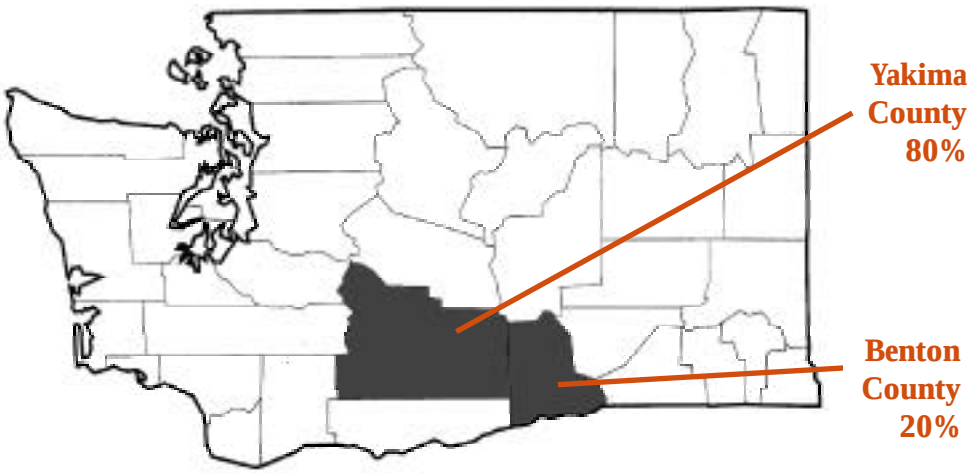
Crop Profile for Hops in Washington

Production Facts

- Washington ranks first in the U.S. in the production of hops.
- Washington accounts for 77% of U.S. hop production and 25% of world hop production.
- Total statewide production and value in 2000 – 52,260,000 pounds, for a total of $95,113,200 farm gate value.
- The cost of establishing a hop yard averages $4,300/acre. Hop production costs for an established yard range from $3,900 to $4,220/acre.
- In 2001, 26,185 acres were in production, with a total U.S. acreage of 35,707.
- Yield per acre was 1,937 lbs. in 2000. More than 60% of the crop is exported to overseas markets.
- Over 90% of the crop is generally contracted at the time of harvest. Some contracts prohibit the use of certain pesticides on the contracted crop, in order to meet the requirements of specific brewing industry customers or to comply with the import tolerance requirements of importing countries.

Production Regions

In Washington, hops are produced in Yakima (80%) and Benton (20%) counties where summers are characterized as hot and dry.



General Information

Dried hop cones are used as flavor components in the brewing of beers and ales. Hop plants are either male or female, producing annual climbing stems from a perennial crown and rootstock. The stem grows in a clockwise direction around its support (as it follows the sun) and may reach a total height of 25 feet or more in a single growing season. The stem dies back to the crown after the hop cones mature.

Hop cones on the vine

The commercial hop is a female plant with flowers that appear as burrs on the side arms that develop along the stem. Each burr eventually develops into a hop cone. Male plants do not produce hop cones, only pollen which causes seeds to be produced in the cones. Hops are vegetatively propagated, with new yards established by planting rhizomes, or potted plants started in a greenhouse from softwood cuttings.

The mature hop cone contains numerous lupulin glands, appearing as a yellow pollen-like substance inside the cone. The individual lupulin gland is a yellow resin gland containing the important brewing constituents of alpha-acids, beta-acids, and essential oils. The amounts and percentages of total composition of these compounds vary between varieties.

Cultural Practices

Initial establishment of a hop yard requires a substantial capital investment for planting rootstock and building a trellis. The trellis is 18 feet high, consisting of some 55 poles per acre connected by heavy wire and cables. Cement anchors buried five feet deep surround the yard and hold the trellis upright under the heavy weight of the crop that develops late in the season. Hops are normally planted on a 3.5' x 14' or 7' x 7' spacing, although variations are sometimes used. Once established, the hop rootstock will produce indefinitely although industry practice is to rotate plantings every 10-15 years. Timing is influenced by disease and pests that cause yields to decline, or different varieties coming into demand.

Pruning is an annual spring cultural practice that holds back the vigorous new annual growth, either mechanically or chemically, until the proper training date for that variety. Mechanical pruning,

Trellised hop plants

using tractor-drawn equipment with spinning steel "fingers," begins in late March and removes debris from the prior season, leaving a clean surface from which the new shoots will arise. Herbicides are important to the industry, for desiccation of hop suckers and excess foliage and controlling various annual and perennial grasses and broadleaf weeds.

In early April the twining process begins, as seven-man crews using tractor-drawn elevated platforms tie the twine (either coir twine made from coconut husks or paper twine) to overhead trellis wires and secure the lower end of the twine into the hill with small metal clips.

Training is the practice of wrapping the hop shoot in a clockwise direction around the twine. Training begins in early May and should be completed before the end of May. The training time is one of the most critical factors in determining yield, due to the relationship between plant height and day length, which affects flowering.

Irrigation of hop fields begins in the latter part of May or early June, depending on weather and growing area. The hop field will require approximately 30 inches of water during a normal growing season. Various methods of irrigation are utilized, including rill (furrow), sprinkler and drip. In Washington most irrigation is by drip method, which is rapidly replacing rill irrigation in order to improve water quality and to allow more timely ground application of pesticides and foliar feeds (the surface of the ground between the rows remains dry).

In rill irrigated hop yards, cultivation occurs four to six times during the season to keep weeds under control, and mechanically maintain hill size. Drip irrigated hop yards are generally cultivated fewer times per season, and some growers are converting to minimum or no-till systems utilizing heavy applications of mulch material to conserve moisture and discourage weed growth. The presence of weeds makes the desiccation of basal hop growth difficult, as good penetration and contact is necessary to remove hop suckers and lower leaves from the plant. Control of this basal hop growth is critical to the control of hop powdery mildew, as the soft, young hop leaf tissue on hop suckers provides a perfect environment for the establishment of disease colonies and production of inoculum that causes cone infection. Weeds in hop yards can also reduce yields, interfere with irrigation, serve as hosts for insects and plant pathogens, and impede harvest.

The annual harvest begins in late August, and progresses through early October. Each variety reaches peak maturity at a different time. Harvest begins in the field as the hop vines are cut at the ground and at the overhead support wires using mechanical top cutting and bottom cutting equipment, and fall into a trailer or truck bed. The vines are transported to stationary picking machines that are capable of picking 8 acres in a single 10-12 hour shift or 15 acres if picking runs round the clock. Most U.S. hop growing operations have one picking machine for each 250-300 acres of hops.

Machines clean hops of debris

The vines are hung upside down on hooks and carried into the picking machine, where hops and leaves are mechanically stripped from the vines and sent through a series of cleaning devices to remove leaves and other debris.

The stripped vines and other debris are chopped and spread back onto the fields. This activity has not resulted in disease

buildup since downy mildew is an obligate parasite and cannot survive on dead tissue. However, with the introduction of hop powdery mildew into Pacific Northwest hop growing regions, growers are concerned that this practice may need to be changed if cleistothecia (spores from sexual reproduction between two different mating types) become widespread in the future, as cleistothecia can exist on dead plant debris.

Cleaned cones are transported by conveyor belt to the hop kilns. Kiln floors are each approximately 32' x 32', and hold some 15,000 pounds of hop cones. Cones are mechanically spread to a depth of about 32 inches. Once the kiln is filled, drying occurs when oil or gas burners are fired and hot air (140°F) is forced indirectly through the bed of green hops. The drying process requires about 9 hours, reducing the hops to 30% of the green weight, with 8-9% moisture content. Hops are removed from the kiln floor and cooled for at least 24 hours. After cooling, the hops are compressed into 200-pound bales and wrapped in burlap, subjected to quality inspection, and transported to cold storage warehouses.

IPM Programs

The hop industry received an EPA PESP grant in 1999 to help lay the foundation for an industry-wide IPM program.

Resistance Management Strategies

The hop industry is actively pursuing a minimum of three alternate chemistries for each major pest and disease of hops for the purpose of resistance management. Currently registered hop pesticides offer inadequate alternatives for acceptable resistance management, which is seriously eroding the efficacy of these products.

Insect Pests

Two-spotted spider mite and hop aphid are the two most immediate and threatening pests. The majority of efforts to control non-disease hop pests are targeted at these two species, and 100% of the commercial hop acreage is treated with insecticides for these two pests.

Spider Mites

Tetranychus urticae Koch

The two-spotted spider mite (TSSM) is the most important pest of Washington hops. Spider mites puncture leaf tissue and destroy leaf cells while sucking the plant juices. Heavy infestations cause leaves to turn brown and die, lowering yields and weakening plants. The mites spin copious amounts of webbing on the undersurface of leaves and may encase cones, hindering their development. Once heavily webbed, chemical control is difficult. Mites also feed on and damage cones, resulting in reddish-brown discoloration which brewers find unacceptable. Mite damage to cones substantially reduces yield and alpha acid content. TSSM is favored by hot, dry weather conditions and left uncontrolled may cause 100% loss of

Hop plant showing mite damage

crop. During the 1998 season some growers experienced a 60% reduction in yield due to TSSM injury. Complicating factors were heat stress of plants and limitations imposed on use of acaricides. These include a limited number of available applications for the season and long preharvest intervals. After using the maximum number of allowable applications for registered products and inside the preharvest interval, growers could do nothing but watch their crop be destroyed or harvest the crop early, sacrificing yield and quality. Overall, Washington production was down an average of 10% in 1998 due to TSSM attack.

Monitoring

All miticide sprays are scheduled based on scouts monitoring TSSM populations. Various sampling schemes have been developed to serve different purposes. Economic thresholds shift with the season,

Without control of these pests, there would be 100% crop loss.

Chemical Control

Hexythiazox (Savey 50WP, 4-6 oz/A). This ovidice was registered in 1999, and works well when application is properly timed. One application per season is allowed prior to adult mite buildup, up to burr formation in hop vines.

Abamectin (Agri-Mek 0.15EC, 16 fl oz./A). 28 day PHI. This product is the industry's primary miticide, with nearly 100% of the acres treated. Overuse has resulted in 100x resistance development since use began in 1989.

Propargite (Omite-CR, Omite 30WS). 14 day PHI. Rates of 1.5-2.25 lbs. AI/A for Omite-CR (24c, WA-940007), or 1.5 lbs. AI/A for Omite 30WS. Omite was first registered on hops in 1971. Resistance has been implicated but not documented. Approximately 20% of the acreage is treated on a regular basis.

Dicofol (Kelthane MF, 1.0 - 1.25 lbs. AI/A). 7 day PHI. Used extensively in the late 1950s until the late 1960s when mites developed high levels of resistance. It is now of limited importance. In recent years, researchers suggested reserving use of this compound only for phytosensitive varieties with one application/season spaced three years apart. Certain customers prohibit the use of Kelthane on crop destined for their breweries.

New registrations for bifenazate (Acramite-50WS, 01-WA-24) and fenpyroximate (FujiMite 5SC, 01-WA-25) are being pursued. Both compounds were granted Section 18 Emergency Exemptions in 2001 (Washington and Idaho).

Hop Aphid

Phorodon humuli

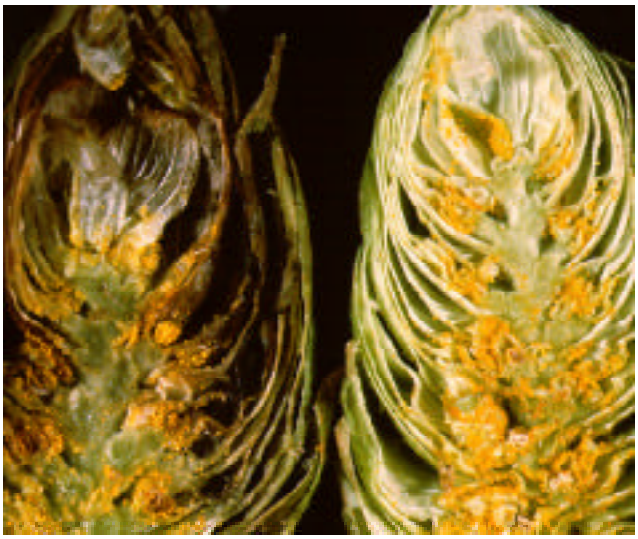
Aphids feed directly on hop plants, extracting cell sap. High populations reduce yields and seriously weaken plants. Aphids may also enter and feed upon the cones, making control efforts with contact insecticides difficult.

Monitoring

All insecticide sprays are scheduled based on scouts monitoring aphid abundance (leaf counts of less than 10 aphids/leaf). Sampling schemes have been devised, but industry-wide firm economic thresholds have been difficult to establish. Growers using drip irrigation may set thresholds slightly higher than growers using rill irrigation, as spray timing in drip irrigated yards is not complicated by coordination of spray and irrigation schedules. The two goals, preventing economic loss at bloom and preventing aphids entering cones late in the season, have different thresholds.

Hop aphids excrete abundant amounts of honeydew, or plant cell sap, composed of sugars passed through the aphid's digestive system. Sooty mold grows on this honeydew and can destroy a crop's value, as mold renders hop cones unacceptable for brewing. Since there is no alternative market for moldy hops, they must be destroyed.

Most hop acreage in Washington is treated one or two times per season although in bad aphid years some yards may be sprayed more often. The average is approximately 1.5 times for the entire acreage. Without control, 100% of the hop acreage would be lost to these pests.



Cross-section of hop cones with sooty mold (left) and without (right). Moldy cones are unmarketable.

Chemical control

Imidacloprid (Foliar application of Provado 1.6 F at 8 fl oz product/A with a 14 day PHI, or systemic application of Admire 2 Flowable at 6.4-12.8 fl oz product/A with a 60 day PHI). This product is the most important aphicide to the industry due to its high level of efficacy, although foliar application causes adverse impact on mite predator populations. A 24(c) registration to apply Admire through drip irrigation systems and as a shanked-in soil application was approved in 2001. Such application methods favor conservation of beneficial organisms. Percent acreage treated is about 100%.

Diazinon (various trade names, 1 lb. AI/A). 14 day PHI. The product is used as an early season aphid control and is important as a rotation partner to prevent resistance development to imidacloprid. It has limited residual activity, which makes it less valuable than imidacloprid, although still a very important insecticide to the industry. Acreage treated about 10%.

Bifenthrin (Brigade, 0.06-0.1 lbs. AI/A). 14 day PHI. An effective compound used to treat about 50% of the acreage. While it also kills some adult mites, it causes spikes in mite populations later in the season. It has great value to the industry as a rescue treatment for lepidopteran pests.

Malathion (various trade names, 1.25 lb. AI/A). 10 day PHI. Registered for approximately 40 years but efficacy is poor and no acreage is treated.

New registrations for **pymetrozine, pirimicarb,** and **triazamate** are pending at EPA. These new chemistries are extremely important for resistance management.

Other Insect Pests

Prionus beetle
Spotted Cutworm, *Amathes c-nigrum*
Redback Cutworm, *Euxoa ochrogaster*
Hop Looper, *Hypena humuli*
Bertha armyworm, *Momestra configurata*
Corn earworm, *Heliothis zea*

These insect pests can cause serious damage at certain stages of growth, but outbreaks tend to be less widespread than those seen with mites and aphids.

The *Prionus* beetle life cycle requires four years for completion. Large larvae live in the hop crown. The extensive damage to the crown results in reduced plant vigor within 5 years. Infested acreage in Washington is limited and is primarily located near coniferous forests that are the primary host of this beetle. In yards with infestations beetles can chew holes in 15 mm. subsurface drip tubing, causing leaks. The economic impact of this pest has been difficult to measure. There is no registered control except pulling the rootstock and fumigating the yard. Beetles and larvae that reside next to the trellis-support poles during fumigation will re-infest the yard after replanting.

Spotted cutworm and redback cutworm are pests of early season crown growth. They are usually not a problem unless a heavy infestation feeds on newly trained vines. Bifenthrin is the only registered compound that is effective but it usually is not economically feasible.

Hop looper is a summer defoliator. Damage is usually confined to the lower portion of the vine. Chemical control can be obtained with *Bt* products if used very early in the life cycle. However, more advanced populations must be controlled with bifenthrin, which can impact predator populations.

Bertha armyworm and corn earworm are pests at harvest. Eggs are laid on pigweed or lambsquarter weeds in the hop yard. Every three to four years, populations reach levels causing severe damage (30%). They defoliate the weeds and move up into hops, chewing on the stems and causing cones to fall on the ground. Bifenthrin allows effective control if the problem is recognized at least 14 days prior to harvest, although beneficial insect populations may be adversely affected.

Chemical Controls

Bifenthrin (Brigade, 0.06-0.1 lbs. AI/A). 14 day PHI. It has great value to the industry as a rescue treatment for lepidopteran pests.

Bacillus thuringiensis var. kurstaki (Dipel, Javelin, 0.5 to 1 lbs. product/A). 0 day PHI. The material must be ingested by the worms to be effective. Approximately 1% of the acreage is treated.

Diseases

Downy Mildew

Downy mildew is a serious threat to profitable hop production. Direct losses result from reduced yields, infected and shattered cones, and crown die-out. Certain hop varieties are more susceptible to the disease, and Oregon growers must deal with annual outbreaks, due to their moist climate. The fungus overwinters in infected hop crowns and first appears in the spring as an infected shoot, commonly known as a primary "spike." The spike has pale green or light yellow, slightly downward-cupped leaves, and shortened internodes. The under surface of the leaves becomes blackened with spores, which spread the disease to other shoots, causing lesions to develop on the leaves. Secondary spikes are formed from these shoots.

Formation of a spike will stop the growth of the infected shoot and reduce or eliminate flowering and cone production. If an outbreak of downy mildew occurs in late June or early July when hop plants are in full bloom, many of the flowers will become infected and die, causing no cones to develop. If infection occurs later in cone development, the result will be death of a portion of the cone. The dead portion becomes blackened and is unacceptable to brewers. Crown infection with downy mildew in certain varieties results in crown death during the winter. Fungicides are utilized on an "as needed" basis to control this disease.

Without control: Susceptible varieties will experience substantial yield loss and crown die-out, necessitating replanting (100% loss).

Chemical Controls

Metalaxyl/Mefenoxam (Ridomil Gold, 0.25lbs. AI/A). 45 day PHI. Used as a tank mix with copper compounds (2 lbs. Kocide 101) for resistance management. Resistance has been documented in Washington hops. One treatment per year is applied on an estimated 50% of the total acreage.

Fosetyl-al (Aliette WSP, 2 lbs. AI/A). 24 day PHI. This fungicide is also effective against downy mildew, and is alternated with copper sprays for resistance management.

Powdery Mildew

Powdery mildew is a serious disease in hops in many hop growing areas of the world. The pathogen was largely responsible for eliminating commercial hop production in New York during the early part of this century. Prior to 1997, powdery mildew had not been observed in the Pacific Northwest. The Washington hop industry has attempted to protect their growing region from introduction of this pathogen through the use of state hop quarantine laws. As the pathogen was not present, no fungicides were registered to control it.

Hop powdery mildew was first observed in 1997. Now that the pathogen is established, it requires aggressive annual prevention efforts, including both cultural practices and preventative fungicide applications.

Without control: 100% loss on susceptible varieties; it is expected that varieties currently exhibiting resistance to the pathogen may eventually become highly susceptible due to genetic adaptation of the pathogen to overcome the plant's genetic resistance.

Chemical Controls

Sulfur is used on 80% of the acreage, as its use is restricted by certain contracts due to brewer concerns about its effect on beer quality.

Trifloxystrobin (Flint, 1-4 oz product/A, 14 day PHI) was registered for use on hops in 2001, following two years of use under Section 18.

In 2001, Section 18s were granted for two protectant fungicides, **myclobutanil** (Rally 40W, 01-WA-14) and **tebuconazole** (Folicur 3.6F, 01-WA-15). While these products provide good protection, reapplication is necessary at 7 to 14 day intervals to insure coverage of new growth, resulting in a program that is not economically sustainable. The industry lacks an eradicant fungicide to kill established infection.

Considerable research is being conducted on cultural practices that can assist in the prevention of this disease, including control of basal growth (suckers) on hop plants. Effective desiccants are required for season-long control of this basal sucker growth, which creates substantial disease pressure and continues to reinfect upper leaves and cones. A Section 18 was granted for Carfentrazone-ethyl (Aim) desiccant in 2001, to allow growers to better control basal sucker growth.

Biological Controls

Kaligreen and Armicarb (potassium bicarbonate) and several crop oils are registered for hops and provide some assistance as tank-mix partners with protectant fungicides.

Serenade *(Bacillus subtilis)* was registered for hops in mid-2000. Research is underway to assess efficacy and determine how to cost-effectively integrate this product into the season-long powdery mildew control effort.

Other diseases include *Verticillium* wilt, and crown and root rot caused by downy mildew or *Phytophthora spp*. The primary viral disease in hops is Prunus Necrotic Ringspot Virus (PNRV), which is spread through propagation material and plant-to-plant contact. The U.S. hop industry promotes the use of virus-free rootstock by growers and regular replanting of hop yards to avoid viral problems. Nematodes are not an economic concern at this time.

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Weeds

Few herbicides are available for hops, and weed control has historically been done by cultivation, which can exacerbate water quality problems in return flows. Less than 30% of Washington hop acreage is rill (furrow) irrigated. Growers are rapidly converting to drip irrigation to improve water quality. However, the cost of drip conversion necessitates the utilization of a 3.5' x 14' plant spacing instead of the traditional 7' x 7' spacing, as only half the amount of drip tubing is necessary to cover the acreage. With 3.5' x 14' plant spacing, growers are unable to cross-cultivate, which exacerbates weed problems within the row.

Research and registration efforts are underway for several new herbicides for grass and broadleaf weed control. Inadequate herbicides are currently available for weed control and desiccation (chemical pruning and sucker control).

Desiccants are very important tools for the hop industry, as early season growth must be burned back for several weeks prior to optimum training dates for the specific hop variety. Desiccation is also important for the prevention of downy mildew through spike removal, and is essential to remove hop suckers for the control of powdery mildew. From late June through harvest, the lower leaves and basal sucker growth need to be removed from hop vines in order to improve airflow through the hop yard, and to control diseases and pests.

Without control: losses will vary by variety.

Chemical Controls

Carfentrazone-ethyl (Aim, 1.2 oz product per treated acre, 7 day PHI) (01-WA-16) was granted a Section 18 in 2001 for hop desiccation (sucker control) to assist in the control of hop powdery mildew.

Paraquat (Gramoxone Extra, 0.47 - 0.78 lbs. AI/A). (24c,WA-930014). 14 days PHI. Used for chemical pruning on hops. Marginally effective when used alone and temperatures are below 75°F. Approximately 100% of the acreage is treated.

Endothall (Des-I-Cate, 0.5-1.0 lbs. AI/A). (24c, WA-870011). 28 days PHI. A desiccant used for chemical pruning. It does not have any weed control activity. Growers generally tank-mix endothall and paraquat to enhance the activity of both products. Temperatures of at least 75°F are needed for acceptable desiccation. Approximately 100% of the acreage is treated.

Norflurazon (Solicam DF, 2.0-4.0 lbs. AI/A) (24c, WA-900032). Controls grasses and some broadleaf weeds in established hops. Apply in the fall or within one week after stringing in the spring. Approximately 20% of the acres are treated.

Trifluralin (Treflan HTP, TR-10, EC and 5 formulations, 0.5-0.75 lbs. AI/A) A dormant application. Controls grasses, but has to be soil incorporated which restricts weed control to cultivated areas. Weed control within the crown is not possible using trifluralin, as foliar spray results in damage to the hop crown in the following year. Less than 5% of the acreage is treated.

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WASHINGTON STATE UNIVERSITY

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Use pesticides with care. Apply them only to plants, animals, or sites listed on the label. When mixing and applying pesticides, follow all label precautions to protect yourself and others around you. It is a violation of the law to disregard label directions. If pesticides are spilled on skin or clothing, remove clothing and wash skin thoroughly. Store pesticides in their original containers and keep them out of the reach of children, pets, and livestock.

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