Alfalfa Production Systems in California

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Chapter 1

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Alfalfa is considered the "Queen of Forages" worldwide and is unrivaled among forage crops due to its combination of high quality, high yield, stand persistence, wide adaptation, biological nitrogen (N) fixation, and soil benefits. Alfalfa is one of the most palatable forages, providing high energy and protein for dairy cows as well as other types of livestock. It is an "engine of human food production," eventually transformed into milk, cheese, meat, wool, and even honey. It provides a livelihood to thousands of farmers, contributes to wildlife habitat, protects the soil, and provides open spaces. It is the first choice of many farmers and ranchers as the premier perennial forage legume.

California's agriculture is most often identified with high-value specialty crops, such as lettuce, tomatoes, fruits, almonds, and grapes. In 2005 the state's agricultural value was over $31 billion per year—first in the nation—and these crops were leading commodities. However, California also produces over 21 percent of the nation's milk and has become the leading dairy producer. As a result, alfalfa is the state's highest acreage crop, and California is the leading alfalfa hay-producing state in the United States. The dairy-forage continuum is the state's most important agricultural enterprise, with dairy ranked as the state's number-one commodity, exceeding $5 billion per year in recent years. There are also significant numbers of other alfalfa-consuming livestock, including beef cattle, horses, goats, and sheep. The linkage with dairy production and other animal enterprises has caused alfalfa and forage crops to play a significant role in the state.

This chapter provides an overview of alfalfa history and production methods, describes its role in cropping systems, and provides a context for alfalfa production in irrigated regions of California.

Alfalfa Growing Regions

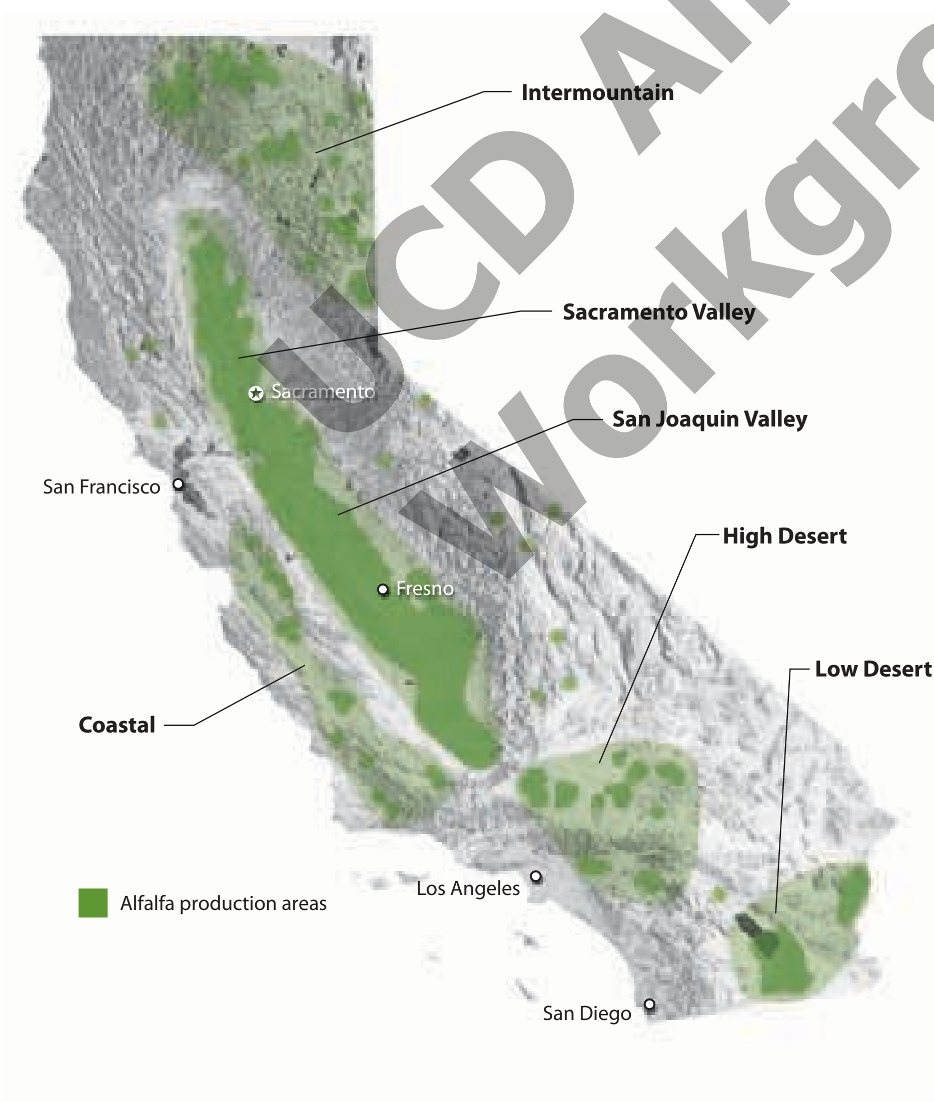
The state of California is highly diverse in its climates and soils, but alfalfa is important in most of the agricultural regions in the state. The primary production areas are the Central Valley and the Low Desert, High Desert, Coastal, and the Intermountain Regions.

Central Valley

Alfalfa is produced throughout California, but the major growing areas are the rich alluvial plains of the Sacramento and San Joaquin Rivers, collectively called the Great Central Valley of California. This region, considered one of the most important agricultural regions of the world, has a Mediterranean climate and is characterized by mostly deep, alluvial soils, but with significant salt-affected soils in the western portion of the San Joaquin Valley. The Central Valley is characterized by hot, dry summers (daily maximum temperatures over 100°F [38°C]) and cool winters (daily maximum temperatures of 60° [16°C]). Rainfall ranges from 8 to 18 inches (20–46 cm) south to north and occurs mostly from November through March, but supplies of irrigation water from rivers, streams, canals, and reservoirs originating from the Sierra Nevada Mountains to the east and north are significant. Over 70 percent of California's alfalfa is produced in the Central Valley (Fig. 1.1). Nearly 100 percent of the state's alfalfa is irrigated.

FIGURE 1.1

Map of production zones in California. The major production zones are the San Joaquin Valley (61% of the state's production), followed by the Low Desert (17%), Sacramento Valley (9.7%), Intermountain (9.5%), High Desert (1.7%), and Coastal (0.5%) Regions. Percentages are from 2005 USDA National Agricultural Statistics Service. Green marks indicate acreage.



Low Desert

The southern Low Desert Region, consisting primarily of the Imperial and Palo Verde Valleys, is an area with searing hot summers (daily maximum greater than 105ºF [41ºC]) and warm winters (daily maximum 75ºF [24ºC]) enabling crop growth throughout the year. This region receives less than 3 inches (8 cm) of rain per year, but receives large allocations of irrigation water originating from the Colorado River. Soils are generally heavy, but some sandy regions can be found, and salts are a significant management issue. Surface f ood irrigation systems are the most common. About 17 percent of the state's production is from this region (Fig. 1.1).

High Desert

The High Desert Region is north and east of the Los Angeles Basin and is characterized by high elevation (1,500 to 3,000 feet [457 to 914 m]) and very low rainfall (less than 5 inches [13 cm] per year). Unlike the Low Desert, winters are cold (mean low of 37ºF [3ºC]), sometimes even snowy, limiting winter growth. Soils tend to be light sandy loams to clay loams, prone to wind erosion, and most water sources are from groundwater. Salinity is a problem in some areas, and water is primarily pumped from aquifers. Less than 2 percent of the state's production is from this region (Fig. 1.1).

Coastal Region

The cool coastal valleys of California can grow alfalfa, but much of the production has been displaced by urbanization and higher value crops in recent years. Less than 0.5 percent of the state's alfalfa is located here (Fig. 1.1).

Intermountain

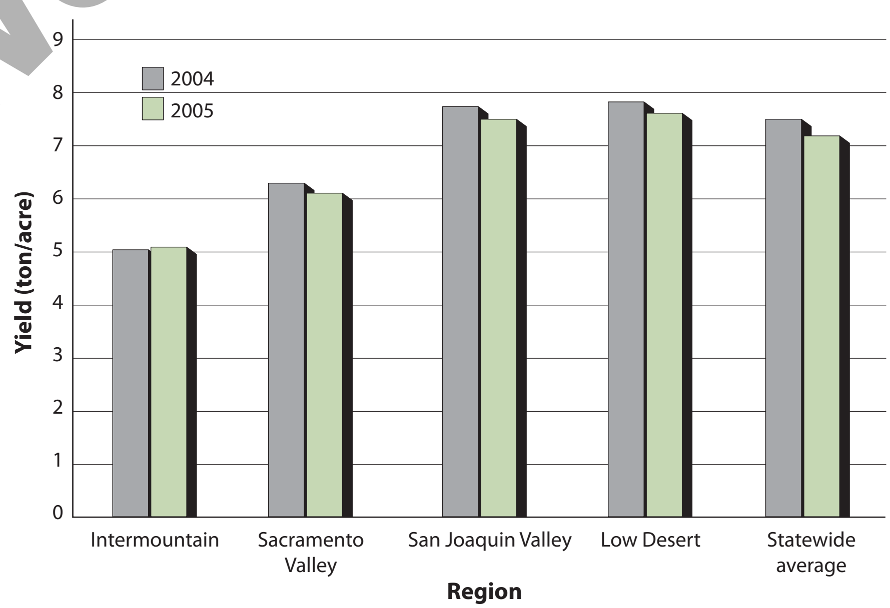
Alfalfa is a significant crop in the more temperate high-elevation Intermountain Regions of California, which experience freezing winters and clear, warm summers. Summer highs average 86ºF (30ºC), and winter lows average 26ºF (–3ºC). Rainfall averages about 20 inches (51 cm) per year. A detailed description of Intermountain alfalfa production can be found in *Intermountain Alfalfa Management* (Orloff and Carlson, eds.). Approximately 10 percent of the state's alfalfa crop is produced in this region (Fig. 1.1).

Production

Statewide, average dry-matter (DM) yields are 7.0 to 7.5 tons per acre (15–17 Mg ha^{-1}) (Fig. 1.2). Growers harvest up to 12 times per season in the southern deserts of California (the average is 6 to 7 through most of the state), producing about 7 million tons (6.3 Mg) per year in California.

FIGURE 1.2

Average yields (to convert t/acre to Mg/ha, multiply by 2.24) for selected production zones in California, 2004–2005 (County Agricultural Statistics Reports).



History of Alfalfa

Alfalfa's history spans more than 4,000 years, originating from the very early history of agriculture (Fig. 1.3). California has played a special role in its history in North America. Alfalfa was likely domesticated near present-day Turkemnistan, Iran, Turkey, and the Caucasus. The earliest written reference to alfalfa was from Turkey in 1300 BC.

Alfalfa was important to the early Babylonian cultures, the Persians, Greeks, and Romans. Aristotle and Aristophanes wrote about it, as did early Roman writers. Alfalfa was reportedly brought to Greece in 500 BC by invading Median armies to feed their chariot warhorses. The forage culture that included alfalfa enabled Roman and other Mediterranean empires to expand, due to the linkage with horses and military might, as well as its role in milk and meat production. Alfalfa was introduced into China in 126 AD, accompanying prized Persian horses given to the Chinese Emperor. Alfalfa moved across the Alps into Northern Europe acquiring the name "lucerne," as it is currently known in many countries. Similarly, the Arab empires in the Middle Ages spread alfalfa throughout many areas of Europe and the Middle East. The word "alfalfa," meaning "best horse fodder," has Arabic, Persian, and Kashmiri roots.

The first recorded attempt to cultivate alfalfa in the United States was in Georgia in 1736. Presidents Washington and Jefferson, as well as others, grew alfalfa, but these early efforts were largely unsuccessful. The important introductions into the United States came during the California Gold Rush around 1850. Unlike many crops that were important in the east and then moved west, alfalfa gained its first foothold in the United States in California and other western states and subsequently moved eastward.

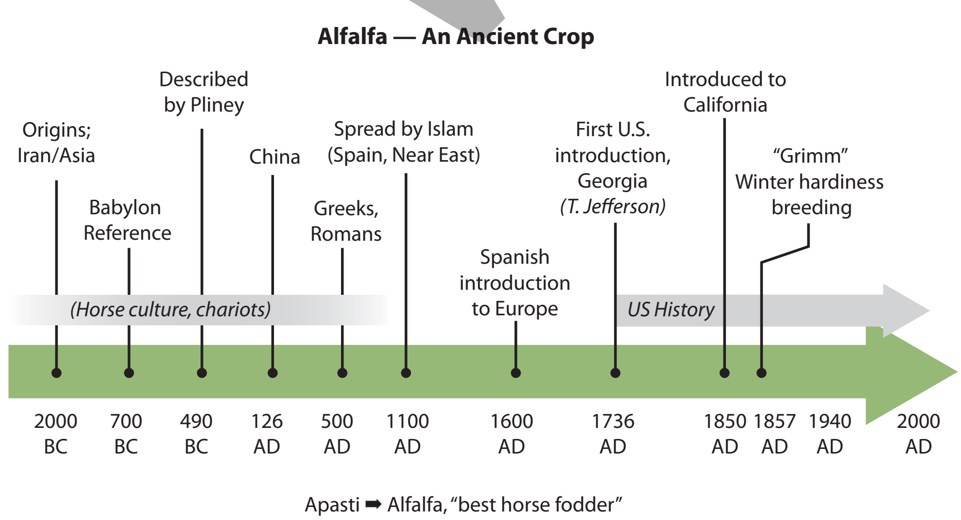
Alfalfa and the Gold Rush

Historians have said that it is impossible to overemphasize the importance of the California Gold Rush of 1849–1860 as it influences the history of the West, and the same can be said for the history of alfalfa, which was linked to the Gold Rush. Although exact dates are unknown, the first alfalfa seed probably entered California from South America between 1847 and 1850. Alfalfa had been cultivated in Chile for more than 20 years prior to this time and was originally promoted to California farmers as "Chilean clover." Although a vast majority of prospectors failed at mining, many were successful in agriculture, and alfalfa was an important component of early California farms. In just a few years, alfalfa spread north and eastward to Nevada, Utah, Oregon, Kansas, and Oklahoma.

Alfalfa was a natural fit with livestock in the expanding West. It readily adapted to the warm sun and deep soils of California where irrigation water was available. While non-irrigated wheat was dependent on far-away markets, and methods for processing vegetables and fruits were not yet developed, there was always a steady, local demand

FIGURE 1.3

Alfalfa was one of the earliest domesticated crops and was an important component of early Mediterranean cultures of Europe and the Near East. It plays an important role today in the regions of California with a Mediterranean climate.



for alfalfa hay. Hay production in California increased from about 2,000 tons (1,814 Mg) in 1850 to 550,000 tons (498,850 Mg) by 1870. This was accompanied by a rise in the dairy industry around cities, particularly San Francisco.

Alfalfa—A Traded Crop

Alfalfa hay has been a traded crop since its first introduction. The availability of river transportation (Fig. 1.4) and the new rail lines built in the 1880s greatly enhanced the viability of alfalfa as a cash crop. The San Joaquin and Sacramento Rivers provided a water highway from the agricultural areas of the Central Valley to San Francisco and other coastal regions. Transportation of hay required baling mechanisms, such as the Petaluma Hay Press (Fig. 1.5). In Southern California, alfalfa hay was raised in the deserts around Los Angeles and was the key first crop in the newly irrigated desert areas of the Imperial Valley in the early 20th century.

Alfalfa—A Western Crop

Alfalfa's sweep across the farming areas of the West was completed shortly after 1900, and alfalfa became one of the key irrigated crops in most western agricultural areas. By the turn of the 19th century, alfalfa acreage west of the Mississippi River accounted for over 98 percent of the total U.S. alfalfa production. In the 1920s, the leading alfalfa states were Kansas, Nebraska, Colorado, California, and Idaho. Most early methods required much hand labor (Fig. 1.6). Later introductions and the spread of "Grimm" and other winter-hardy cultivars assisted in the development of alfalfa for northern midwestern states and eastern states, and by 1940, midwestern and eastern production exceeded western production.

Yield and Quality Changes

Since the early 1920s, alfalfa yields have increased about two-fold in California (Fig. 1.7). This amounts to an average increase of nearly 0.5 ton per acre (1.1 Mg ha^{-1}) each decade. The primary factors for this increase were (1) expansion of alfalfa into higher-yielding districts like the Imperial Valley, (2) mechanization techniques that enable more cuttings per year, (3) techniques leading to improved irrigation management, such as laser leveling and better sprinklers, (4) new varieties

FIGURE 1.4

Hay was transported in the late 1800s and early 20th century on the many waterways of California's San Joaquin and Sacramento Valleys. Alfalfa hay was a traded commodity from the earliest periods in California.

FIGURE 1.5

The Petaluma Hay Press was an early baler developed in Petaluma, California, (near San Francisco) to bale hay from stationary stacks.

with higher yield and pest resistance, (5) new pest management methods, (6) increased use of fertilizers, and (7) better agronomic techniques, such as time of seeding and harvest scheduling.

In recent years, intensification of management for quality, particularly shorter cutting schedules (e.g., < 28–30 days), have likely had the effect of slowing yield increases (Fig. 1.7). Cutting schedules in the 1950s through the 1970s were clearly longer than current practice, thereby resulting in lower-quality hay. Thirty- to 40-day schedules were normal in this period, while currently, 22- to 28-day schedules are more typical to achieve higher quality. Petaluma Hay Testing Service in Petaluma, California, has shown a gradual increase in quality of the samples received from about 53 percent total digestible nutrients (TDN) to above 55 percent TDN (90% DM) since 1970 (Fig. 1.8), a measurement based upon fiber concentration. Since cutting for quality almost always sacrifices yield, this may explain a large portion of the yield "plateau" that some observers say has occurred over the past 20 years.

FIGURE 1.6

Early methods of western alfalfa cultivation included field stacking of hay in large units, with the use of the Jackson Fork, using horse-drawn derricks.

FIGURE 1.7

Yearly average alfalfa yields (to convert t/acre to Mg/ha, multiply by 2.24), California, 1912–2006 (USDA National Agricultural Statistics Service).

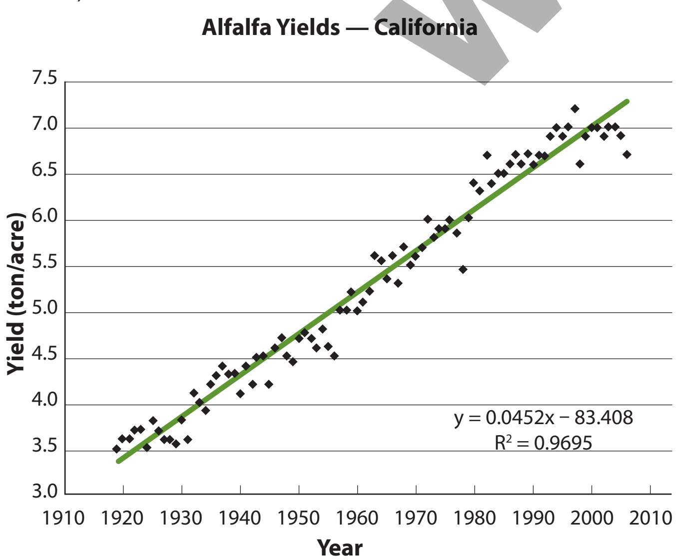
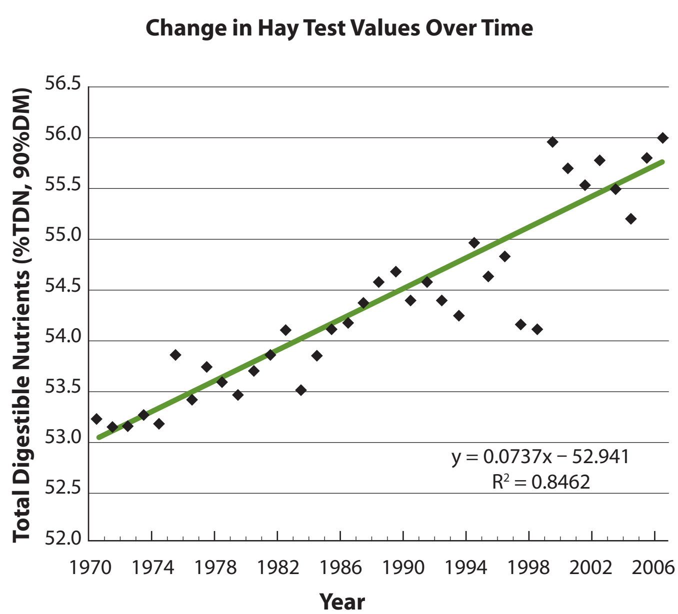


FIGURE 1.8

Changes in forage quality analysis since 1970. Each point is the average of thousands of samples received each year by Petaluma Hay Testing Service, Petaluma, California (data courtesy of Don Waite).



Variety Improvement

In the early 20th century, there were only five alfalfa variety groups known to U.S. researchers, mostly by their country of origin or land races, such as "California Common" and "Kansas Common" and "Peruvian." In the late 1920s, breeders discovered that they could select for improved performance and disease resistance, beginning with bacterial wilt. By the 1950s, a greater number of alfalfa strains were available, mostly selections made by the U.S. Department of Agriculture (USDA) and State Experiment Station researchers. Key milestones have been the development of aphid resistance, nematode resistance, and resistance to root diseases, particularly phytophthora, and the development of "nondormant" lines (such as CUF 101), which are much higher yielding in long-season regions like California. By the 1970s, the private sector began to dominate alfalfa breeding, and since that time dozens of new alfalfa varieties have been released each year (see Chapter 5, "Choosing an Alfalfa Variety").

Current Status and Statistics

Worldwide, alfalfa is grown on approximately 79 million acres (32 million ha), 70 percent of which comes from the United States, Russia, and Argentina. In the United States, alfalfa competes with wheat as the third most important crop in value, depending on year (Table 1.1). Alfalfa is California's highest acreage crop, and California is currently the leading producer of alfalfa hay in the United States (Fig. 1.9). Alfalfa is the dominant forage grown in the western United States under irrigation (Fig. 1.10), and is first either in acreage or value of agronomic crops in all western states.

Acreage

Alfalfa acreage in California reached a maximum of over 1.2 million acres (486,000 ha) in the 1960s, and has ranged from 950,000 to 1.15 million acres (385,000 to 466,000 ha) since

TABLE 1.1

Top six value crops in the United States, including value of milk produced for reference. Alfalfa is included in the "all hay" category and competes with wheat for the third or fourth place in value, depending on year. (USDA National Agricultural Statistics Service)

Crop	2003	2004	2005	Rank
	Value in Billions ($ × 1,000,000,000)			
Corn	24.5	24.4	21.0	(1)
Soybean	18.0	17.9	16.9	(2)
Hay (all)	12.0	12.2	12.5	(3)
Hay (alfalfa)	6.7	6.9	7.3	(3–4)
(Milk)	*21.4*	*27.5*	*26.9*	
Wheat (all)	7.9	7.2	7.1	(3–4)
Cotton	5.5	4.8	5.6	(5)
Potato	2.7	2.6	2.9	(6)
All Field Crops	**82.3**	**80.7**	**76.8**	

FIGURE 1.9

Leading alfalfa-producing states in the United States (USDA National Agricultural Statistics Service). Note: haylage is omitted from this total, which is significant in several states, especially Wisconsin.

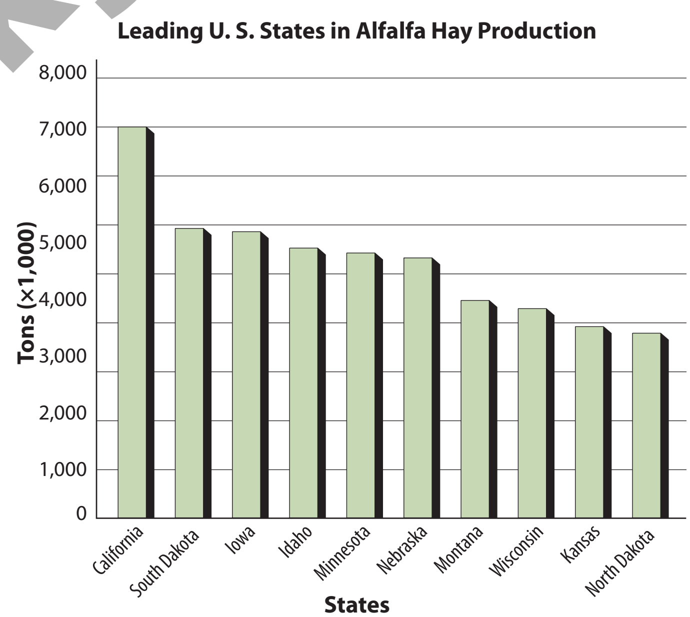


FIGURE 1.10

Irrigated alfalfa production in the United States (USDA National Agricultural Statistics Service).

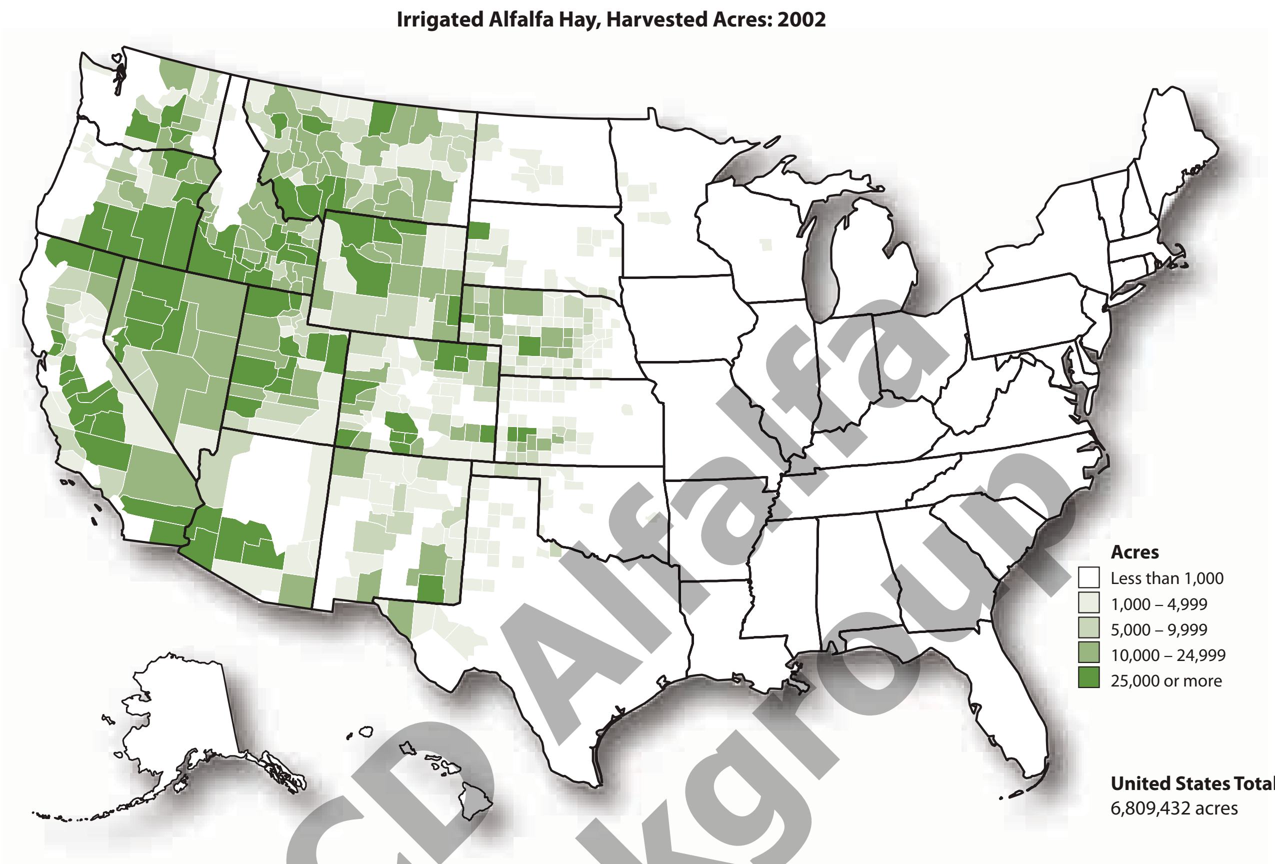
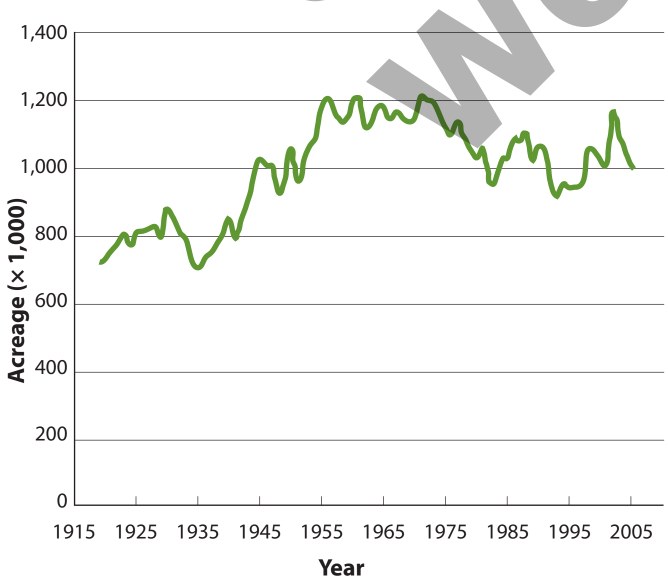
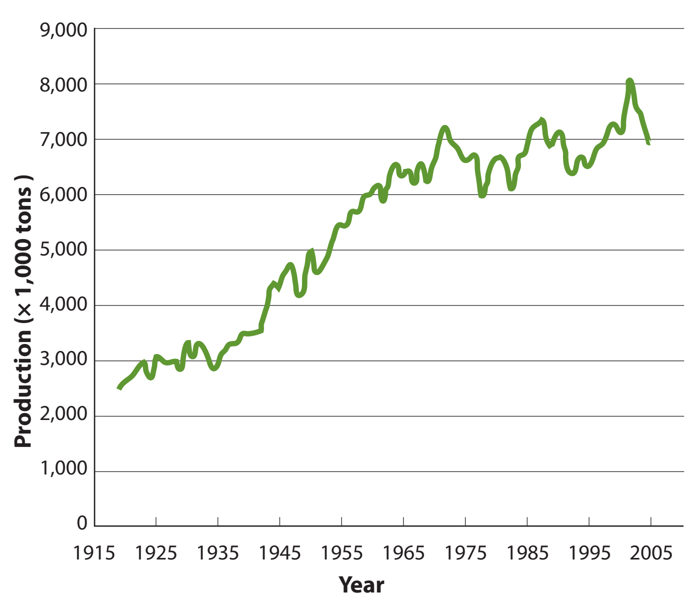


FIGURE 1.11

Trends in California acreage and production, 1920–2005.





that time (Fig. 1.11). However, due to higher yields (Fig. 1.7), overall production has continued to increase slightly. Conversion of alfalfa acreage to higher-value specialty crops, urban conversion, and limitations of water supply have been factors limiting California's alfalfa acreage during the late 20th century and early 21st century. Countervailing these trends has been the phenomenal increase in California dairy cow and recreational horse numbers, thus increasing the demand for forages. As a result, acreage has remained fairly constant for decades. All forages (alfalfa, irrigated pasture, corn silage, small grain forages, and miscellaneous hays) occupy over 2 million (810,000 ha) of the 9.4 million irrigated acres (3.8 million ha) in the state.

Dairying in California

The growth of the dairy industry in California has been a major factor inf uencing alfalfa production in this region. California surpassed Wisconsin as the number-one dairy state in 1993 (Fig. 1.12), and now produces more than 21 percent of the nation's milk. The growth of western dairying, particularly in California, was a major trend during the last quarter of the 20th century. In 2005, California milk production was about four times that of 1975 production (Fig. 1.13). Milk cow numbers have increased an average of over 3 percent per year, and production per cow has increased an average of 2.2 percent per year over this period in California. At least 75 percent of the alfalfa in the state goes to the dairy industry. This trend for growth in dairying has also occurred in several other western states, particularly Idaho, New Mexico, and Arizona. By 2005, western states accounted for over 40 percent of the nation's milk supply, up from 15 percent in the 1970s (Fig. 1.14).

A typical California dairy farm currently averages over 800 milking cows, and this number increases every year. In 2007, there were approximately 1.8 million dairy cows in California on less than 2,100 dairy farms. Growth in dairying is driven by growth in western populations, lower costs of production than in other regions, availability of

FIGURE 1.12

Top 10 milk producing states in the United States, 2005.

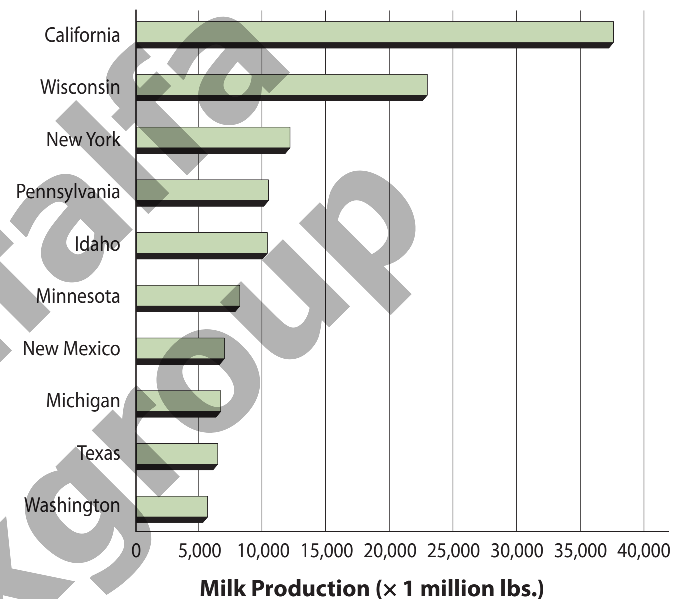
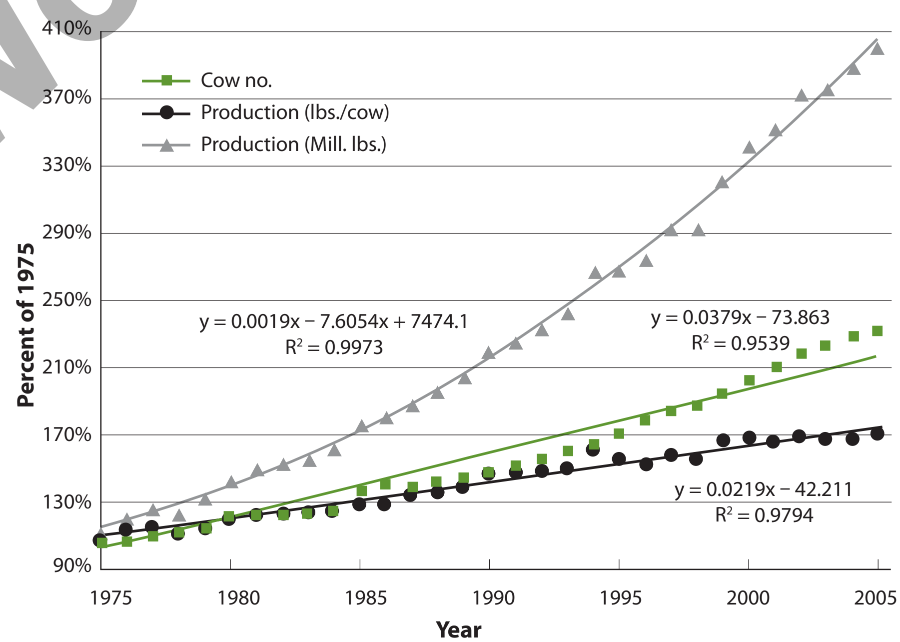


FIGURE 1.13

Total milk production, dairy cow numbers, and production per cow, expressed as a percentage of 1975 (USDA National Agricultural Statistics Service).



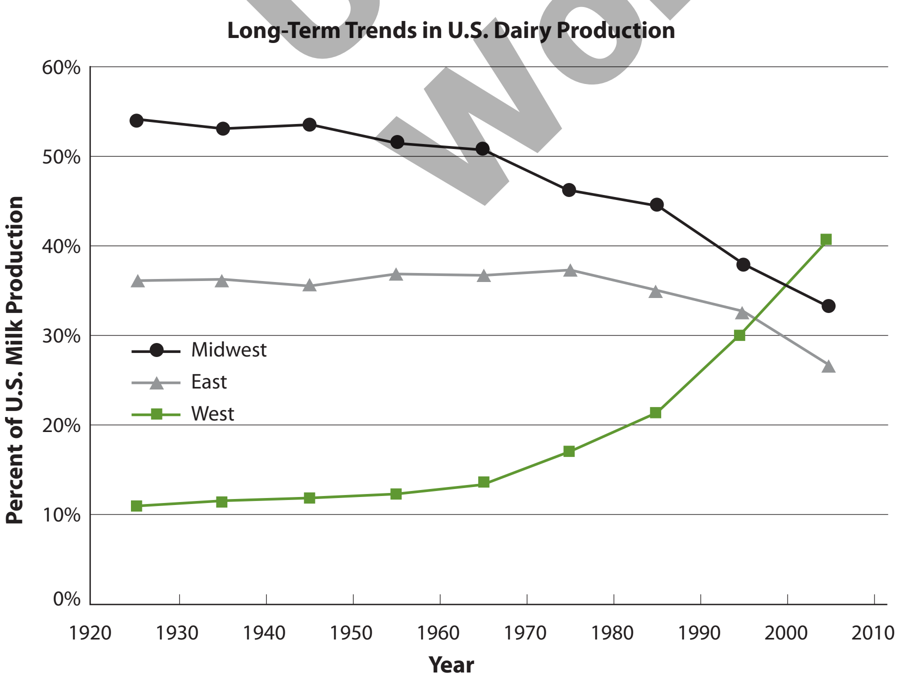
high-quality forages and by-products for feeding (such as whole cottonseed, citrus pulp, and tomato pomace), availability of labor, and reinvestment by dairies displaced by urbanization.

California dairy units consist of large corrals with open shelters and large milking parlors, and are characterized by high capital investments, high culling rates, and confinement housing. Grazing of alfalfa or other forages is a minor component of most California dairies, but grazing occurs on some Coastal and Northern California dairies.

Unlike many other dairy regions, the vast majority of the feed consumed by California dairy farms is purchased, including the majority of the alfalfa hay. Although dairy farms produce sizeable quantities of corn silage, small grain silage, and some alfalfa, the majority of alfalfa in this region is traded on the open market. The segregation of the alfalfa hay producer (seller) from the dairy producer (buyer) is a unique feature of western forage systems. This has large implications for alfalfa production, since forage quality testing plays an important role in setting price, and storage and transportation are important economic factors.

FIGURE 1.14

Change in milk production, 27 eastern states, 12 midwestern states, and 11 western states as a percent of U.S. production (USDA National Agricultural Statistics Service).



Alfalfa Production Methods

In many respects, much of California presents an ideal location for growing alfalfa. Plentiful sunshine and warmth; lack of excessive rain during the growing season; fertile, well-drained soils; and the availability of sufficient irrigation water enable production of high-quality, high-yielding alfalfa in many California regions. Water, however, is increasingly a key limiting resource.

Alfalfa as a System

Established alfalfa crops interact in complex ways with other crops, farming activities, and many other organisms in the surrounding ecosystem. Alfalfa's dense canopy and crown structure afford a wide variety of habitats for exploitation by a diverse array of organisms. Alfalfa's deep and extensive root systems create a biologically rich belowground environment. In addition to the symbiotic relationship with *Rhizobium* bacteria that fix atmospheric nitrogen in alfalfa roots, root exudates create a rich rhizosphere and a favorably crumbly soil structure. The vigorous canopy and roots support herbivores of various types, from vertebrates to a wide range of arthropods.

Alfalfa is most often grown in pure stands in California, but sometimes it is grown in mixed culture with various forage grasses. Alfalfa stands in California average 3 to 4 years in longevity, but in some cases stands may remain in production for up to 8 years. Such longevity provides a temporal stability that is uncommon with most agricultural crops and provides ample time for the establishment and development of a diverse community of organisms, including many types of wildlife.

Crop Rotation

Alfalfa is highly valued by farmers for its rotational benefits, including soil improvement and benefits to subsequent crops. Alfalfa is most often grown in rotation with wheat, corn, cotton, sugar beets, and processing tomatoes. Given the diversity of California agriculture, it is common to have individual farms producing walnuts, almonds, or rice on some fields, and tomatoes, cotton, wheat, or corn rotated with alfalfa on others. Growers of vegetable or specialty crops especially value the rotational benefits of alfalfa, since it improves water infiltration and soil fertility and can provide a less weedy environment for subsequent crops.

In the regions surrounding dairy farms, corn silage has increased significantly in recent years, grown in rotation with alfalfa and small grain forage. This is an important fact for alfalfa producers, since corn silage has replaced alfalfa in many dairy rations over the years. The benefits of alfalfa in rotation with corn include its provision of nitrogen to the corn crop; a range of 40 to 120 pounds per acre (45–134 kg ha) N is typically credited to the alfalfa in an alfalfa–corn rotation.

Alfalfa has unique production features in the desert and Mediterranean areas of the West that are distinct from higher rainfall areas. The obvious differences are related to the need for irrigation water, but a range of other factors are also unique to arid production systems, including cutting schedules, stand establishment methods, pest management, and variety selection. Alfalfa is a very adaptable plant and can be grown under a wide range of soil and climatic conditions. Although a wide variety of methods are used to produce alfalfa, the following represents an overview of the typical methods used in many parts of the state.

Soil Types and Site Selection

Alfalfa can be grown on a wide range of soil types, but a key requirement is good internal drainage and lack of subsoil impediments. Soil types chosen vary from sands and sandy loams to clay loams, loamy clays, and deep cracking clays. Alfalfa is frequently produced on heavy soils in California, which is not true of higher-rainfall regions. A key reason is the ability to control water applications, avoiding saturated soil conditions (see Chapter 2, "Choosing Appropriate Sites for Alfalfa Production").

Stand Establishment

To establish an alfalfa crop, growers must first consider subsoil impediments and correct those with deep tillage, if necessary. "Deep ripping" using deep chisel plows or other implements is common. Soil amendments of gypsum or sulfur for salt-affected soils are sometimes used, and fertilizer problems are addressed before planting. Lime is used occasionally, but acid soils are not common. Since check-flood irrigation and other surface irrigation methods are dominant in these regions, land leveling utilizing laser technology is often preferred to assure uniformity of irrigations (Fig. 1.15). Sprinklers are frequently used for stand establishment, followed by flood irrigation during production. Seeding is accomplished utilizing grain drills, broadcast air planters, Brillion seeders, aircraft, or no-till planters. Fall planting, mid-September through mid- to late October, is recommended. Growers can plant in winter or spring in most regions, usually with less success, but rarely in midsummer due to excessive heat. Companion crops are rarely used, and herbicides are usually used to control weeds while young seedlings are developing. Optimization of stand establishment techniques is critical to ensure the long-term success of alfalfa production (see Chapter 4, "Alfalfa Stand Establishment").

FIGURE 1.15

Land leveling during stand establishment.

Varieties

California is unique compared with other regions of the United States in that the full range of fall dormancy (FD) classifications of varieties are utilized. Nondormant varieties (those that grow actively in the winter, FD 8–11) dominate the desert zones, and semidormant to nondormant varieties (FD 4–9) are grown in the Central Valley, whereas dormant varieties (FD 3–4) are grown in the Intermountain north. Growers sometimes choose dormant varieties that yield less but produce higher-quality forage, even in "nondormant" areas. Plant breeders have been successful at developing varieties with a wide range of resistance to diseases, nematodes, and insects—more so than any other agronomic crop (Fig. 1.16). In recent years, genetically engineered Roundup Ready varieties have been introduced. Variety selection is an important component of both profitability and a successful pest management program for alfalfa (see Chapter 5, "Choosing an Alfalfa Variety").

FIGURE 1.16

Variety selection.

Irrigation

One of the most important aspects of alfalfa production in the arid West is the need for irrigation water. Nearly 100 percent of California's alfalfa crop is irrigated, although some dryland alfalfa is produced in coastal and mountain regions. Management of irrigation to match crop needs is often the most yield-limiting factor for California alfalfa production. Alfalfa requires 5 to 6 acre-feet (1550-1800 mm) of water per year in the Imperial Valley, and about 4 acre-feet (1200 mm) per year in the San Joaquin Valley, and 2.5–3.0 acre-feet (760 - 900 mm) in the Intermountain area. However, frequently more water is needed to leach salts and to compensate for irrigation inefficiencies. The majority of water comes from surface-water sources (rivers, streams, canals, and reservoirs), but pumped groundwater is used in some regions. More water is applied to alfalfa in California than to any other crop, accounting for nearly 20 percent of the state's agricultural water use. However, alfalfa is one of the most water-use efficient crops and produces more dry matter per unit of water than many crops. In the Central Valley and Imperial Valley, check-flood surface irrigation is most common, while sprinklers are common in high desert and mountain regions. Sprinklers are commonly used for stand establishment (Fig. 1.17), followed primarily by flood irrigation for forage production (Fig. 1.18). Timing of irrigations is highly influenced by cutting schedules, since the soil must dry for harvests, approximately every 28 days. Growers typically irrigate once, twice, or sometimes three times between harvests in surface-irrigated systems. Alfalfa grown on heavier clay-containing soils is irrigated less frequently but with more water applied per irrigation than alfalfa grown on light-textured, sandy soils (see Chapter 7, "Irrigating Alfalfa in Arid Regions").

FIGURE 1.17

Sprinkler irrigation during establishment.

FIGURE 1.18

Gravity-fed surface flood irrigation is the most commonly used in California.

Insects

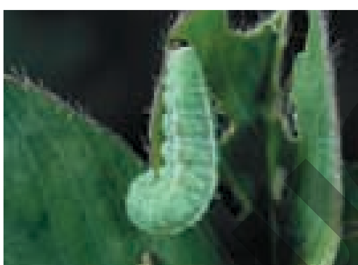
Alfalfa supports an incredible diversity of insects, most of which have little or no impact on the plant itself. Alfalfa has been called an "insectary" since it is home to many predators and beneficial insects (Fig. 1.19) that move among crops and provide biological control of pests in diverse cropping systems as well as in alfalfa itself. For example, while over 1,000 species of arthropods have been identified from alfalfa, fewer than 20 are pests and fewer still are serious pests. These serious pests include the alfalfa weevil in the spring (Fig. 1.20), a complex of caterpillar larvae (alfalfa caterpillar and armyworms) in the warmer months, and a complex of aphids throughout the year. Most growers use pesticides to control these insect pests based on IPM (Integrated Pest Management) principles. Numerous management strategies, including resistant varieties, biological control, chemical control, and cultural control, have been devised to mitigate pest impact on alfalfa yield and quality (see Chapter 9, "Managing Insects in Alfalfa").

FIGURE 1.19

Beneficial insects are common in alfalfa (lady beetle feeding on aphids).

FIGURE 1.20

Alfalfa weevil larvae , a major pest in alfalfa.



Weeds

Weeds have a tremendous effect on forage quality and significantly lower the economic value of alfalfa (Fig. 1.21). Weeds have less effect on yield, and actually sometimes increase yield, but can make the hay unmarketable. Herbicides are frequently used to control weeds during stand establishment, since alfalfa seedlings are slow to develop and susceptible to weed competition. This is the most critical period in which to control weeds. After alfalfa plants are well established and vigorously growing, weed intrusion is less common. It's often said that the best defense against weeds is a vigorous competitive stand of alfalfa. After establishment, herbicides and sometimes grazing are used to control winter annual weeds and summer annual grasses (see Chapter 8, "Weed Management in Alfalfa").

FIGURE 1.21

Chickweed in alfalfa.

Diseases and Nematodes

In California's dry climate, diseases are generally not the most important yield-limiting factor, but several diseases and nematodes can be found. Seedling diseases often kill young seedlings on wet, heavy soils during cold periods. Root diseases can damage or kill established plants. Stem nematode (Fig. 1.22) and root knot nematodes are important pests in several areas of California. Selection of varieties to resist diseases and nematodes is the major control strategy available to growers (see Chapter 10, "Alfalfa Diseases and Management," and Chapter 11, "Parasitic Nematodes in Alfalfa").

FIGURE 1.22

Stem nematode in alfalfa.

Vertebrate Pests

Gophers, ground squirrels, and voles are serious pests (Fig. 1.23) in alfalfa fields in most areas of California. Flood irrigation helps keep gopher populations in check, but numbers can still reach damaging levels under some conditions. Meadow

FIGURE 1.23

Pocket gopher in alfalfa.

voles have cyclic populations that reach damaging levels in some years (see Chapter 12, "Vertebrate Pests").

Cutting Schedules

Cutting frequency has a very important effect on both forage quality and yield; longer cutting schedules result in higher yield and lower quality, while shorter cutting schedules result in lower yields but higher quality. After the first harvest in the spring, and through the long, hot summer, alfalfa is typically harvested every 26 to 28 days to maintain the high quality demanded by the dairy industry. Short cutting schedules reduce stand, vigor, and persistence and favor weed intrusion (see Chapter 13, "Harvest Strategies for Alfalfa").

Harvest Methods

Greater than 98 percent of California's alfalfa is baled as dry hay, not ensiled or grazed. Alfalfa is most frequently harvested with a "swather" (Fig. 1.24), or mower-conditioner, which cuts off the plant and crushes the stems to speed drying. Both sickle-bar and disc-type mowers are used. The hay is placed in windrows, and after a few days is raked to enhance drying. Baling occurs from 3 to 10 days after cutting, depending on time of year, soil type, size of windrow, temperature, and humidity. Bale size ranges from "small," three-tie square bales (80 to 140 pounds [36–64 kg]) to "large," rectangular bales (750-pound [340-kg] to 1-ton [907-kg] bales). The latter has become more popular in recent years due to handling and shipping advantages. Some smaller (60-pound [27 kg]) bales are occasionally used for retail markets for horses. Round bales are rare due to difficulty in transportation. Alfalfa hay is frequently baled at night, since dew is needed for leaf retention. Square bales are collected using a bale wagon, or harrow-bed, which automatically stacks the hay on a platform and deposits the hay on the roadside for loading (Fig. 1.25). A "squeeze" (modified forklift) stacks bales on f atbed trucks for hauling, so that hay is nearly entirely mechanically handled. Hay is usually stored outside for short or long periods, but moved to open-sided barns or tarped for protection from sun and rain (see Chapter 14, "Harvest, Curing and Preservation of Alfalfa").

FIGURE 1.24

Swathing alfalfa.

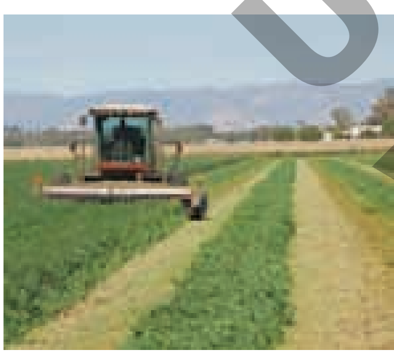


FIGURE 1.25

Alfalfa hay is frequently "roadsided" in the field before movement to dairies (Imperial Valley, CA).

Forage Quality and Markets

Most California alfalfa hay is consumed by dairies. There are intense pressures on growers to produce high-quality hay (low in fiber concentration; high in protein; and free of weeds, molds, or other defects). Alfalfa forage quality, as defined by the USDA Market News, ranges from Supreme and Premium, to Good, Fair, and Utility, or very-low-quality hay. Forage quality is typically defined by the needs of dairies since the vast majority of California's alfalfa crop is consumed by this sector. The value of hay in the marketplace is often defined by total digestible nutrients (TDN), calculated from acid detergent fiber (ADF). However, neutral detergent fiber (NDF) is more commonly used by nutritionists to balance rations, and other analyses may inf uence price, such as crude protein (CP), digestibility, ash, and minerals (DCAD or ion balance). Price differences between high and low categories range from $25 to $80 per ton (907 kg), or as much as half of the value of the hay. A majority of the hay produced for the dairy industry is analyzed by laboratories. (see www.foragetesting.org; also see Chapter 16, "Forage Quality").

Utilization

Alfalfa can be fed fresh as pasture or greenchop, or preserved as hay, silage, or dehydrated meal, pellets, or cubes. Its main use is by livestock. Pure alfalfa is preferred by the dairy industry, whereas grass–alfalfa mixtures (cool season forage grasses) are often favored by horse owners. Alfalfa can be successfully incorporated into dairy, beef, goat, and horse rations, and its combination of energy, good intake, protein, and effective fiber is highly desired by animal nutritionists. Some alfalfa (as well as other hays) is exported from California and other western states, particularly Washington, to Pacific Rim countries, primarily Japan. Alfalfa has been used for human consumption in the form of "alfalfa sprouts," a very minor use of alfalfa seeds, or as health supplements made from the leaves. Industrial uses of alfalfa for production of enzymes, or fractionation of the crop to use the stems as a bioenergy source, are currently being researched (see Chapter 17, "Utilization by Livestock," and Chapter 19, "Industrial Uses").

Economics

Alfalfa must compete economically with higher-value vegetables, orchards, grapes, and tomatoes for acreage and water in California. However, it has maintained its position as the state's highest acreage crop due to its economic value, steady demand, cash-flow characteristics, and rotational benefits. The value of alfalfa has, at times, exceeded $1 billion per year in California (Fig. 1.26). Unlike crops such as wheat, corn, rice, and cotton, alfalfa receives no government price support but has held its own economically in the most competitive and dynamic agricultural region in the United States. Alfalfa production entails lower investment and lower economic and biological risk of crop failure than many specialty crops. It provides reliable income and profit potential and enjoys consistent demand. Alfalfa has favorable cash-flow characteristics, since it provides early income potential in spring and a steady return after each harvest over the summer, unlike annual crops which produce one income in the fall. Many growers keep alfalfa in the crop rotation mix primarily due to its benefits to the following crops and a steady cash flow. Cost studies have been published for alfalfa (http://alfalfa.ucdavis.edu); also see Chapter 23, "Alfalfa Marketing and Economics."

FIGURE 1.26

California alfalfa is frequently transported long distances.

Organic Alfalfa

This sector constitutes less than about one-half percent of production but is growing due to increased conversion by some dairies to organic milk. Alfalfa is often used to transition to organic production of other crops due to its soil benefits, and is highly beneficial to organic vegetable and fruit producers. Weed and insect management and maintenance of soil fertility are key limiting issues for organic alfalfa producers (See Chapter 21, "Producing Alfalfa Hay Organically").

Seed Production

California continues to be the leading alfalfa seed producing state in the United States. Although seed acreage has diminished in recent years to less than 30,000 acres (12,000 ha), it remains important in Fresno and Imperial Counties. Alfalfa seed production is a specialized process, requiring different irrigation and pest management skills. Growers produce seed from fields specifically designated as seed fields using wide rows on beds. Seed is also produced from hay production fields where the growers produce hay during spring and allow the plant to set seed later in the summer. Irrigation must be carefully controlled to stress the plants to encourage flowering and seed production. Alfalfa is a cross-pollinated crop that requires pollinators for successful seed production, and alfalfa honey is an important by-product of seed production (see Chapter 22, "Alfalfa Seed Production").

Alfalfa and the Environment

Alfalfa is well known for its ability to improve soil conditions and to provide important wildlife habitat and environmental benefits. The deep roots of alfalfa help mitigate environmental problems by taking up nitrates from the soil, preventing contamination of groundwater. Alfalfa protects the soil from water and wind erosion with its vigorous canopy, rooting system, and lack of tillage for multiple years. Alfalfa is important for wildlife in agricultural systems. It is estimated that of 675 wildlife species inhabiting California, 25 percent of them use alfalfa for feeding, reproduction, or cover (Fig. 1.27).

FIGURE 1.27

Blue heron in alfalfa.

Potential negative effects of alfalfa on the environment include its high water use and potential effects on water quality, specifically off-site movement of organophosphate pesticides. Efforts to improve irrigation efficiency are ongoing, and methods to prevent off-site movement of pesticides have been identified.

Alfalfa's role in protecting the soil, reducing the energy costs of agriculture, N_2 fixation from biological sources, mitigating dust contamination of the air, absorbing nitrates from the soil, and providing wildlife habitat are features of interest to those interested in sustaining the agricultural landscape (see Putnam et al. 2001. Alfalfa, Wildlife and the Environment).

The Future of Alfalfa

Some have predicted the demise of alfalfa in California due to water restrictions, urbanization, and the rise in the importance of orchards, vineyards, and specialty crops. While these factors are real and important in restricting the alfalfa acreage in California, the high productivity, wide adaptation, rotation benefits, and strong demand for this crop suggest that alfalfa has an important role in the state, now and for the future.

FIGURE 1.28

Central Valley of California.

The increased demand for forage crops due to the dairy and livestock sectors has tended to counteract the trends of urban sprawl, water restrictions, and conversion to higher-value crops. Therefore, acreage has remained almost constant over the past 20 to 30 years (Fig. 1.28). This will likely continue, at least for the immediate future. The future of alfalfa in California is tied to several important factors, including water transfers, to the fate of the dairy industry, other livestock demands, and competitive crops.

Dairy Industry

Probably the most important of these is the fate of the dairy industry (Fig. 1.29). The phenomenal growth rate in dairy cow numbers in California will not continue forever. Environmental and regulatory restrictions, economics, and urbanization will eventually curtail the growth in cow numbers, but California dairying has proved to be a resilient industry, with some of the lowest costs of production in the nation. Thus, it is likely that

FIGURE 1.29

Dairies are the most important consumers of alfalfa.

California will remain the leading dairy state for the coming few decades. Although the beef cattle industry in California has been declining slowly for decades, the number of horses has steadily increased. The market for alfalfa and other forages for horses has become more important in recent years and it is anticipated that demand will continue to be high in the future.

One important trend is the replacement of alfalfa in dairy rations with corn silage, cereal forages, and cheap by-products such as distiller grains (from ethanol production), and cottonseed. The amount of alfalfa produced in the state per dairy animal has fallen from about 40 pounds per animal per day (18 kg) in the 1960s to about 20 pounds per animal per day (9 kg) today. This indicates a replacement of alfalfa in dairy rations by other ingredients. Corn silage has risen from a minor acreage crop to over 400,000 acres (162,000 ha) in 2005. The role of alfalfa in dairy rations is likely to be continually challenged in future years.

Horses

A major trend in the United States has been the increase in the number of recreational horses, which have become major consumers of both alfalfa hay and other hay products. As populations increase in the urban West, this trend is likely to intensify, creating new markets for alfalfa that are distinct from the dairy markets.

Crop Competition and Urban Sprawl

The Central Valley, where over 70 percent of California's alfalfa is produced, is one of the most rapidly urbanizing regions of the United States (Fig. 1.30). Population rates have grown from 25 to 50 percent per decade in some areas. Urban sprawl competes with agriculture for both land and water, and transfers of water are one of the primary mechanisms of urbanization. This trend in urbanization of the Central Valley is of considerable concern to those interested in sustaining agriculture for future generations. Growers will likely continue to convert acreage from crops such as alfalfa, cotton, and wheat to perennial orchards or grapes and, ultimately, to housing. This will have the effect of moving alfalfa to more marginal soils and utilizing more saline waters or wastewaters in the future.

FIGURE 1.30

Urban growth in the Central Valley.

Water and Water Transfers

Limitation of water supplies is undoubtedly the most important single issue that will impact the viability of alfalfa grown in California in the future (Fig. 1.31). In drought years, competition for water becomes especially acute, and there is little doubt that urban or environmental demands for developed water will intensify. There is also little doubt that these demands will be satisfied through transfers from agriculture, which consumes nearly 80 percent of the developed water in the state. Forage crops and annual agronomic row crops (e.g., cotton, corn) are particularly vulnerable.

California's water management policies are evolving toward a more "market-driven" water exchange system. This may enable water users to transfer water from one crop to another, or from one use to another, on a temporary basis. Alfalfa is very drought tolerant and can survive temporary droughts. Current research on deficit irritation of alfalfa may provide the basis for the feasibility of water transfers from alfalfa fields during drought periods while maintaining forage production in a water-limited future. However, it is clear that water issues will remain the most important limitation for alfalfa.

FIGURE 1.31

Water supply and quality are critical issues.

Genetic Engineering

Genetic modification of alfalfa through biotechnology, as well as traditional plant breeding, will be important in future years. The introduction of Roundup Ready alfalfa in 2005 created the first genetically modified alfalfa product. Efforts to introduce high-quality traits for more efficient fiber and protein use are ongoing and could result in significant innovation in alfalfa varieties and utilization in coming years. Genes for drought tolerance, salt tolerance, pest resistance, and yield and quality characteristics are being researched. This could result in plants that require less water and fewer pesticides, and which could be grown on poorer soils or with wastewater. However, concerns about gene transfer to organic crops or crops grown for GE-sensitive markets, and the potential for weed resistance to herbicides, may limit public market acceptance and the use of genetic engineering in alfalfa as it has in other crops.

Energy Crops and Industrial Uses

Although livestock production, particularly dairy, is likely to remain the most important use for alfalfa, industrial and energy uses for alfalfa in future years are currently under investigation. Alfalfa's productivity makes it also suitable to the production of specialty compounds, such as enzymes in the leaves, but these concepts require further research and face regulatory impediments. Alfalfa is a good candidate as an energy crop, due to its rotational benefits and its lack of need for nitrogen fertilizers, which require fossil fuels. The fractionation of alfalfa into a higher-quality leafy portion for high-quality animal feed and a lower-quality stem portion suitable for biofuels has been proposed. The development of other energy crops (e.g., corn, switchgrass) may also have profound effects on alfalfa due to competition of fermentation by-products and competition for acreage.

Environmental Services

The role of alfalfa in providing a wide range of environmental services may be increasingly recognized. Alfalfa's role in absorbing wastewater from municipalities and animal facilities is likely to become more important in future years. Forages are uniquely qualified for this role, since there are fewer risks when wastes are applied to forages, as compared with food crops. It is possible that alfalfa's role in providing a wide range of environmental benefits, from mitigation of groundwater pollution to improvement of air and water quality and provision of open spaces and wildlife habitat, may become as important as economic factors in determining acreage in the future.

It is clear from this discussion that although alfalfa has some important challenges, it has many characteristics that will enable this crop to remain a vital component of California agricultural systems in the future.

Additional Reading

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