the short handled hoe (el Cortito) was the primary weed control method for most vegetable crops in California from the early 1900s through the 1960s. The short handled hoe was 8-24 inches in length and its use required workers to bend over at the waist to bring their eyes closer to the ground. When bending, workers could clearly distinguish between weeds and crop plants. Typically, the short handled hoe was used for 28 hours per carrot acre and 45 hours per celery acre [1],[2].

The use of laborers for removing weeds was facilitated by low wages (10¢/hr) and a large number of available workers. The average farm worker wage rate increased to $1.00 per hour in the early 1960s. Several factors led to this increase: a crackdown on illegal entry of farm workers, the push for farm labor unionization, and the end of the Bracero program in 1964. With the increased costs and difficulties of obtaining qualified farm labor, emphasis was put on chemical herbicide research to control weeds in vegetable crops [3].

Farm workers made numerous complaints against the short handled hoe, stating that they suffered permanent back pain as a result of using the hoe for extended periods of time. In 1972, California Rural Legal Assistance (CRLA) petitioned the California Industrial Safety Board to ban the use of the short handled hoe as an unsafe tool for workers to use. In 1975 the Industrial Safety Board issued the regulation that permanently banned the use of the short handled hoe in California.

The predicted dire economic effects of the ban on the short-handled hoe did not materialize because growers switched to the use of economical, effective chemical herbicides [4].

The use of herbicides greatly reduced the costs of removing weeds in comparison to hand labor. In 1960, the cost of the herbicides and their application was $10/acre in comparison to hand hoeing costs of $100/acre for spinach, $80/acre for celery, $125/acre for onions, and $400/acre for strawberries [5]. The use of herbicides is credited with reducing the use of the short handled hoe in California onion fields by 120 hours/acre, which is equivalent to 2 million hours/year [6].

References
Herbicides Keep Processed Green Peas Free of Poisonous Contaminants

U.S. Pesticide Benefits Case Study No. 27, May 2011
Leonard Gianessi and Ashley Williams

Weed control in processing peas is crucial because weed competition reduces yields of shelled peas and weeds contaminate harvested peas with seeds or fragments that reduce the quality and market value of the peas [1]. Canada thistle buds and nightshade berries are similar in size and shape to peas and are difficult to remove from harvested peas. Growers can have pea loads discounted or entire fields left unharvested due to Canada thistle contamination. Removing nightshade is particularly important because the berries are poisonous [2]. It is essential to keep pea fields relatively weed-free, ensuring high quality green peas [2].

Weeds reduce the yields and the quality of peas when soil moisture is limited. Weed competition under these conditions causes the typically tender, high-quality peas to become hard. These small, hard peas are difficult to separate. Therefore, they reduce the grade of the processed product [3]. Since growers plant green peas in narrow rows, it is difficult to use cultivators without severely injuring the pea plants [2]. Prior to the development of herbicides, growers frequently found it necessary to go through pea fields with a scythe and cut the thistle plants [4]. Early experiments with herbicides showed a reduction of 90% in Canada thistle development in treated pea fields [4]. Herbicide use in peas expanded rapidly due to excellent control of Canada thistle, nightshades and annual broadleaf and grassy weeds, which had been reducing yields by up to 64% in some fields [5].

References
The European Corn Borer (ECB) will reproduce on snap beans, although they are not its preferred host. They overwinter as larvae primarily in field corn crop residue. Mating occurs in grassy and weedy areas and the females move into snap beans, sweet corn and other crops to lay eggs. The females will lay 500 eggs in groups of 5 to 50. Larvae of the first and second generation bore into pods of snap beans to feed on the bean. Damaged pods show entry holes, possibly surrounded by excrement called frass.

Although ECB feeding injury probably does not reduce yield, growers must avoid product contamination by both larvae and damaged pods. Uncontrolled, the ECB would damage 1-2% of the snap bean pods. Since larvae are located inside the pod, it is very difficult to grade out larvae-containing pods. However, during processing, larvae can migrate out of the pods and float to the top of the food package, providing an unpleasant surprise for the consumer [1]. Processors reject beans having infestations in excess of one larva per 1000 pods [2],[3]. Many field infestations would exceed this level if insecticides were not sprayed [4]. In North Central states, the ECB would result in 100% lost green bean production on 85% of the acres without treatment [5]. Preventive treatment is necessary if the buyer requires 100% pest injury-free beans, which is usually the case for beans grown for processing.

References
Artichokes Would be Filled with Worms without Insecticide Use

U.S. Pesticide Benefits Case Study No. 29, May 2011

Leonard Gianessi and Ashley Williams

The artichoke is native to the Mediterranean area. The plant came to California with Italian immigrants in the mid-1800s and commercial production began in the early 1900s. California produces 100% of all commercially grown artichokes in the U.S.; the U.S. ranks sixth in the world in artichoke production. All artichokes grown in California go to the fresh market. Many growers regard the climate of the Monterey Bay area as one of the best in the world for artichoke production [1]. The artichoke is a member of the thistle family. Perennial artichokes are harvested for 5 to 10 years before replanting.

The artichoke plume moth (APM) is native to North America. Prior to the introduction of artichokes, several thistle species commonly occurring throughout California served as primary hosts to the APM. Adult females deposit an average of 170 eggs on artichoke plants. Larvae start tunneling into the leaf stalk and work their way toward the center of the bud [2]. Larvae of the artichoke plume moth feed on all parts of the plant, but economic losses result when they feed on artichoke buds. The buds are unmarketable as a result of the eaten away portions of the bracts, borings inside of the heads, and blackened heads from feeding and frass exudation [3],[4]. Larvae may feed from 36 to 86 days [5].

In 1922 the damage was so severe that growers requested aid from the University of California. Applications of nicotine, pyrethrum, cryolite, and lead arsenate failed to reduce the percent of wormy artichokes [4]. In the 1952-53 and 1953-54 seasons, losses reached proportions as high as 50% to 70% [5]. Research in 1956 demonstrated that 8-9 applications of new chemical insecticides killed 96-100% of the larvae on plants [6]. Insecticides came into common use in the 1960s [3]. Current research demonstrates that insecticide applications can reduce APM infestations from 80% (untreated) to 2% [7].

References
Insecticides Keep Worms and Their Excrement Out of Cucumbers and Pickles

U.S. Pesticide Benefits Case Study No. 30, May 2011

Leonard Gianessi and Ashley Williams

The most troublesome insect pest on cucumbers in Florida and the southeast is the pickleworm [1]. The moth that produces the pickleworm has been known since 1782, but the pickleworm as a pest appears to have escaped attention until 1869 when it was described in processed pickles [2]. Pickleworm is a tropical insect which survives the winter only in south Florida and south Texas. Pickleworm is highly dispersive and invades much of the southeast each summer. They migrate north when environmental conditions become favorable. North Carolina and South Carolina regularly experience crop damage by pickleworm, but often this does not occur until August or September [3]. In contrast, northern Florida is flooded with moths each year in June.

Egg production is estimated to be 300 to 400 eggs per female [3]. When about half grown, the pickleworm bores into the side of a fruit and feeds there until it has eaten out a cavity. The larva’s entrance is marked by a small hole, through which frass is extruded. Fruits that are entered by the pickleworm are made unfit for human consumption because of the tunneling and excrement of the insect [4].

Natural enemies are of no significant benefit in suppressing pickleworm populations; consequently, populations usually increase rapidly and often destroy the crop if insecticides are not applied [5]. Frequent foliar sprays are needed to prevent the pickleworm from entering and contaminating pickles [6]. Pickleworms can pass unnoticed inside fruit and may not be found until after the fruit is processed. Fear of product contamination precludes acceptance of any pickleworm infestation. Lack of treatment may result in condemnation of an entire crop [7]. Pickle processors will refuse to accept a truckload of cucumbers if they notice even one with a pickleworm hole [8].

References
Walnut Growers Have Sprayed Insecticides for 80 Years to Prevent Major Losses

U.S. Pesticide Benefits Case Study No. 31, May 2011

Leonard Gianessi and Ashley Williams

The codling moth has been known to attack walnuts in California since 1909 [1]. At that time, less than 1% of the crop was affected. An increase followed, with yearly fluctuations, and by 1918 the infestation had become serious – as high as 50% in some orchards [1]. At the insistence of the California Walnut Growers Association, a special appropriation was made by the legislature. The Citrus Experiment Station undertook studies aiming for control of the pest [1].

Each overwintered female deposits about 30 eggs singly on leaves near nuts. Later generations of females lay an average of 60 eggs on leaves or nuts. Young larvae penetrate directly through the husk and shell into the nutlets. The larvae remain in the nuts about 35 days, on average [1]. The larvae leave the nut after completing their development. The damage caused by the codling moth is different with each generation [2]. First generation larvae reduce yield directly by causing nutlets to drop from the tree. Nuts attacked by later first generation, second, and third generation larvae remain on the tree but are unmarketable due to the feeding damage present in the kernel [2]. Even though only a portion of the kernel may be consumed, the remainder is practically worthless.

Early research determined that there was only one thoroughly satisfactory method for controlling the codling moth: to coat the nuts with an insecticide to destroy larvae before they enter the husks [1]. By 1926, spraying was the commercial practice employed in all of the codling moth infested groves [1]. Insecticide tests have shown that untreated walnuts incur about 15-18% codling moth damage at harvest while insecticide-treated walnuts incur less than 1% damage [3],[4].

Although over 250 biological control organisms have been shown to attack codling moth, none are capable of keeping populations below that which causes economic damage [5]. A classical biological control program for codling moth was initiated in California walnut orchards in 1992 [6]. Following an initial survey for parasitoids of codling moth in Central Asia, three species were selected for importation and release in California. The introduced parasitoids were released in 72 walnut orchards. The most successful parasitoid was *M. ridibundus*, a cocoon parasitoid, which parasitized only 9% of the cocoons in walnut orchards [6].

References


Codling moth

Codling moth damage

Spraying walnut trees
Herbicide Use Has Resulted in a Significant Reduction in Energy Use

U.S. Pesticide Benefits Case Study No. 32, May 2011
Leonard Gianessi and Ashley Williams

The cost of fuel for farm operations remained inexpensive through the 1950s and ‘60s, but increased dramatically following the energy price shocks of 1973-74 and 1980-81. Fuel price has increased dramatically in recent years (Figure 1). Energy price increases significantly altered the pattern of energy use on U.S. farms, resulting in a large decrease in direct energy use (Figure 2). Since the late 1970s, the direct use of energy by agriculture has declined by 26%, while the energy used to produce fertilizers and pesticides has declined by 31% [1].

The decline in agricultural energy use resulted in a significant reduction in agriculture’s share of the nation’s total energy usage. In 1978, the total direct and indirect energy used in agriculture accounted for about 5% of U.S. energy use [2]. Currently, the direct energy use in U.S. agricultural production represents about 1% of total U.S. energy consumption while the indirect energy use to manufacture the pesticides and fertilizers represents about 0.5% [1].

Agriculture has made dramatic efficiency gains in energy use. Since 1973, farm output has grown 63% while direct energy consumption has declined 26%. As a result, direct energy use per unit of agricultural output is 50% less today than it was in the 1970s (Figure 3).

Herbicides have been a main factor for the decrease in energy use [4]. The energy price increases stimulated an increase in conservation tillage, reducing fuel consumption relative to conventional tillage [5]. The additional energy embodied in herbicide use in reduced-tillage systems is much less than the energy conserved by reduced tillage [6]. A moldboard plow consumes 17 times more diesel fuel per acre than an herbicide sprayer. A row-crop cultivator requires 0.4 gallon/acre per trip while a herbicide sprayer requires 0.1 gallon/acre [7].

The Conservation Tillage Information Center (CTIC) has estimated a savings of 3.9 gallons of direct fuel use per acre by going from conventional tillage to no-till [8]. By 2008, the number of no-till acres reached 88 million, implying an annual fuel savings of 343 million gallons.

References
Insecticides Increase the Value of Avocados by 40%

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California is the second largest producer of avocados in the world, behind Mexico, and produces about 10% of the world’s supply. California avocados are marketed almost entirely through the fresh produce market. At one time, a significant amount of blemished fruit grown in California was processed into guacamole products. In the past decade, however, all of the major avocado processors have turned to avocados grown in Mexico as the source of avocado pulp for their processed products. For this reason, it is critical for California avocado growers to minimize blemishing of the fruit they grow. Blemished avocados suffer a significant discount in the produce marketplace.

Historically, the production of avocados in California required little usage of insecticides. Avocado pests were generally kept under commercially acceptable control by a variety of beneficial insects, diseases, and weather conditions. Since the introduction of avocado thrips in 1996, insecticide use in California avocado orchards has increased dramatically.

By May 1999, 95% of California acres were infested with avocado thrips [1]. Thrips are a major pest in California; both larvae and adults feed only on developing avocados [2]. Feeding scars develop and radiate towards the top of the fruit [3]. Scarring can be severe enough to render the entire fruit surface brown. Fruit that are entirely scarred can continue to grow, and the flesh of the fruit is a healthy green. However, even partial fruit scarring results in downgrading in packinghouses because of cosmetic damage [1]. The amount of fruit downgraded due to an untreated thrips infestation can be as high as 95% [1]. Fruit are downgraded to a lesser quality equivalent to a 40% decrease in price [4].

Insecticide use reduced fruit scarring to 0.6% in experiments. Insecticide control lasts for eight weeks and kills 80-90% of the thrips [5]. Treating with insecticides has effectively eliminated quality damage for producers [6].

References