



Small Scale & Organic Hops Production

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Introduction: The project

The Hops Project started because I wanted desperately to grow hops. Before we moved to our farm, my partner, an avid homebrewer with a penchant for putting anything I grew into his brew kettle, had finally convinced me to buy a hops seedling. We planted it against the 8' cedar fence around our (then) urban garden, with a little string for it to cling to. While I was pleased with the way it claimed its little patch of soil, I was not yet inspired. That happened later in the summer, as I happily spent an afternoon weeding my herbs and vegetables. I noted that, when I was at the beginning of one row, the tip of the hops plant had just reached a knot in the fence. By the time I had finished my row that afternoon, the plant had grown a full foot past the knot: I measured. I was entranced - and somewhat nervous! This must have been the plant that inspired John Wyndham's famous novel *The Day of the Triffids*. I decided that these amazing plants deserved a home with me, wherever I went. Since then, I have discovered that hops are a bit like orchids - not in the beauty of their flowers, but in the obsessions they create amongst growers.

Once we started Left Fields, growing hops became an integral part of our farm and brewery. However, it soon became clear that there was no information out there intended for growers like us – small-scale, organic, and low-input. All the material seemed to be written for large producers, or home growers of only one or two plants. While entertaining, the latter had little in-depth agronomic information, and were useless on the subject of drying and packaging. The former tended to make use of very expensive machinery and buildings, and were high-input and conventional in nature. We were left to figure out small-scale trellising and drying on our own. Fortunately, the hops grew well despite our ignorance, and starting with clean ground gave us a pest-and-disease-free start. Four years on, we have learned a lot, we are propagating hops at a great rate, and breaking ground for a new hopyard.

We have also discovered a huge potential market, as interest in organic brewing grows exponentially along with the rest of the organic market. Microbreweries of all sorts, organic and not, are springing up all over British Columbia, indeed, all over Canada. Public interest in the source of food (which includes beverages) has meant a real growth in small-scale agriculture marketing direct to the consumer right across Canada. Both wineries and breweries have been taking advantage of this market niche alongside organic and other small-scale growers, participating in agri-tourism, farmers' markets and community markets. The distinctiveness of hops, along with its interesting history in BC, means that not only is there a specialized market waiting to be filled, there is also a huge potential for agri-tourism on hops farms.

Investment Agriculture Foundation's support has made it possible to share what we have learned with other growers through this manual.

Although I find hops fascinating in themselves, the fact is that their chief purpose in life is to give flavour and aroma to beer. The stress in this manual, therefore, is on the characteristics of hops as they are used in brewing. While not strictly agronomic, the makeup of the hop, its oils and acids, are critical to the function they serve for the customer. Any grower of hops must be very familiar with the uses of hops and the desired acid and oil profiles for any given variety – for these are what make the sale. A low-acid bittering hop will simply not be marketable, for example. It also makes it possible to understand the quality of hops as determined by testing labs – and these are the reports the brewer will look at to decide on what to purchase.



Brewers Gold: Hops History in BC

By Greg Evans

The 135 year story of commercial hop growing in our province begins in 1862 when Thomas and Marietta Lee planted an experimental crop in Victoria to supply the city's pioneer brewers. It was their successful initiative that inspired others, such as Isaac Cloake and William Towner, to plant several acres of hops on their North Saanich farms in response to a keen desire by local brewers for self-sufficiency in brewing materials. Economics also played a vital part in this decision as the cost of importing hops into Victoria from San Francisco had become punitive by the mid-1860's. By the 1880's, North Saanich hop growers were producing enough hops to satisfy the needs of local brewers. So good was the yield that they were able to supply foreign brewers as well, who were faced with crop failures in their countries. Profits were good and the future for BC hops looked bright. Such optimism soon spurred a "hop craze" in other parts of the province.

By the 1890's, hops were under cultivation in Squamish, Vernon, Kelowna and around Chilliwack in the Fraser Valley, the latter becoming in time Canada's largest single hop growing area (and at one time, the largest hop-growing area in the Commonwealth). The boom, however, was short-lived. By the onset of World War I, commercial hop production had ceased everywhere except in the Fraser Valley. A number of factors led to the demise. On the Saanich Peninsula, the inability to effectively fight a massive infestation of hop louse was the primary reason for the industry's collapse. In Squamish and Vernon, the fall of international markets led to the hop fields being abandoned in favour of other, less externally-dependent agricultural activities. However, hop cultivation in the rich alluvial soil of the Fraser Valley continued to grow and reached its zenith during the late 1940s, with close to 2,000 acres in production and 4,000 people employed for the annual picking season. A number of varieties were grown throughout history of BC hops, in particular Brewers Gold, Fuggles, Cluster, Nugget, Bramling, Mt. Hood, Hallertau and Willamette. Many of these varieties are staples for contemporary hopyards all over North America.

The Valley industry was augmented in 1936 by hops planted by Harry Ord near Kamloops, where the dry climate initially gave good results. In the early 1950's, Lillooet and Creston joined in as hop producing communities but their success was short-lived due mainly to a variety of climatic and economic factors. This decade also witnessed the onset of mechanization and with it a dramatic decline in the need for human labour. One mechanical picking machine could replace 200 people. Declining, too, was the actual size of the industry, which now had to face the competition of the massive hop production of the Yakima and Willamette Valleys, in Washington and Oregon respectively. By 1973, production had ceased in Kamloops and slowly but surely the names once synonymous with Fraser Valley hop production, like the Henry Hulbert Hop Company and the BC Hop Company, faded from the landscape. The end truly came in 1997 when the John I. Haas Hop Company at Sardis harvested its last crop. It was not just the companies that faded from the landscape. Gone too were the people who made the annual trek to pick hops.

During August and September, the prime picking season, the hop industry demonstrated the cultural mosaic of Canadian society, employing Mennonites, Chinese, Japanese, Euro-Canadians and First Nations people. The annual picking season was arguably the most important to First Nations families, often referred to as the backbone of the industry. This was a time to see distant friends, share histories, trade, arrange marriages or play *slahal* – the 'bone game' which tested the mental and spiritual powers of players. In previous generations, these social needs were met by the potlatch cycles. In 1884, however, potlatching was banned by the federal government. The annual gatherings at the hop fields substituted, somewhat inadequately, for this important institution. Important aspects of aboriginal cultures could be maintained. Working on the hops farms not only provided an important opportunity to gather but also offered a chance to earn cash in a rapidly changing economic world. Tasks were divided by sex and age: women and children normally picked the hops, placing them in a basket or sack, with the very best pickers accounting for more than 200 pounds per day. The greater the weight picked, the greater the reward, in wages or goods and services at the company store. The men, on the other hand, were responsible for the vine cutting and pole work and for transporting the hops from the fields to the kilns where they were dried and packed into 200 pound bales ready for shipment.

Men also accounted for the majority of workers who were employed year-round in activities such as cultivating, spraying and shipping. The hop farms took on the look of instant towns during the harvest. While pickers were expected to bring their own clothing, food and bedding, the growers provided accommodation, tents and later cabins or bunkhouses. They also often provided transportation by bus or train, often from distant points around the province. By the 1930s it was also common for the growers to provide medical staff, a well-stocked general store, post office, confectionery and even a dance hall, where, as one old-time picker remembers, romance was often in the air.



The next time you drive the Trans-Canada Highway, look to your right as you approach Chilliwack. There, through the trees, you can still see the vine stripping building, the kilns, the cooling shed and baling house of the John I. Haas Hop Company – a lonely reminder of our hop growing legacy.

Abandoned hops barns in Kamloops. The foreground building is the vine stripping building, with stripping wheels piled outside. The conveyor runs up to the kiln and baling house in the background.
photo R. Kneen

How hops fit in a diversified farm

Hops are both a fascinating plant and a potentially valuable income source on a diversified farm. They can be grown on huge acreages or in smaller plots, and reward the grower either way.

Experience at Left Fields tends to indicate that hopyards of over 1/2 acre are more efficient, encouraging the creation of a better trellising system and holding enough plants that the performance of one individual plant will not greatly affect the whole harvest. In addition, larger yards yield quantities which are more commercially viable, whether one is working with two varieties for a microbrewery or meeting the needs of a homebrew store. Yards which focus on producing rhizomes may be well under 1/2 acre in size, with as few as five hills of each variety grown, and homebrewers may stick with only two or three plants.

A hopyard is more than just a hopyard: it is also potential pasturage for some livestock, or it may grow forage crops as well as green manures for the yard itself. With judicious choices in cover crops, it may also serve as a year-round home for predatory insects, an attractant for pollinators, and can supplement year-round songbird habitat. At Left Fields we have noticed that the tall poles for the trellising are favorite resting spots for both owls and red-tailed hawks who prey on field mice and pocket gophers, both of which can cause havoc in the hopyard. These birds tend to hunt on the fringes of the yard itself, as the wires make flying inside the hopyard somewhat dangerous.

Both sheep and chickens can be rotationally grazed in the hopyard. Both perform different services for the hops, and can be rotated at separate times in the year. Sheep keep the growth of smother crops in the alleyways under control, and are used extensively in New Zealand to strip the lower stems of the hops of leaves, assisting in disease and pest control. Chickens are useful early in the season as weeders, and on hot summers can also be very helpful in controlling grasshoppers. Their scratching also opens the soil around the crowns of mature plants, and can help with disease prevention. With both sheep and chickens, care must be taken that the crowns and growing tips of the plants are not harmed by scratching or direct grazing. This will mean that livestock should not be used in nurse beds or around baby plants, and that the youngest growth of the year should be protected; plants should be monitored closely while livestock are in the yard. However, livestock also spread manure, which is a valuable side benefit. Livestock should be removed from the yard around two weeks before harvest, to allow manure to disintegrate, and therefore to remove the threat of contamination of the hops cones. It should also be noted that sheep can graze to a height of over 4', and should therefore be used only in yards with tall trellising, as they would be grazing off the most productive part of a dwarf variety.

The major seasons for work in the hopyard are early spring and fall, which can integrate well with other activities on a mixed farm. Vegetable farms tend to have a conflict during these seasons, which are also planting and harvesting times, but many fruits (cherries, plums and late apples are good examples) integrate well with the hops season. Livestock also integrates well, as long as the major reproductive season is timed so as not to coincide with the emergence of the hops shoots.

Like most crops and all livestock, hops growing requires infrastructure. Trellising and drying both require machinery and a not insignificant input of cash to construct. Once constructed, however, there is minimal cash input annually. Hops crowns live for up to twenty-five years in good conditions, and can be propagated readily after the first year or two, making them economical in the long term. Their ease of reproduction, and the fact that most yards will be growing their own replacement stock, also means that gradual shifts in varieties can take place without huge cash inputs. This is especially the case if a nursery is maintained, where new varieties are grown on trial, and where replacement stock of main crop varieties is grown out for the first year.

In general, a yard can be trellised for around \$6,500 CDN, with annual inputs of only \$200 or so as maintenance. This compares to an annual income once the plants are established of \$5-12,000, depending on production and variety. (Prices and costs for 2003.)

Market potential

Direct sales to brewers, rather than hops brokers, will yield both maximum prices and a rewarding relationship for all concerned. The homebrewer market, as well as the microbrewery market, can have the side benefit of more willing help at harvest time, as customers can be easily encouraged to help, turning a long chore into a party. Many microbrewers in the Pacific Northwest are seeking a direct relationship with their hops growers. They want to know where their ingredients are grown, and their knowledge and enthusiasm is passed on to their own customers. They can thus be a valuable source of new customers for hops and hop by-products, as well as a source of inspiration.

In 2001, Canada imported approximately 51.6 metric tonnes (113,520 lbs.) of hops. Canadian organic consumption is about 2% of the market in food, and the organic market is growing 10-20% per year. Two percent of 51.6 tonnes is 4,000lb. Quality hops will find a conventional as well as an organic market, however, so the potential market for BC organic hops is orders of magnitude greater than this. Furthermore, the Canadian organic market for hops can be expected to grow by 200-300% over the next three years as existing organic breweries consolidate their market share. New brewers can be expected to enter the organic field at the same rate of growth as the organic industry in general.

However, the major market for hops remains in the US Pacific Northwest, where the concentration of breweries is approximately eight times that of BC. (There are over 30 breweries in Portland Oregon alone, as compared to 14 in BC.) In 2001, over 25 breweries in Portland alone committed to brewing at least one organic beer as part of their regular lineup, and by winter 2003 most of those were using some organic ingredients. As of 2004, one brewery was certified organic.

Canadian brewers have been slower in getting on board, but BC already has one totally organic microbrewery with five regular styles of beer, one regional brewer making one regular organic beer, and one brewpub periodically brewing three different styles organically. There is interest in organic brewing on Vancouver Island (two breweries), Ontario (one) and Québec (Québec's regional brewery, Unibrou, already uses organic and non-GMO ingredients, and is actively looking for more).

Over the past four years, Canadian organic consumers have been purchasing a wider range of products. This means that consumers are looking for new products like organic beer. The market is growing for organic hops as a beer ingredient – and also for organic hops in other markets. Teas, medicinals or "nutraceuticals", vine wreaths and hops pillows are all areas where hops growers can find other markets.

In addition, with the growth of organic consumption throughout the marketplace, homebrewers are also beginning to move to organic ingredients. All the organic breweries in the Pacific Northwest field inquiries weekly from homebrewers trying to find sources for organic ingredients. U-Brews and homebrew supply shops will be the best way of reaching this market.

One of the most common complaints by organic brewers is the lack of organic hops. While Yakima Chief carries USA-grown organic Cascade hops, they are the only commercial source for USA-grown organic hops, and there is only one variety grown. Freshops (a hops broker) carries a few New Zealand hops, Pacific Gem and NZ Hallertauer, as well as German Spalt Select, all available only as whole hops. Hopunion (another hops broker) carries only pelleted hops and only German types best suited for lagers. There is a gap between the styles of beers being brewed organically throughout the Pacific Northwest and the hops available. Spalt and Hallertauer are noble-style hops, suitable primarily for lagers, not the robust ales made in this region. Fuggle, Nugget, Golding, Cascade, Mt. Hood, and Willamette are all popular varieties with Pacific Northwest brewers, but are not grown organically on a commercial scale.

Preferred hops listed by production quantity, USA 2000

Washington State	Oregon	Idaho
Nugget	Nugget	Zeus
Galena	Willamette	Galena
Zeus	Perle	Cluster
Willamette	Mt. Hood	Willamette
Millennium	Golding	Mt. Hood
Cascade	Fuggle	
	Tettnanger	

Acreage numbers for conventional hops have been falling worldwide over the last ten years. This is due in large part to a shift in the beer market towards 'light' beers, which use far fewer ingredients, and less of them, and in brewing technology to make more use of hops oils and extracts, rather than whole hops.

However, this has been countered by increasing hops consumption by smaller brewers, who make up the bulk of the specialty marketplace. According to Hopunion, one of the largest hops brokers in the USA, acreage of hops grown for the microbrew market remains stable. Organic hops production is not yet on the charts, but it can safely be assumed that once quality and quantity reach commercial levels, the market will follow that of specialty hops, with extreme growth for the first few years, and stability after that. Microbreweries and regional breweries are returning to more traditional methods of brewing and styles of beer, calling for more hops, different varieties, and more distinctiveness throughout the process. Brewers are increasingly seeking to make their breweries and products unique. In the past, this has been mostly a marketing effort, but this is being replaced by brewers who are looking for unique ingredients and for a more direct relationship with the people who grow them. One of the largest craft-style breweries in western USA, Anchor Steam, makes annual trips with all its employees to the hopyards and barley farms where their ingredients are grown. These trips are not only part of ongoing staff training, but part of their publicity machine as well. Brewers across the continent are now picking up on this idea.

Getting to Market

Once the hops are grown, picked, dried and packed, they must be stored - and the best place to store them is in your customers' freezers. Direct sales to breweries or homebrewers will double the return to the farmer, while sales to a hops broker may mean selling the entire crop with one phone call. As with any farm gate sales, convenience and best price often have to be traded off against each other.

A hops broker will often be able to take larger quantities of hops at any one time, and will re-sell to breweries and stores. However, the price paid to the farmer can be as little as one-third the retail price. Hops brokers are also an excellent source of information on trendy varieties, the quality of your harvest, market locations, and packaging needs. They may use your hops to mix with others for pelletizing, or may desire larger packages which they will break down for their own customers.

Selling direct to brewers usually means selling smaller amounts of the harvest at once, as most brewers do not have the capacity for storage of a great deal of hops. However, selling direct creates a dynamic and valuable relationship. A good relationship may mean all the difference in a poor production year, as a brewer may be willing to cope with the vagaries you face as a farmer, where she/he would not if they were purchasing 'faceless' hops. Likewise, new or particularly beautiful hops are inspiring to the brewer, and can mean better sales at better prices.

<u>Yield potential</u>		
Variety	Yield lb/acre	Price/acre @ \$4.5/lb CDN
Nugget	2,445	\$11,002
Willamette	1423	\$6,403
Cascade	1785	\$8,032
Golding	1231	\$5,539
Fuggle	1065	\$4,792
Mt. Hood	1900	\$8,850

Selling to homebrewers has the potential to be a minefield, with many very small orders to fill and some extremely fussy customers! It may be easier and more efficient to sell to U-brew stores or homebrew supply shops, with larger orders and prices the same as the price to brewers.

Pricing

Throughout the hops market, organic pricing is roughly 1.5 to 3 times that of conventional hops. In the USA, organic hops retail for US\$7.25-9.50/lb, while conventional hops retail for US\$4.80-6.10/lb. This price is the same to brewers or homebrew supply shops. The average price to farmer for non-organic hops: US\$1.91/lb. This is a rather dramatic difference! One hops broker estimates that the minimum price to organic farmers would be \$4.50/lb CDN. If farmers package and sell directly to breweries, they would be charging a retail price, starting around \$12/lb CDN.

There is currently no commercial organic hops production in Canada, so the price has yet to be set. Freshops, an Oregon hop broker, is extremely interested in Canadian organic hops, as they currently represent organic hops from New Zealand and Germany, with minor production from the US in Cascade hops only. Canadian hops remain attractive to the US market because of the difference in the dollar. In addition, Canadian hops retain an excellent reputation throughout the American market due to the past excellent production quality.

Canada imported approximately 51.6 metric tonnes of hops in 2001. Much of this would have gone to Molson, Labbatt, and the Sleeman group. BC microbreweries can use anywhere from 135kg/year to 1,250kg per year per brewery, depending on size. BC is currently home to over 14 microbreweries and 20 brewpubs. Most of these breweries use whole hops. They tend to use mostly the same varieties as US microbreweries: Cascade, Willamette, Fuggle, Nugget and Golding are perennial favorites. Some prefer the 'noble' hop varieties, but even these use North American grown noble types, rather than true noble hops.

Small hops growers thus have access to the entire western Canadian and Pacific Northwest microbrewery and brewpub market, with potential huge sales. This relies on quality hops, good delivery to the market, and growing varieties that brewers are looking for. The best way to determine your local market is to talk directly with the local brewers – every region of BC has at least one! A listing of all local breweries can be obtained through the Liquor Control and Licensing Branch, as well as through the Craft Brewers' Association of BC.

<u>Market Potential</u>			
Est. Price/lb	Production in lb/Acre	Potential income/acre	Potential Market
CDN \$4.50	1,100 - 2,400 lb/acre	\$4,950 - \$10,800	3,000 lb per variety

<u>Preferred Hop Varieties, British Columbia</u>	
Organic	Conventional
Golding	Northern Brewer
Pacific Gem	Cascade
Fuggles	Mt. Hood
Nugget	Kent Golding (BC Golding)
Hallertauer	Fuggles
Spalt Select	Hallertauer
Cascade	Saaz
	Sterling

<u>Canadian hops imports in \$1,000US</u>				
1995	1996	1997	1998	1999
9,785	10,940	11,537	9,148	8,500
* source: Brewers' Associatin of Canada				

<u>[conventional] Hops: Acreage, Yield, Production, Price, and Value, 1992-2001</u>					<u>Oregon</u>	
Year	Harvested Acres	Yield Per Harvested Acre Pounds	Production 1,000 Pounds	Marketing Year Average Price \$ Per Pound	Value of Production 1,000 Dollars	Value Per Harvested Acre Dollars
1992	7,900	1,479	11,684.0	1.86	21,732	2,751
1993	7,900	1,500	11,850.0	1.95	23,108	2,925
1994	8,000	1,715	13,720.0	1.96	26,891	3,361
1995	8,641	1,595	13,782.4	1.90	26,187	3,031
1996	8,486	1,383	11,734.5	1.81	21,239	2,503
1997	8,352	1,625	13,572.0	1.68	22,801	2,730
1998	6,161	1,660	10,227.4	1.98	20,250	3,287
1999	5,822	1,730	10,072.0	2.04	20,547	3,529
2000	5,819	1,785	10,387.0	2.20	22,851	3,927

* figures are in \$US; from Washington Agricultural Statistics Service 2001



General Hops Horticulture

Hops are one of the two members of the plant family *Cannabaceae*, which includes hemp and cannabis, and which is closely related to the nettle and hemp families. Wishful thinkers please note that Cannabis and hops cannot interbreed. There are only two recognized species of hops: *humulus lupulus* and *humulus japonicus*. *Humulus japonicus* is an annual with virtually no resins, and is useless for brewing, although it is a very attractive vine. Hops are native to the temperate zones of the northern hemisphere, and are grown worldwide between the 30th and 50th latitudes, north or south. They are extremely hardy and long-lived, and under good conditions each vine will produce up to 0.8kg (2 lbs) of hops a year.

Hops, *humulus lupulus*, are an herbaceous hardy perennial vine. They have a permanent rootstock which can grow over 3.6 m (12') into the soil, and which can live for over 25 years. During the first year, growth above ground will be limited to under 6', while the plant puts its effort into establishing the basis of its extensive root system. Each spring, the hops crown or root will sprout dozens of little square-stemmed shoots, which climb clockwise by the use of tiny hairs on the stems and backs of leaves. The climb both by gripping with these hairs and by twining. Left to their own devices, they will climb any other nearby plant, and will also wind around themselves to an extraordinary height.

The plants die back to the ground every year, and can grow up to 9 m (30') in one year. Hops are usually grown on a trellis system, ranging in height from 3.6 - 6m (12 - 18'). Because they are such large, rapidly growing plants, hops require a large amount of solar energy, as well as water and nutrients. Good soil, plenty of compost, sun and water will provide strong, disease resistant plants.

Hops plants produce both rhizomes and true roots. Each crown, or root ball, is made up of both types of roots. True roots become quite woody as they mature and grow in size, and do not produce reproductive buds. Rhizomes, which tend to grow just under the surface of the soil and which ray out from the centre of the crown, are thick and juicy, with marked buds and rootlets. The most common method of reproduction of hops commercially is by cutting off and replanting these rhizomes.



hops rhizome, showing rootlets and buds

The vine (also called a 'bine', both terms are used throughout this manual) grows rapidly in early spring, with growth of up to 30 cm (12") in one day. The plant initially puts its effort into vertical growth, with flower-producing branches being produced later in the year, often after the plant has reached the top of the trellis on which it grows. These horizontal branches vary in length by variety, with Goldings producing some of the longest branches. Around mid-summer, each branch will sprout clusters of little burrs, whose pointy styles give them a spiky appearance. If there are males in the hopyard, this is when pollination will occur. Regardless of whether the burr is pollinated or not, the styles eventually fall off as the florets grow into petals and form cones. Each branch supports several clusters of hops cones, usually in little groups of threes. The cones mature for picking between August and September, and the vines are usually cut back to the ground at or shortly after harvest. After harvest, the hops plant continues to build reserves and put out rhizomes until the ground freezes.



hops at the burr stage – Left Fields

Hops are dioecious, which means that the unisex male and female flowers are borne on separate plants. They can be reproduced by seed,

cutting or rhizome. Male hops produce a great deal of pollen, and old hopyards used to have only one male plant for every 100 female plants. Male plants contain much fewer resins than female plants (10-15 resin glands, compared to females' 10,000+¹). Hop growers who are not actively breeding new varieties do their utmost to exclude male plants from the hopyard, as the seeds do not benefit the brewing process, and because unintentional crosses can easily occur. One cross-pollinated seed can sprout in the middle of a hill of another variety without the grower being able to tell its shoots from those of the original plant, and the crop can quickly be contaminated. In addition, seeds can add as much as 15% to the finished hop weight², and brewers resent paying for non-usable weight. However, pollination does increase cone size and thereby higher yields, so male plants are sometimes used in yards growing only varieties with otherwise poor yields. Care must be taken to isolate such yards and male plants, as their high pollen production combines with the height of the plants themselves to ensure that pollen can be borne by the wind over great distances. Throughout this manual, the focus is on reproduction by rhizome, which produces genetically identical plants – but most importantly, female plants. Hopyards are assumed to be made up of female plants only, although one or more varieties may be grown in the same yard.

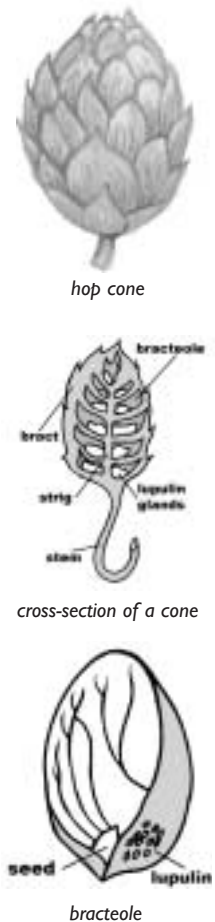
For brewing, the useful part of the plant is the female flower or cone, also called a strobile. It is easily distinguished from the five-petaled male flower, as the cone is much larger and is made up of many scale-like bracts. The cone is made up of a central stem, called a strig. Bracts, which contain no resin-producing glands, and bracteoles, which do, are little petals attached to this central stem. At the base of each bracteole is the seed (if any) and the lupulin glands – the most important part of the plant to a brewer. The lupulin glands are tiny and yellow, filled with the resin containing alpha and beta acids and hop oils. Because the lupulin glands look somewhat like pollen, they are easily mistaken for it, but they are not at all the same.

Lupulin

The lupulin resin is made up of a number of different acids and oils, each of which contributes in a slightly different way to the brewing process. Those of primary interest to the brewer are the alpha and beta acids.

There are three main alpha acids: humulone, adhumulone, and cohumulone. Adhumulone occurs in only minor amounts, and is not known to be particularly important. Humulone is the most studied alpha acid, with cohumulone being the subject of much controversy among brewers and researchers. Cohumulone is thought to produce a harsher bitterness, so that a low cohumulone profile is often sought. Nevertheless, some of the new high-alpha hops contain high levels of cohumulone, and are still popular. Alpha acids produce bitterness in beer, critical to the dry-sweet balance which gives beer character. They are, however, not water-soluble, and must be boiled in the wort in order to isomerize. This simply means that the molecules have been slightly rearranged and have become more water-soluble.³ Alpha acids do deteriorate over time, and varietal specification will indicate what percentage of the alpha acids are lost over a given period at a stated temperature. This is a major factor in varietal storability, and should be a major factor in determining which varieties to grow, and which to sell first. In addition, alpha acid production changes based on climate, water, plant health and nutrition and other horticultural factors. Varietal specifications give a general guideline, but only annual testing of each crop can accurately state the value for any given crop year.

Alpha acids are usually listed in varietal specifications as a total percentage for the weight of the hop, and are used to determine the bittering quality of the hops. Cohumulone percentage is also listed, as a percentage of the total alpha acids (not on the weight of the hops).



¹ p. 20, Using Hops, Mark Garetz

² p. 5 Hops and Hop Picking, Richard Filmer

³ p. 120, Using Hops, Mark Garetz

Beta Acids are somewhat different. They are lupulone, colupulone and adlupulone. While they are only marginally bitter, they do become more bitter through oxidation, both in storage and during boiling. They appear to work in conjunction with alpha acids to make older, stale hops more bitter than alpha acid degradation would appear to indicate.⁴ Beta acids are listed in hops profiles as a total for all acids as a percentage of hop weight. They are not normally considered critical to brewing quality.

Hop oils are made up primarily of myrcene and humulene. Hop oil percentage is used to determine the aroma qualities of a given hop, just as alpha acids determine the bittering qualities. Myrcene, although a major hop oil constituent, is only significant because 'noble' hops should have a low percentage of myrcene. In contrast, noble hops should have a high percentage of humulene, which appears to ensure that hops will retain their aromatic characteristics despite oxidation through aging. Hop oils are listed separately as percentages of total oil content, and collectively as a percentage by hop weight.

Hop Varietal Specifications

There are hundreds of varieties of hops in use throughout the world. Some are differentiated by their agronomic characteristics, some by their use in brewing. Many older varieties have fallen out of favour due to changes in the brewing industry; in the past, brewing was done only when the hops were ready, so storagability was less important. Likewise, many older varieties performed well only in specific areas, and have not adapted well to modern large-scale, widespread hops production. Over the years, hops have been developed to grow both short and tall, for disease and pest resistance, and for higher alpha-acid production.

Hops are usually divided into 'bittering', 'aroma', and 'noble' varieties. Bittering hops usually have a higher alpha-acid content than the others, and store very well. They may not have a particularly pleasant aroma, however, and are not usually used for both purposes. In contrast, aroma hops have a lower alpha-acid content, but a higher hop oil content. They don't age as well as bittering hops, but can be used as both bittering and aroma hops in the same beer. Noble hops are a special group. There are four recognized varieties: Hallertauer Mittlefrüh, Tettnang Tettnanger, Czech Saaz and Spalt Spalter. They are primarily aroma hops, but many of the classic European lagers use them for both aroma and bittering. True noble hops (so-called, perhaps, because they were so highly prized) can only be grown in the correct region – similar to appellations in wine. Noble hops are characterized by an alpha:beta ratio of about 1:1, relatively low counts on both acids, and a high humulene level. Cohumulone and myrcene levels are low, and the hops do not tend to store well. There are a number of varieties which perform almost the same way in brewing, and which, while not 'true' noble hops, are excellent substitutes for the North American grower.

Bittering hops vary wildly in alpha acid content. Contemporary varieties like Pacific Gem, which was developed in New Zealand specifically for organic cultivation and high bitterness, have about 18.5% alpha acid, compared with older bittering varieties like Nugget at 12-14% or Centennial at 9-11%. These new high-alpha hops tend to store well, and brewers use much smaller quantities of them in each batch, making them economical for the brewer. It is also easier for the new grower to achieve good results with these high-alpha hops, making them an excellent choice for novices. Many of them are also more disease resistant and very productive.

Aroma hops are a little trickier, as their lower alpha levels and high oil content are more dependent on soil, weather and water. However, brewers tend to be less concerned with alpha ratings on these hops, as they are not being used to bitter the beer. In fact, variable results from year to year can be turned to the grower's advantage, as both brewer and grower can capitalize on the uniqueness of each year's production. This is a major advantage for the small grower working directly with small breweries, where uniqueness is valued. Large national or international breweries value consistency above all else, and are inappropriate markets for smaller producers of more diverse hops.

Soil and Fertility

In general, hops are a pretty forgiving plant. While they will live for up to 50 years in good soil, they will grow well and live for up to 15 years in moderate soil. The main requirements are a well-drained soil, not heavily nitrogenated and with good soil structure. Left Fields hopyards are a light, loamy surface soil with a heavy clay

⁴ p. 120, *Using Hops*, Mark Garetz

and gravel substrate. Because hops are a long-lived plant, you will have a number of years to assist in soil improvement in your hopyard – as long as the area right around the young plants is fertile and well-drained, you'll be off to a good start.

The other major consideration is weeds: because of hops' long life-span, it behooves the farmer to ensure that the nascent hopyard is as weed free as possible before the hops go in. At least one year of smother cropping and green manures should be allowed to kill weeds and improve the soil before planting hops. This season can also be used to create the trellising system, so it need not be considered a 'down' year.

At the beginning of each year, plants should be side-dressed liberally with well-made compost. Green manures in the alleyways and additional side-dressings of compost in the fall will ensure a long and happy life for your hops. Big plants need lots of nutrients.

pH and nutrients

Hops prefer a pH of 6.0-6.2, or a mildly acidic soil. There are a number of ways of amending your soil pH; one of the best long-term methods is by use of various green manures. Nitrogen-fixing green manure crops, like clover, vetch, peas or other legumes, are a good choice for slow release of nitrogen back into the soil as they decompose. Excessive nitrogen in the soil is not likely to be a problem with this method of adding nutrients - the problems which conventional growers face stem from the overuse of chemical fertilizers which are heavy in nitrogen. Green manures also accumulate potassium, calcium and other micronutrients, as well as improving soil structure and encouraging beneficial insects and soil life.

If a green manure includes a high percentage of legumes, or if it is an immature green plant, the carbon:nitrogen ratio is narrow. Decomposition will be rapid, causing a swift release of carbon dioxide. This benefits crop growth and by producing carbonic acid, helps lower the pH of alkaline soils, increasing the availability of phosphates and micronutrients.⁵

Please see "Covering the Soil" for further discussion of green manures and intercropping.

Drainage

Water is both boon and bane to the hops grower. Being rather massive plants, hops require plenty of water during the growing season – but letting the plants themselves get wet, or letting water pool around the base of the plants, and you are inviting diseases which are very difficult to control.

Start by examining the soil and the lay of the land in your prospective hopyard. A field that has standing water, or into which water does not readily sink, is not your best choice. A well-drained field which may have somewhat inferior topsoil can be amended and built up over time, and is far easier to correct. Subsurface drainage, whether tile or pipe, is very likely to be damaged by the large roots of the hops.

Many hops growers plant their hops into hills, or ditch the space between the rows of hops – not to an extreme extent, which would impede movement in the field, but sufficient to keep water from pooling at the base of the plants. Over time, tillage between the rows and the growth of the hops crowns themselves will help build such hills.

Water

The most important issue with water and hops is delivery. It cannot be repeated often enough: don't sprinkle irrigate your hops! Both mildew and verticillium wilt are exacerbated by excessive water remaining on the plants, either as standing water or as stems and leaves which are constantly damp.

If you *must* sprinkle irrigate, you must ensure that the plants are not damp overnight (don't water in the evenings) and that the base of the plants is kept clear enough to allow the crowns to dry out.

Drip irrigation systems are not only easier to use, they deliver the water right to the base of the plant, and they do not waste water spraying into the air. Drip systems, once installed, can be run on timers, and while they are

⁵ p.50 *Organic Field Crop Handbook*, Ed. Anne Macey, 1992 Canadian Organic Growers

more expensive to install, they cut down on manpower quite considerably. The main consideration with a drip line for hops is ample volume and direct target. 1/2" line with emitters placed at every plant is relatively cheap and easy to install. Best of all, you don't have to replace it every year (unless you run over it with the tiller).

Do be aware that if you have hard water, you may have to invest in emitters which can be taken apart and cleaned: hard water will build up in the nozzle of some emitters, causing them to silently stop watering your precious bines. Check the lines about three times each growing season to ensure that debris or scale has not clogged any of the emitters.

One further note on drip irrigation: mice like to chew on drip tape or soaker hoses, as the natural salts in water build up on the pores of the line. They particularly like to do this when you have it all tidily stored away over winter. This is not a problem with heavier-weight 1/2" delivery line with emitters, and this line also does not need to be removed from the field over winter, once it is drained.



The edge of this hopyard reveals irrigation overhead – in the ultra-dry Yakima Valley, excessive moisture is not a problem!

Like most perennials, hops water needs change as they age. Young plants have small and rather tender root systems, and require frequent deep watering to ensure their health. Likewise, most of the plants' growth happens in the spring, so they do need more water early in the growing season. Once the hop cones have set, you can gradually decrease watering until harvest.

Climate

Hops are native to many parts of the world and different varieties have been found growing anywhere from desert locations to 7000 ft. elevations. A minimum of 120 frost free days are needed for flowering. Direct sunlight and long daylength (15 hours or more) is also needed. As a consequence of daylength and season length, hop production is limited to the latitudes between 35 and 55 degrees, north or south. Hops can be grown outside these latitudes, but it is unlikely that they will produce cones. They are particularly sensitive to short day lengths, and are unlikely to be productive when grown too close to the equator.

Hops have been grown across central North America, with great success. The major hops growing areas combine long, bright days with a dry climate - as long as there is plenty of water available. The Yakima Valley in Washington State continues to be the major centre for hops production in the USA, while the semi-desert area around Kamloops in BC grew hops for many years. Hops can be grown successfully in much moister climates, however, as long as the season is long enough and bright enough.

Diseases

Powdery Mildew

Hop Powdery Mildew appears to be related to the Powdery Mildew which affects alliums in particular. It is a fungal disease which appears early in the season, around May or June. Early signs are white, powdery patches of fungal threads which creep over the surface of a leaf, growing into the leaf itself and spiking out in spore-bearing branches. The vast numbers of these spores allows them to spread readily, carried by the wind to neighbouring plants, infecting both leaves and the developing cones. Burrs affected by the mildew will either not produce cones at all, or will produce deformed cones, while more developed cones will turn a 'foxy' red with spore cases.⁶

This fungus is extremely readily spread at all stages. Infected leaves spread spores to neighbouring plants, while cones carrying the winter spore cases shatter easily, dropping the spore cases to the ground where they infect new growth the following year.

As with all diseases, good sanitation in the hopyard is key. Wild hops growing in the vicinity of the yard often carry the mildew spores, and should be rooted out and destroyed - or at least pruned back vigorously and monitored as you monitor the hops in the yard itself. Bines with signs of the infection should be cut and burned

⁶ pp.258-259, *Diseases of Fruits and Hops*, Masseur

away from the hopyard before the hops shatter. Stripping off the lower leaves of the bines also helps get rid of any early spores, and again these should be removed from the yard and destroyed. Training and pruning the vines so that adequate sunshine and air are admitted to the entire plant will help control the outbreak of Powdery Mildew.

It is also not recommended to apply heavy doses of nitrogenous fertilizer or uncomposted manure (not including that which is directly applied by grazing animals, as this is rarely in such concentrations), as these will cause soft sappy growth which is particularly susceptible to infection.

Sulphur-based fungicides control this disease, and can be applied as soon as the first spots of mould are seen on the leaves. It can be applied later, but application after the mould has reached the developing burrs will still result in at least a partial loss of crop. It is most effective applied as a dust in warm, dry weather. Be careful that liquid sulphur formulations do not include wetting agents prohibited by organic regulations.

Powdery Mildew is more often seen on the East Coast of North America, and was one of the factors which drove major commercial hops production westward. If you observe this disease in a commercial hops growing area, please be sure to notify other hops growers or the local hops growers' association, as it can be devastating if not dealt with in time.⁷

Downy Mildew

As hops moved west to avoid Powdery Mildew, they found a new fungus - Downy Mildew, now the single most devastating disease in Western hopyards. Hop Downy Mildew (*Pseudoperonospora humuli*) is specific to hops, and may not be found in non-traditional hops growing areas.⁸ The disease is first noticed as the young bines grow out in spring - which is fortunate, because this is also the time of greatest activity in the hopyard, allowing plenty of opportunity for the observant grower to discover and treat it early on.

Infected bines characteristically become stunted, with thickened clusters of pale, curled leaves. Closer inspection of these spikes will show a silvery upper surface, with the underside being blackened with mildew spores. These brittle dwarfed shoots are called 'basal spikes', and are the result of an infection in the bud from which they sprouted. 'Lateral' or 'terminal' spikes occur further up a bine, as side branches or apical growth turn into spikes. The number of infected bines in a hill can vary depending on the severity of infection. Sometimes only one bine will be infected, sometimes a whole hill.

Infection can also come later in the season, particularly if early spikes are not detected and removed. Leaves will develop small, dark or black irregular splotches of spores, which run together to form large angular patches as the fungus develops. Infected cones start with four vertical dark strips, but turn brown and worthless later. Wet weather shortly before harvest can cause rapid spreading of the fungus, and turn an entire crop worthless in a few days.⁹

Mycelium of this fungus can live within rootstock and rhizomes, as well as within the tissues of infected bines, leaves and cones. It can be spread by spores dropping onto buds as they form, by water standing on the plants, or by infected rootstock.

The first recourse is, as always, prevention. Ensure that your rootstock comes from clean farms. If possible, choose resistant varieties – Fuggle, though susceptible to other diseases, seems to be quite resistant to Downy Mildew, while Golding is one of the most susceptible.

Good sanitation is required: remove all spikes as soon as they are noticed, and destroy or burn outside the hopyard, making sure that none are left on the soil to infect other plants. This operation will have to be repeated several times as new spikes appear. It may be necessary to remove an entire crown or section of it, if it continues to sprout only spikes. Bines should be pruned well to ensure that even in wet weather they do not hold too much moisture, as this may result in a severe infection. Lower leaves may also be stripped, to assist in keeping the plants dry and improving air flow. Using drip irrigation rather than sprinkle irrigation will also assist in keeping most diseases at bay.

⁷ pp. 202-203, *Using Hops*, Garetz

⁸ p. 202, *Ibid*

⁹ pp. 260-261, *Diseases of Fruits and Hops*, Wormald

As with Powdery Mildew, use of heavily nitrogenous fertilizers should be avoided, and nitrogen applications must be balanced with phosphates and potash. Only use properly-made compost, not raw manure.

Finally, in wet summers it may be necessary to spray with copper sulphate or bordeaux mixture (lime & sulphur). Copper compounds are more effective against Downy Mildews of various sorts (not just those affecting hops), while sulphur compounds are more effective against Powdery Mildews.¹⁰ Bordeaux mixture does tend to encourage Red Spider Mites, however, as it drives away the natural enemies of the spider mite.¹¹

Verticillium Wilt

Most vegetable growers will be familiar with the fungal infection *Verticillium* wilt, as it affects a wide range of vegetables as well as hops. The first symptoms usually appear fairly late in the season, as the hops are maturing and often when the cones are half-grown. Leaves will yellow and wither, with the lower leaves turning yellow first. The discoloration often starts as strips between the veins, and expands until the whole leaf turns yellow or brown. It is most easily identified as the leaves begin to yellow, as the leaf develops a streaky appearance, with strips of yellow around the veins with dull, cooked-looking green strips between the veins.¹² The leaves do not become flaccid, but stay relatively rigid until they detach from the bine. At this point, *Verticillium* fructifications can be observed as a thin, light grey, almost white, coating along the leaf veins, most concentrated where the leaf stem joins the main blade of the leaf.

This is not to be confused with the normal browning and dropping of leaves which occurs on the lower part of the plants. Bines infected with *Verticillium* wilt will eventually turn entirely brown and will lose their whole crop of hops. Browning and thickening of the lower stem, with splitting of the bine or peeling bark is a constant feature, along with an excessively firm attachment of the bine to the crown, so that when a section of diseased bine is pulled away, a piece of the crown comes with it.¹³

This disease is resident in the soil, so that even if diseased bines are removed and clean bines planted in the same place, the disease will return to the clean stock. Fuggle is one of the most susceptible varieties, so if the disease presents itself in a Fuggle yard, it may be necessary to change to another variety.

Water-logging seems to be the most common carrier of this disease. Water must not be allowed to stand on the surface near the base of the plants in wet weather.

All wilting bines should be cut out, removed from the yard, and burnt. Badly infected hills should be removed entirely. Good sanitation will prevent the spread of this disease, with early cutting out of infected bines and careful removal of all affected leaves, which carry the spores of the fungus.

Nutritional deficiencies

Most hops issues can be simply dealt with by assiduous sanitation and applications of compost. Not all compost is the same, however, and resident deficiencies in soil micronutrients can also result in problems. Pale green leaves and weak crowns tend to produce few bines, indicative of a nitrogen shortage. Pale foliage accompanied later in the season by bronzing or scorching of older leaves indicates a shortage of potassium. A lack of phosphorus is shown in dark green leaves with down-curved margins. All these can be readily dealt with by the application of well-made compost, compost tea, and the use of green manures.

Other Diseases

There are a number of other diseases which can affect hops, although they are not often major problems in commercial yards. Chlorotic and Mosaic viruses both affect hops, as do *Sclerotinia* wilt, *Cercospora* Leaf Spot, *Fusarium* and *Gibberella* funguses. Treatment for any of the above diseases is the same as for mildews or *verticillium* wilt: good sanitation, with removal and burning of infected bines, cones and crowns. Since these are common diseases of fruit and vegetables, any standard reference work can be consulted for more information.

¹⁰ p. 34 *Diseases of Fruits and Hops*

¹¹ p. 236-237, *Pests of Fruits and Hops*

¹² p. 43 *Homegrown Hops*, Beach

¹³ pp 252-254, *Diseases of Fruits and Hops*

Pests

Aphids

There is a specific species of aphid that loves hops – *Phorodon humuli* – but other aphids will feast on hops as well. Aphids attack leaves, stems and cones, and are thus capable of entirely destroying a crop. As every home gardener knows, aphids are easy both to detect and kill on an individual basis, and virtually impossible to destroy en masse. Once they infest the cones, they are pretty much impossible to control by conventional means, as no spray can work into a tight green cone to reach the aphids. Once inside the cone, their honeydew starts the growth of a black sooty mould which ruins the cones. If a cone full of aphids is dropped into a picking basket full of healthy cones, this mould can spread rapidly and destroy a basketful while it is still in the dryer.¹⁴

Fortunately, there are any number of means of controlling aphids. The most effective natural control is the introduction of ladybird beetles and lacewings. Ladybird larvae are voracious eaters of aphids, while the adults are rather less effective. Care must be taken to ensure that ladybirds, if bought from a commercial source, stay in the hopyard long enough to lay their eggs. This can be tricky, as they tend to fly directly away from the spot they are released. Lacewings, on the other hand, eat more aphids and tend to stay in the yard better. They are also more mobile than ladybird larvae, and better at finding prey than adult ladybirds. Another very effective predator is the Aphid Midge (*Aphidoletes Aphidimyza*), which is a native North American insect. It survives low numbers of prey (as in when it has already eaten the first outbreak of aphids), but reproduces quickly and has a strong tendency to kill more prey than it needs to eat. Again, *Aphidoletes* can be purchased commercially. For more information, see *BC Organic Grower*.

Aphids can actually be destroyed by a strong spray of water, but this also has a strong tendency to damage the plants on which they feed. More effective sprays include insecticidal soaps, which dry out the aphids. Again, however, if the aphids are not directly hit by the spray they will not be killed. In addition, soaps also kill lacewings, removing both pest and beneficial insect at once. Diatomaceous earth has the same advantages and drawbacks.

Trap crops work well if they are carefully maintained, but they can also become a breeding ground for aphids, which reproduce and spread more quickly than most gardeners can destroy the trap crops.

Spider mite

The other major hop pest is the Red Spider Mite (*Tetranychus urticae*). Spider mites tend to be more of a problem in hot, dry climates. Females overwinter mainly in the soil, emerging in spring to climb the vines and feed on the underside of the leaves. They make fine white webs on the underside of leaves, chewing away at the leaf surface. They start to feed and breed first thing in the spring, continuing throughout the season. During the summer, they are actually a greenish-yellow colour with dark markings – only the overwintering females are the red colour which gives them their name. As the plants grow, the mites keep moving to the growing tips, making this the best location to look for them. An easy field test is to remove a young leaf from the growing tip of the plant, and sprinkle the undersurface with dry, dusty soil. The soil will stick to the mite's webs, making them much easier to see.¹⁵

As spider mites emerge from the soil and start feeding on the young plants early in the spring, this is the best time to control them. Surplus bines should be pruned early in May, and the lower leaves of remaining bines stripped of leaves, to force the mites to go further to find food and to remove early arrivals. Pyrethrum spray should then be applied to the plants on a warm dry day, when more mites will be active. Since they may overwinter in cracks in the poles of trellising, pyrethrum spray should also be applied to the bottom few feet of the poles. If an infestation is detected only later in the year, control is much more difficult. If the hops are in the burr stage, a lime sulphur spray may be applied to the whole plant.

Predaceous insects for the Spider Mite include Anthocorid Bugs, which are, unfortunately, driven away or killed by application of Bordeaux mixture, resulting in higher numbers of Red Spider Mites in hopyards which have also had a run-in with Downy Mildew.

¹⁴ p. 204 *Using Hops*

¹⁵ p. 235 *Pests of Fruits and Hops*

Covering the Soil

Mulch

Because hops are so long-lived, they must be treated more like trees – at least as far as weed management goes! Mulch is the best method of keeping weeds down, the soil moist, and increasing fertility. The main rule with mulches of any sort is that, while the crown should be surrounded by the mulch, it must not cover the crown. Too much mulch right up around the crown will encourage damp stems, mildew and wilt.

Paper mulch

Paper mulch can be made from old newspapers, feed bags, or it can be bought in commercially-produced rolls. If you are using recycled materials, be aware that some bags use plastics in their construction. Bags which have non-removable plastic liners cannot be used as mulch. The advantage of paper mulch is that it is cheap (especially if you can use recycled materials). It keeps soil dark, and will decompose if left in place year-round. However, it does not let moisture through, and can contribute to excessive drying in your soil.

Straw or hay mulch

Straw or hay must be thickly applied to provide any sort of smothering effect. Large round bales can be easily unrolled between the rows, while square bales have to be broken up to be laid. Both can be incorporated into the soil at either the end of the growing season or the beginning of the following season, or fresh mulch can be laid on top of the old mulch, depending on the degree of decomposition. Hay may bring in weed seeds itself – many a grower has found enterprising grasses growing from the top of the mulch layer, while other weeds languish beneath. On the other hand, hay and straw also let moisture and air through, and will thus not have a negative impact on microbial life in the soil. In addition, they will increase fertility and aeration if incorporated into the soil before they are fully decomposed.

Wood chips/Bark mulch

Both of these are favorites with the landscaping industry, but are not recommended for use in the hopyard. Cellulose takes a long time to break down, and robs the soil of nitrogen for a long time during this process, although those nutrients will be available again later in the cycle. Once decomposed, however, these mulches can increase tilth and help break up heavy clay soils.

Green Manure

Green manure is the common name for a number of ways of using plants to increase soil fertility. This can include cover crops (grown to cover the soil during a dormant season), smother crops (grown to smother weeds), green manures (plants which fix nitrogen and increase the availability of other nutrients when incorporated into the soil), and allelopathic crops (which produce natural toxins which impede the growth of certain weeds). Green manures are often also grown to provide habitat for bees and other pollinators, or to break the life cycle of pests (although this use is not particularly relevant with a perennial crop like hops).

The planting pattern of commercially grown hops – long rows with wide alleyways between – mandates the use of some sort of living mulch or green manure. Since the soil should be covered, why not use plants, which can feed the soil and potentially improve your whole hopyard? The only negative issue I have found in using various cover crops between the rows is that they can become too tall, and that they have a tendency to get right into the rows and the crowns themselves, becoming weeds in their turn. Excessive height both impedes traffic (especially if you're trying to maneuver a tall orchard ladder or walk about in hop-picking stilts) and can suffocate baby hops. The remedy for this is both careful seeding and a careful choice of crops.

I have used fall rye, common red clover, buckwheat and oats as green manures in the alleyways. While fall rye has a strong allelopathic action, it is hard to kill and must be incorporated into the soil as soon as possible in



*paper mulch made from used malt bags covered with wood chips from fruit trees.
Left Fields*

the spring, before it gets too tall. It can, however, be seeded late in the fall and will germinate readily even if not thoroughly covered with soil. Common clovers, while superb at covering the soil, tend to get very tall and invasive - getting them out from between the hops can be a real challenge. The best method of dealing with clover is to mow it, or provide animals to mow it for you. Mowing keeps it to a manageable length and provides green material for mulching in the rows themselves. Buckwheat is another good smother crop, often used in rotation with rye. In general, I tend to lean towards planting a perennial green manure which can be plowed down every two years (less work for me), and which will provide both a cover and smother for weeds. There are a number of excellent resources available on the use of green manures, which provide considerable detail on seeding rates, timing, and seed mixes.¹⁶



Merino lambs keep the hopyards clean in New Zealand's spray-free and organic hopyards. Photo courtesy New Zealand Hop Marketers Ltd.

Brown manure cannot be discounted in both weed management and soil fertility. As noted above, livestock can be used to control permanent plantings in the alleyways and to provide a little fertility of their own. New Zealand's organic hops growers run sheep in their hopyards¹⁷. The sheep eat both the alleyway greenery and nibble the lowest leaves from the hop bines, saving a great deal of labour for the grower who would otherwise have to hand-strip the bottom of the bines. Chickens can be used to control flying and crawling insects, especially grasshoppers. They also scratch around open soil and eat weed seeds. As long as they don't scratch the crowns up too much, chickens can be very useful in keeping the hopyard clean. This technique has been used extensively in BC by Fred Reid of Olera Farms, who runs chickens in his raspberry fields.¹⁸

In addition, a small-scale grower can make use of the alleyways between the hops to grow another crop for harvest. Left Fields has grown peas, both snap and pod varieties, which are usually finished and cleaned up before the hop harvest. Peas seem to be an excellent vegetable choice, for they help fix nitrogen, they can be trellised so as not to interfere with movement around the hops, and they can also be grown on drip irrigation. Experiments with lettuce and other greens which like the partial shade provided by the hops were less successful, since these crops don't do as well on drip irrigation. Beans, both green and dry varieties, are harvested too late in the year, and tend to conflict with hop harvest. The basic criteria for choosing an intercrop with hops is the ability of the plant to do well on drip irrigation, time to harvest, and whether its growth habit will interfere with the hops themselves. In addition, one must consider whether such a crop will remove nutrients from the hops, or add to soil fertility. This is especially important because most vegetable crops are removed from the field upon or after harvest, and therefore do not provide a net gain for the hops.

¹⁶ throughout, *Organic Field Crop Manual*

¹⁷ www.nzhops.co.nz New Zealand Hop Marketers Ltd.

¹⁸ Olera Farms, Fred Reid

Hopyard design & trellising

Planning a hopyard is much like planning an orchard: one is thinking 15-25 years ahead. While there is always space for experimentation, designs and implementation must take permanence into consideration. Materials must walk the fine line between short-term economy and long-term durability. While cutting a few days off the initial preparation of the yard sounds like a good idea, it must be balanced against the need to spend several more days each spring re-building your trellising or replacing inadequate irrigation lines.

Site Selection

Once you have examined the soil on your farm and decided which area has the best potential for hops growing, it is time to look at some of the other factors. External considerations include ease of access and proximity to the various inputs. Within the yard itself, exposure to sun and wind are critical considerations in design. In addition, there must be sufficient space left around the yard to ensure that the guylines and anchors do not interfere with proximate uses of the land.

Proximity

Access to water is one of the critical issues, and perhaps the most obvious. For those unfamiliar with drip irrigation, there is one key consideration in design, apart from proximity to the water source: ensure that you will not be driving over your water line. If you run water lines across the alleyways, down which you are likely to be driving several times a season, protect them. Burying lines is one solution, but one accidental pass with the rototiller can wreak havoc.

Hops also require a fair amount of supervision, with daily or weekly inspections for diseases or pest outbreaks, weed control, ripeness of hops, and readiness of green manures for tillage. Good management dictates that the yard should thus be situated in an area which encourages frequent walks through the yard. The closer your yard is to the centre of activities, the more likely you will be to take those frequent walks. Harvest time is another point at which this proximity will become critical. The hops must be transported very quickly from the field to the dryer, and the closer the yard is to the dryer, the better.

If you are planning to use livestock in your hopyard, proximity to other pasture or barn space must also be considered. Again, initial planning for ease of access will assist considerably in the daily management of the farm. While this may seem obvious, the little walk across the unfenced driveway from the pasture to the hopyard may become a huge issue when the sheep go the wrong way and there's only one person to do all the work. It's so much easier to, say, drop a section of electric fence to allow the sheep directly into the yard from a neighbouring pasture!

Finally, one should ensure that there is easy vehicular access to the yard. Compost, mulch, tools and tillers will all be needed at various points in the year, and their access must be facilitated.

Internal Considerations

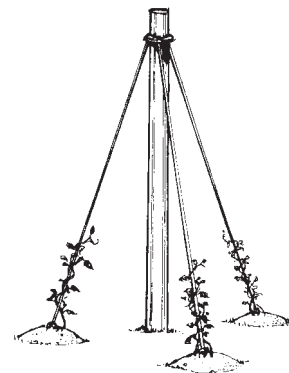
Hops require the longest possible exposure to sunlight during the day. Sites with partial shade should not be considered. At the same time, exposure to wind may be an issue. While wind can help keep the hops dry (especially if you are in a damp area), it can also damage the ripening cones. If the windiest time of year in your area is midsummer or earlier, wind damage is not likely to be a problem. In this case, you will want to structure your yard so that wind is funneled through the bines to aid in keeping them dry. If, however, your heaviest winds come in the fall, damage to the ripe cones may well become a problem. In this case, you may want to consider situating the yard behind a windbreak or running the rows so that wind will tend to flow around, rather than through, the yard. You may also want to consider planting short-season varieties, so that harvest is more likely to happen before fall winds. Alternatively, you may use short-season varieties on the windward side of the yard, and harvest without pulling down the bines, so that they provide some protection for other bines in the yard.

Layout

There are dozens of different methods of trellising hops, with designs adapted for everything from the grower of one or two backyard plants to yards with thousands of plants, from yards utilizing only hand labour to totally mechanized farms – and everything in between. Primary consideration in this manual is for a small to mid-sized yard, with over 100 plants.

Single-pole trellising

There are two main types of single-pole trellising, both of which tend to be in use primarily in very small yards. The first type uses one long, slim pole per hop plant, with one or two shoots per plant trained around the pole. This method of trellising has been in use since the 18th Century in England.¹⁹ The major drawbacks to this system are the need for a constant supply of 12' poles (unless treated, they rot fairly quickly), and the immense labour in putting them in and keeping them upright every year. The major advantage is that the hops grow readily around the poles, and there is no need for the complicated and expensive wirework of other designs.²⁰



The other type of single-pole trellising is both simpler and more practical. Tent training²¹ consists of one central pole over 12' in height with hops planted in a wide ring around it. Twine is strung from the top of the pole to each plant, creating a teepee-like effect. This is simple and easy to construct. The advantage to this system is that it is readily installed with a minimum of machine labour and makes efficient use of even a small space to grow lots of plants. The disadvantage is that one tent can only have one variety (of course, this is only a disadvantage to the home gardener, who may desire three or four varieties). In addition, the bulk of the hops cones are found closer to the top of the plant, which is where the wires or twine comes together, resulting in a very dense mass of hops at the top of the pole. This may well result in a lower hop yield. Finally, most modern hops are bred to do best at a trellising height of over 12', and may not produce as well on such a short trellis. However, the use of dwarf hops varieties would solve this particular problem.

Horizontal Trellising

In the late 19th C in both England and the USA a new method of hops trellising came into vogue. It was known as Horizontal Trellising, and was the precursor to the modern system of pole and wire trellising. With horizontal trellising, one relatively short pole (8-9' long) is set in each hill. The tops of all the poles are connected by a twine running both ways across the yard.²² The hops grow up each pole, then are forcibly twined horizontally across the twine past the next pole. When they are midway across the second string, they are allowed to drop down, twining with the next plant. With this method, most of the growth of the hops is horizontal, requiring only a short ladder to reach most of the hops. However, current experience says that most hops cones are produced on the vertical growth of the plants, so this system may result in lower yields.

Modern Trellising

The standard trellising worldwide now is a system of tall poles supporting horizontal cross-wires running in both directions across the yard. Two strings are run from each crown up to the wires. Poles are 16-18' high, and are set one every 5 plants or so (depending on plant spacing). Heavy wires or cables run the length of the hopyard, supported by the poles. Lighter wires or cables are run cross-wise, anchored to the outside cables. In most larger yards, the poles are set in a checkerboard pattern, so that the load of the plants is distributed most evenly. The outside poles are slanted outwards, to help equalize the strain of the cables, and are anchored by a simple but solid system of guy wires.



This Washington State hopyard shows the end poles set on an angle, with centre poles spaced one every fourth plant, both directions. Cables run both lengthwise and crosswise in the field, with lighter cable for stringing hops run parallel to the beds. These hops are also cultivated in both directions.

Spacing

In this design, hops are spaced 4-5' apart in the bed, with 8-10' between the beds (this distance is dictated by the size of the machinery used to till between the beds). As they mature, the crown can get up to 4' across, so each bed needs to be at least that wide. Large yards tend to use a wider spacing between the plants (about a 7x7' grid), allowing tractor work to be done in two directions in the yard. Smaller equip-

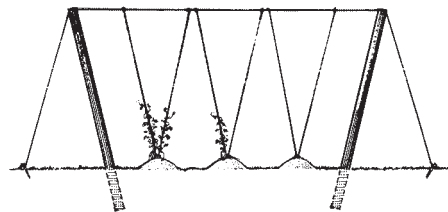
¹⁹ p.20 *Hops and Hop Picking*, Richard Filmer

²⁰ p. 73 *American Agriculturist*, March 1865

²¹ p. 198 *Using Hops*, Mark Garetz

²² p. 73 *American Agriculturist*, March 1865

ment, however, allows much tighter and more efficient spacing of plants without sacrificing airflow or plant size. If more than one variety is grown in a yard, adequate separation between varieties is a must. A simple method is to keep twice the distance between plants of different varieties.



Two twines are strung in a 'V' from the top wires down to each crown. Two or three bines are trained onto each string, the rest being pruned off regularly throughout the season. There are two methods of stringing hops on this system. The simplest and most common is to run the twine parallel to the beds, with each pair of strings sharing a supporting wire with the neighbouring plant. Alternatively, twine can be run perpendicular to the beds, so that the alleyways have an arch of hops over them. With this method, the twine must be 'arched' by tying each plant's strings together about 5' off the ground. Otherwise, it becomes impossible to drive between the rows.

Trellis height is one of the more difficult considerations. Many new varieties are bred to grow best on 18' trellises, whereas older varieties tended to work just as well on anything over 12'. Needless to say, the taller the trellis the more difficult it is to put up and maintain. Left Fields uses both 15' and 18' trellises. Shorter trellises tend to encourage the plants to become more bushy, so allow for this when determining planting distance. At the same time, shorter trellises may help long-season hops mature more quickly, as they reach the top of the trellis earlier and start to work on horizontal growth of fruiting spurs. 18' trellises are the industry standard, and commercial equipment is all designed for this height. Harvesting frames and wagons in particular are made for this size of trellis, and may get hung up on lower trellises.



These edge poles in a large Washington hopyard use the same weight cable for both guy lines and cross cables. Cables run both directions from these poles.

In general, however, the smaller hopyard can work more easily with a trellis of 16'. This is tall enough to allow the more vigorous varieties room to grow, while still being relatively easy to manage with small equipment. It also makes it a lot easier to find poles the right size.

Materials

Poles

The best material for poles is old-growth cedar, either round or split. Old-growth cedar has a much higher turpentine content than young, fast-growing cedar, and will therefore last longer. Cedar poles are easier to handle in the large sizes required, and tend to have some flex in them, allowing them to take the strain of the cables. Traditionally, chestnut poles were used, as they had both flex and durability.²³ Chestnut can be coppiced, which allows for almost infinite growth of replacement poles. Pine or fir can also be used, but will require either more frequent replacement or some sort of preservative treatment. Organic standards do not allow the use of CCA (copper chromium arsenate) treated posts, as they have been found to leach arsenic into the soil. Alternative treatments include charring the surface of the pole to a depth of 1/2" where it contacts the soil. Whatever the treatment (or lack thereof) used, it is best to count on replacing poles every 5 years or so, and to include this in the design of the yard. Whatever the height above ground, about 3' of the pole should be in the ground.

Outside poles should be larger than internal poles; outside poles, which are canted on an angle of about 60°, should be 6" or more in diameter at the base and no less than 3.5" at the top. Inside poles can be 4" or so in diameter at the base, but must not narrow below 3" at the top.

Cables & Wire

Major cables and guy wires should be the same strength and diameter. 3/8" aircraft cable is an excellent choice, being both extremely strong and relatively easy to use, although many yards use heavier cable. In



guy line anchor used on ginseng trellising (left & centre of picture): strong, but expensive. Right: forged steel loop used to anchor cross cables.

²³ pp23-24, *Hops and Hop Picking*

general, larger yards should use heavier cable with less give. Wire rope clips or cable clamps are the simplest way to tie off cables, and need not be forged steel. Cable clamps provide a great deal of strength with a minimum of expense, once the clamp tool has been purchased. Anywhere a cable is asked to double back on itself, an eye must be used inside the loop to prevent fraying of the cable. Cross wires must be greater than 12 gauge steel – experiments at Left Fields with 12 gauge high-tensile fencing wire were not successful, as the wire stretched or broke outright under the weight of the plants. Again, larger yards use lightweight cable for cross-wires, as it has strength without stretch.

Hardware

While there are any number of types of hardware that can be used to attach cables to poles and each other, most hopyards in North America simply wind the ends of the cables around the poles or each other. Cables are tightened using a come-along, then wound around the pole, doubled back on themselves and secured with cable clamps. This requires a minimum of labour and material. Should a pole need replacing, cables can be unwound (this part isn't easy) and then put back on the new pole.

Turnbuckles can also be used to tighten cable on shorter runs or where other equipment is difficult to use. You'll need an eye bolt to connect them to the post - in all such cases, drop forged rather than cast steel must be used for both bolt and turnbuckle. A cast steel bolt will open from the strain after a relatively short time.

Inside posts need only hold up the cable, not tighten it. One can simply thread the cable through a hole drilled in the top of the post, but this makes it difficult to tighten the wire, which doesn't slip through the pole easily, and very difficult to change posts without re-doing the entire trellising system. A better solution is to use a length of ready-rod (threaded steel rod), bent into a hook at one end. The straight end is slipped through a hole in the pole and secured with a washer and nut. The hook holds the cable, and the nut can be tightened so that the hook holds the cable tight against the pole once the cable is tight. This ensures that the cable will not bounce out in heavy winds.

Anchors

There are as many anchor devices as there are farmers - it all depends on what's at hand. However, for the pull and weight of hops trellising, we have found one kind of anchor indispensable and easy to build. These anchors hold the corner and edge pole guy lines. They are made from a 3.5' section of heavy rebar, bent at one end into a loop. The other end is welded onto a 6x6" steel plate which has been cut down the centre of two sides, with the resulting flanges bent in opposite directions (see drawing). This is then screwed into the ground on the same angle as the guy line. Once it is buried up to the top 4" or so, the guy line is connected and tightened. In gravelly or loose soil, a hole can be dug and the anchor buried. This style of anchor is ideal for clay or loam soils. Large rocks can get stuck in the plate, and gravel tends to simply bounce around and make it impossible to screw the anchor into the soil. If the anchor must be dug in, it is advisable to use a larger plate, and the plate need not be cut and bent into flanges.



This is an edge pole, with guy line wrapped around the top and fastened with two cable clamps, as is the cable running across the field. The cable parallel to the line of poles is run through the gap between the guy line loop and the pole. Cables between the poles are simply looped around the parallel cable and clamped.



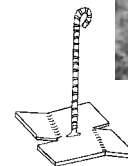
A simple pass-through for an interior pole: a piece of threaded rod with a hook bent into one end. The hook closes against the pole as the nut is tightened.



A length of pipe with a slot cut for the end of the anchor makes a great handle to screw the anchor in with.



Turning in the anchor.



Wooden anchors, or anchors which are placed on the opposite angle to the guy line simply cannot withstand the pull of the system. They may be effective on very small systems, but we have found that there are many more drawbacks than benefits. Wooden stakes rot readily, while rebar or T-bar tends to cut through the soil and loosen the pull.

Twine

The classic hops twine is made from coir, coconut fibre. It is very strong, will stretch when wet but tighten again as they dry. If composted, it will biodegrade over a year, although it sometimes takes longer to fully degrade.

Left Fields has used untreated sisal twine with good results as well. Sisal does have a tendency to snap as the vines bounce in the wind, especially if the twine is not very tight, and it will biodegrade readily - sometimes a bit too readily. However, it is cheap and readily available, and can be replaced or repaired throughout the season if need be.

Putting it all Up

As any fruit grower knows, setting up trellising is time-consuming work, especially so as the poles get taller and the wires get heavier. Poles may be installed by using a hand auger, motorized auger or tractor-mounted auger, with a 2.5 - 3' hole. The primary consideration (after placement) is that the poles are deep enough and that the soil can be tamped down around them again. Edge poles must be put in on an angle of about 60-65°, and may require temporary guy lines to keep them in place while the cables are strung. It may be easier to install all the interior (vertical) poles first, then put in the edge poles with the cables to hold them. It is strongly recommended to install any hardware before the poles go up - there's nothing quite as vertigo-inducing as trying to drill through the top of a swaying pole while on top of an 16' orchard ladder.

In every yard over 0.5 acre, you will need to have cable running in both directions, anchored to poles at each end and supported by interior poles). Cross-wires (which will support the hops vines themselves) run the length of the row (unless you are going to 'arch' your twine and grow more closely spaced plants) and are supported by the cabling. As noted above, cables are attached at both ends by the simple expedient of wrapping their ends around the supporting pole and clamping the free end with two cable clamps. They are tightened using a come-along which is anchored either to the pole itself or to another cable. Guy lines are attached and tightened the same way. You can also use turnbuckles to tighten the cables, but they cannot be removed once the cable is tight, and add considerably to the cost of installation. In addition, they have limited range of motion, and as the cable stretches over the years they will reach the end of their range sooner or later.

Cross-wires should be light cable, 1/4" or less. High-tension steel wire is only adequate for a very small yard, as it stretches readily and does not handle horizontal pull well. These cross-wires can be attached to the cables by simply looping loosely around the cable and clamping the free end to itself. Again, they can be tightened using a come-along attached to the terminal cable.

Once the whole trellis is in place, it is time to string the vines. Please see Spring Activities for a full discussion of stringing.

Annual maintenance

Once you have a well-made trellis, annual maintenance should be restricted to tightening cables occasionally, replacing guy-lines (Left Fields once had a guy-line snap when a heavy wind blew a portable chicken-shed against the line, which was also under heavy stress at the time), and occasionally replacing poles. A spring walk-about should give you a good indication of the work to be done over the next year. The major work fall not under the category of trellis maintenance, but of plant maintenance, with pruning and re-stringing vines every spring.

Spring Activities

Root prune or divide rhizomes

As soon as the ground can be worked in the spring, it is time to clean up your crowns. Over the last year, the hops have been busy not only setting cones, but increasing their root structure. Only some of those roots are dedicated to feeding the plant - the rest are for propagation. In the first year of the bine, there will be very little rhizome growth, as the plant puts most of its effort into improving its basic root structure. As the plants mature, however, they focus more on propagation. Some large mature crowns can produce 20-30 rhizomes per plant, each of which can be divided in several parts for propagation.



This three-year old crown is putting up plenty of new shoots! Note the drip irrigation emitter right at the main crown.

If such exuberant growth is left unchecked, the plants will soon cover the entire acreage with a solid mass of plant material. Needless to say, for the purposes of hops production, this is not desirable! Therefore, one of the major spring tasks is to prune back this growth. Large hopyards control rhizome production throughout the season by tilling all around the crowns. Then in the spring, a special crowning machine is used to mow the old growth from the top of the crown and stimulate new shoots. This machine is a bit like a cross between a mower and a rototiller, as it cuts off the dead old growth below the soil surface.

In smaller yards, or where you would like to make use of the rhizomes, spring work is more involved. As soon as the soil can be worked, the area around each crown is carefully dug over with a fork. Rhizomes, which have an obvious fleshiness, and which grow horizontally just below the soil surface, are separated from roots and cut from the plant (see picture pg. 10). They can be replanted or discarded at this point, and should be cut from the parent crown as close to the main plant as possible. Some rhizomes can be up to 5' long on a healthy plant! This is also an excellent opportunity to clean up weeds which may have made incursions into the crown.

Set out new plants

If at all possible, the rhizomes should be replanted as soon as they are removed from the parent plant. Properly treated, a rhizome can be stored for 2 months, but they lose vigour over time.

Hops should be planted as early in the spring as you can get your hands into the soil. A good rule of thumb is to plant hops the same time you would plant peas or fava beans. Hops, especially if they have been mulched after planting, can easily withstand a light frost. Although they can be planted as late as the end of May, this reduces their growing season and wastes the best part of the spring.

New plants desire a hole about 1.5' square, with a generous helping of compost and kelp meal mixed into the soil at the bottom. Water the hole well, then plant the rhizome 1" from the soil surface, with a bud pointing upward. If there is already green growth on the rhizome, tuck it all into the soil and just barely cover with earth. Water well. Baby plants require frequent short waterings to keep their root system growing.

Top-dressing, mulch & cover crops

After digging rhizomes or root pruning old stock, a generous top-dressing with quality compost is next. New plants have received their dose in the planting hole, and need only be top-dressed after their first year. Top-dressing can also be done in the fall, following harvest.

If mulch of any sort is going to be applied, it should be done immediately after planting, top-dressing and rhizome harvest. This is especially important for new plants, where mulch will hold in moisture and reduce weed competition. Early spring is also the time to till in winter cover crops and sow fresh green manures.

Check irrigation

Each season, irrigation lines must be checked for mouse damage, lines which have been run over, and new emitters must be installed with new plants. Old emitters should be checked to make sure that they have not become clogged with soil or calcium buildup, and filters should be checked.

Twine bines

When laying out the hopyard, you will have determined whether your twine will run along the rows or across them. The procedure for twining the bines is the same for either setup, however. Twine must be anchored to the top wire and drop down to be anchored at the base of each plant. The twine can be tied to the overhead wire, with two lengths of twine per plant, or it can run from one plant, loop over or hook onto the overhead wire, and drop down to the next plant. Tying the twine to the wires requires someone on a ladder, lift or stilts to tie the twine. Hooking the twine requires S-hooks already installed on the overhead wires and a long pole with a hook at the end, to lift the twine into the S-hook. Looping the twine over the wire can be done by simply tossing the end of the twine (usually tied to something throw-able) over the wire. Your choice of technique will depend on the equipment available, your skill on stilts, or your ability to throw a ball (juggling experience helps).

No matter what the method of tying to the overhead wires, the twine must also be anchored at the base of each plant. The most common method uses a piece of heavy, stiff wire (12 gauge high-tensile wire works well) bent into a W shape and pushed well into the soil. The twine is



Older hops twining around their strings. When harvesting for eating, take the tip of a new shoot down to where the leaves start to emerge.

is tied to the centre point of the W. As the plant pulls on the twine, the outer legs of the W spread apart and anchor it into the soil. Another method depends on having some of last year's stalks available. If there are one or two old vines left in the crown, the twine can be tied directly to them. This is not recommended for plants younger than 3 years old, as the root system may not be strong enough to withstand the pull of the twine.

With any twining system, the bines must be trained onto the twine when they are about 3' high. At this point, it is easy to prune back damaged, short or excess bines, leaving only two or three per twine. Each crown can produce dozens of shoots, but the hop grower must be ruthless in choosing only the strongest, fattest ones to reach maturity. Like all pruning, this can be a difficult emotional process in the beginning, but the results are so beneficial as to make it a pleasure after all. Pruning forces the plant to put most of its effort into the shoots you have selected, and results in larger vines and bigger hops cones. It also results in a large basket full (or several) of tasty hops shoots. Sauté them lightly in fresh butter with a few sunflower seeds or hazelnuts, and add them to a spring salad or eat over rice. They are an excellent spring green!



Hop stringing on stilts.

Photo from [Hops and Hop Picking](#), Richard Filmer

Each bine must be carefully wound around the twine in a clockwise direction (following the sun). If the growing tip of one of the bines is broken during this process, the bine will eventually start a new tip for that bine, but the plant's growth will be severely set back. Should this happen - and with crisp young plants it is easy to do - simply cut off the maimed shoot at ground level and remove it from the twine, training up another in its place. If the plant is big enough that this is excessively difficult, add another bine to the string. Once you have trained enough shoots for any given plant, prune all the remaining shoots back to the ground. As for most work with hops, it is a good idea to wear long sleeves for this job, as the tiny claws which help the vine grip and climb also cling to skin. Hoppers' Rash is unpleasantly itchy, although it fades quickly with liberal applications of aloe.

Summer Activities

Summer activities in the hopyard are both constant and undemanding. Regular walks through the yard are vital, for with them you will keep new side shoots pruned down, ensure that all the plants are getting adequate water, and monitor weeds, insects and diseases.

New shoots will emerge from the hops throughout the growing season, and must be cut back to the soil. Otherwise, they will compete with the bines you have already selected for this year's harvest. This pruning can stop shortly before harvest, when the vines are starting to put out next year's rhizomes.



Laterals, which will bear the hop cones, are starting to form at the juncture of leaf and stem in June.

If, through good management and good luck, you have a relatively weed-free hopyard, your summer work will consist of keeping it that way. A program of hoeing, mulching, using cover crops and green manures, and tillage should maintain your yard in good condition while feeding those great big hops plants.

Monitoring insects and diseases will be critical all summer long. In the early, damp part of the season, watch for signs of mildew. As the season progresses, your attention will shift to insects, with aphids and spider mites starting to appear. In a particularly dry year, you may have problems with grasshoppers as well. Unfortunately, the only real way to treat grasshoppers organically (which is the only long-term solution) is to improve bird habitat to encourage predator birds to nest and hunt in your hopyard. Fortunately, chickens provide much the same job for many farmers, and are somewhat easier to introduce in the short term. Please refer to the section on pests and diseases for more on this subject.



these very young cones still show hairs remaining from the burr stage
oxidized aromas. Too green, and the lupulin will not be aromatic enough.

Harvest Time

This is the golden time of year for a hops grower, as your hands become sticky with fragrant, bitter lupulin. Despite their soporific effect, this is no time for drowsing. Timing of the hops harvest is critical. The goal is to pick hops when the lupulin is most aromatic and the cones are starting to dry. Too dry, and the cones will yellow and shatter while being processed, and the lupulin will start to develop fascinatingly unattractive 'skunky' or

The most straightforward way to tell if a hop cone is ready to be picked is to look at it and feel it. As the hops mature, they gradually lighten in colour from a rich, brilliant green to a paler shade, with some of the bottom bracts turning slightly golden. The lupulin will also gradually change colour, darkening from a very pale gold to a dark yellow reminiscent of Ministry of Transportation vehicles. As the lupulin darkens, it also becomes more sticky - in some varieties, you can judge ripeness by the stickiness of the cones. Cones will also go from feeling distinctly damp when squeezed to feeling light, papery and quite dry, and will become more resilient.

To judge when to harvest, pick a selection of cones from different places on the plant, making sure to pick from both top and bottom, as the top hops will be greener than those at the bottom which were set earlier. Look at several of the hops, checking for general colour and lupulin colour. Feel the whole handful together and determine how dry it is. You may have hops which are at different stages of ripeness on one plant. This necessitates determining whether to pick the whole plant at once - which is by far the simplest method - or picking only sections at a time. Commercial growers will want to cut and harvest the whole plant, and must seek a medium in their determination of ripeness. Erring slightly on the side of less ripe ensures that, while the alpha acids may be slightly lower, the hop will dry well and not be oxidized. Over-ripe hops will tend to shatter and oxidize, and will have a more negative effect on the whole batch.



While further along than the previous photo, these cones are not ripe yet - they are small and fluffy, and have very little lupulin.

Judging hop ripeness is definitely an art when practiced this way. Over time, you will learn which areas in your yard ripen first, which varieties mature later than others, and which are most consistent in ripeness on each bine. Do make sure that you walk the entire yard as harvest approaches, checking several plants of each variety you grow.

As noted, timing is critical at this juncture. A heavy wind, common in the autumn in many parts of the country, can turn a perfect crop into a dessicated, wind-burned mass good only as compost in a matter of hours. This is also the one point at which a heavy frost can potentially damage a crop beyond hope, as can hail. Even the depredations of grasshoppers cause less damage than an untimely wind or frost! It is far better to pick a crop a little early than to risk damage by these natural disasters.

The day chosen for hops picking should also be dry, with calm air, preferably not the day after a heavy rain. This is both for the convenience of the pickers, as it prevents cones from sticking to the fingers and breaking as they are picked, and for the benefit of the hops themselves. Hops will dry better and be slower to heat up in the pickers' baskets if they are not wet when picked. A day free of strong wind will also make it easier to take the bines from the trellising, and will be safer if ladders or stilts are used by the pickers.



ripe hops, ready for picking

Methods of harvesting

Growers with smaller yards may choose to pick their hops directly from the bine while it is still attached to the trellis. This is a great way to keep the hops clean, and is one of the most pleasant ways to pick. This method also allows the grower to leave less ripe cones on the bine to await a second harvest. It does necessitate climbing a ladder or using a cherry-picker type device to get to the top of the plant, which can be a challenge for some. Moving the ladder constantly can also become quite time-consuming, and one ladder per picker is required. When picking, use a clean 5-gallon (20L) bucket with a hook to attach it to the ladder. This leaves both hands free to hold onto the ladder or the plant and to pick. A clean burlap sack or onion sack can also be used, in which case a wire loop can be inserted into the top to keep it open, and the whole can be tied to the ladder or belt of the picker. Hooking the container onto the ladder directly is safest, and the container can also be easily moved up and down the ladder as the picker moves.



picking hops from a 16' orchard ladder at Left Fields.

Large-scale growers usually remove the hops from the trellis first, then remove the cones from the bines, either mechanically or by hand. The first step is to get the plants off the trellis. A tractor-pulled wagon with a picking platform is customary in large yards. The plants are first cut off at the base, leaving them hanging from the trellis. One or two people atop the platform cut the tops of the plants off the trellis, and lay the whole plant in the bed of the wagon. The load is then taken to the barn, where the hops can be removed from the bines either mechanically or by hand. Alternatively, the hops can be cut from a ladder or by a person on stilts. Scale and available equipment are the main factors in determining the method used. No matter what the technique used to remove the plant from the trellis, care must be taken not to treat the plants roughly. If any livestock have been used in the yard, the plants must not touch the ground. They can be laid on a tarp or any other clean dry surface.

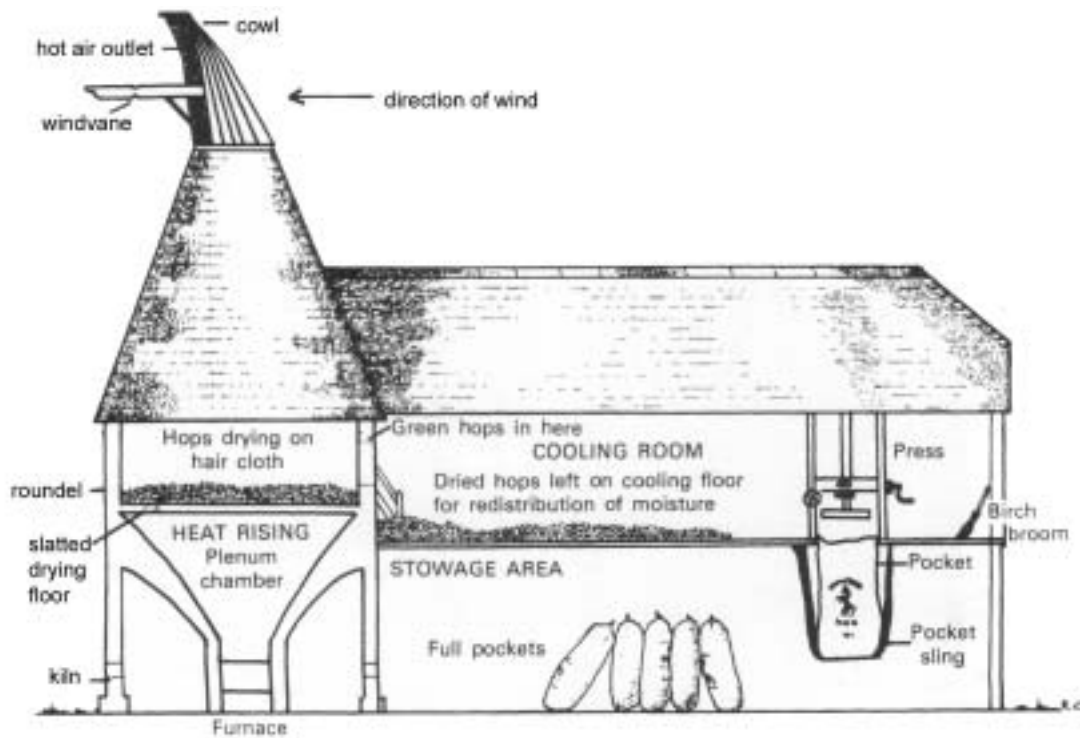
After the bines have been removed from the trellis, the cones must be picked. A table or rack with frames along each long edge to hold burlap bags is an excellent way to make this job easier. Build the table at a height convenient to the pickers, who stand along each edge stripping the vines. One or two plants at a time are laid on the table and picked clean. The technique for hand picking is the same regardless of scale. Holding the plant itself in one hand, strip the cones off the stems with the other. Try not to get bits of vine or leaf in with the cones. There should be no bunches of three or more cones. A clean pick is worth just as much as a fast pick, for time is also spent cleaning the hops after picking. Handle each cone gently, for the lupulin can easily drop off the cones, losing most of the value of the crop.

Large operations rely on quantity to overcome the natural loss of lupulin caused by mechanical picking. In mechanical picking, the whole plant is hung up next to a series of revolving wheels, whose serrated wire teeth strip cones and leaves from the plants. The cones and leaves then pass through a series of screens and blowers which remove most of the stems and leaves, and then pass up a conveyor belt to the oasthouse, or hop drying kiln. This rather violent process does result in a loss of lupulin, but the sheer quantities dealt with by these growers, and the reduced personpower spent picking, seems to be worth it for them. It is unquestionable, however, that the nimble fingers of a skilled hand picker result in a finer quality harvest.

When hand-picking, the vessel used is also of critical consideration. If left after picking in a non-breathable container for more than an hour, hops can sweat, heat, and start to mould before they hit the kiln floor. Burlap sacking or other open-weave sacking is the safest choice, although if the trip to the kiln is short, plastic buckets can certainly be used. Hops should never be left in the picking container overnight. If a small bucket is used for picking, a larger, breathable container can hold an hour's worth of cones ready for transport to the oasthouse.



These retired hop rollers reveal the wire teeth used to strip the hops from the vines in mechanical picking.



Design for Victorian-era oasthouse.
 graphic from *Hops and Hop Picking*, Richard Filmer

Another cautionary note: workers at Left Fields have often found that picking hops is soporific work. Whether it is the aroma, or the oils being absorbed by the skin of the pickers, conversation tends to slow after the first hour, and lunchtime is often marked by the sudden plop of heads on tables. Liberal application of water, internally and externally, as well as lively music, helps significantly in keeping pickers awake and work speeding along.

Drying

While the machinery of hops drying has changed significantly over the centuries, the principles have remained pretty much the same. Hops must be dried rapidly, over even heat not over 60°C (140°F). Good air flow is essential. Over the drying period the hops go from about 80% moisture to 8% or so, losing weight and increasing friability. The hops should be dry within 12 hours, and should be packaged as soon as they are cool.

In a traditional oasthouse, hops would first be collected in a 'greenstage', an area where green hops were dumped from their picking baskets prior to being put into the drying area. Older oasthouses used a slow-burning wood fire, built in a brick or stone kiln with a slatted wood floor overhead on which the hops were laid. Tilted, cone-shaped cowls on the roof of the oasthouse would swing around against the wind, creating a vacuum in the oasthouse, pulling heat through the hops on the drying floor.²⁴ Green hops would be piled on the drying floor over a burlap cloth (to prevent them from falling through into the kiln) 42cm deep or so, depending on how wet they were. They would be raked level and occasionally turned while drying, and would be dry within a day or so. Upon drying, the hops would be shoveled into a burlap-lined hole in the floor, where a man would 'tread' the hops, compressing them in the bag. When the bag was full, it would be pulled out of the hole and sewn up. The hops would then be ready for storage, shipping, and use by breweries.

Today, hops are dumped onto the same burlap sacking on the floor of the dryer, and hot air is still forced through them. But today, the floor is steel mesh, the hops are mechanically harvested, and gas-fired hot-air furnaces dry the hops in less than 8 hours. They are still compressed and wrapped in burlap sacking, but the compression is done by hydraulic press. Most large breweries use hops pellets or hops oils, not even the whole hops themselves, requiring further mechanization and refinement of the hops.

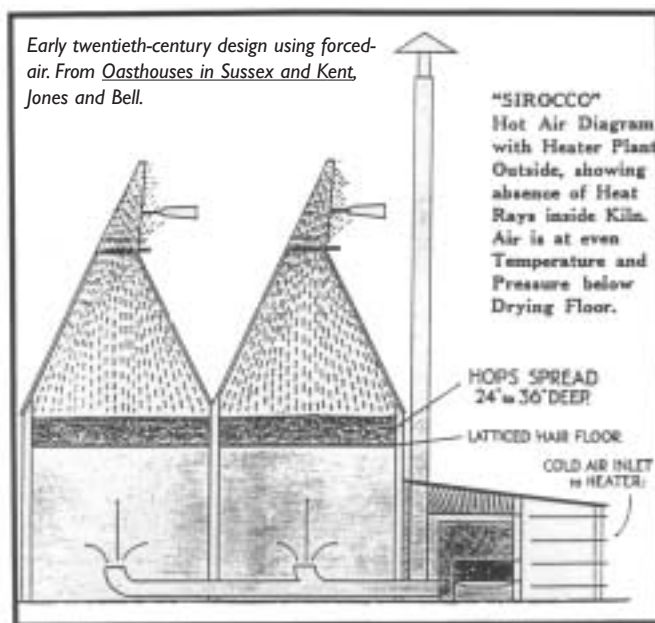
²⁴ p. 4, *Oasthouses in Sussex and Kent*, Jones and Bell

Small scale producers need to find solutions which lie somewhere in between the beautiful, wood-fired white-washed stone oasthouses of Kent and the modern beauties of large-scale efficiency.

The small-scale oasthouse can use any convenient and cheap source of heat: solar, hot water, natural gas, or wood. The main rules are that the heat source should be directly under the hops, and that hot air should be forced through the hops evenly. The bed of the dryer, or the racks on which the hops are laid to dry, should be large enough that the hops are no more than 30cm (12") deep. (Please note that large kilns will spread the hops up to 90cm (36") deep, but this depth of hops requires very careful monitoring of moisture levels and very efficient oasthouse design.) If the hops are spread on the floor of the dryer, the floor should be made of slatted or lattice steel, with sufficient support to allow a person to stand on it, if it is too large to easily reach across. There must also be a fabric cover over this floor, usually made of burlap or possibly linen. Finally, provision must be made for cooling the hops after drying and before packaging. This can be done by moving the hops from the drying floor to another, similarly structured area with a cooler temperature (and still lots of air flow), or by cooling the main drying area. Hops should be cooled to 20-30°C before packing.

Most heated-air furnaces or dryers can be used to dry hops, if they are able to put out sufficiently heated air. Grain dryers can easily be used, if adapted for slightly different temperatures than usual. The main concern is that air flows well through the hops as they dry, for otherwise the moisture driven out of the lower layers will collect in the centre of a bed of hops and cause them to blacken.

Hops at Left Fields have been dried very simply with reasonable success. The oasthouse occupies the top floor of a barn, which is situated facing directly into the prevailing wind. Natural air currents flow through the front opening of the barn and out under the eaves. The area is kept hot by passive solar radiation. The hops are laid 10-12cm (4-6") deep on racks of screens, which are made from cedar and fiberglass window screening. The shallow depth of the hops allows drying to proceed quickly, while the rack system allows plentiful air flow between and around the racks. Each rack can be monitored separately and moved, stirred or cooled as needed. This system also allows for a large number of different varieties of hops to be harvested and dried at the same time without mixing – vital for a small and diverse hopyard. The major improvement required to this system is to increase the temperature in the drying area. This is to be done by piping solar heated hot water beneath the drying hops, and using solar powered fans to add to the air flow. Hops dried in this way, in the dry September weather of the Shuswap, can be ready to pack in under 12 hours, depending on the depth of the hops bed and the initial moisture level of the hops.



The larger the harvest, the more effort it will take to dry it all the shortest amount of time. Larger growers would do well to construct a dedicated oasthouse, with a reliable and safe heat source. Such a structure should also contain a dedicated cooling area, a packing area, storage for baled or bagged hops, and a covered greenstage for collection before going into the dryer. This greenstage area can also be used as a picking area, if hops are taken from the trellis and brought in to be picked. The greenstage may also double as storage for dried hops bales.

Oasthouses can also be used to dry other crops, if the heat source is controllable. Onions, garlic, herbs and seeds can all be dried in the same area, if care is taken to ensure that waste does not contaminate the materials upon which hops are dried. In small dryers, steel screens which are removable for cleaning will facilitate this, as will the use of dedicated hops drying screens or sacking.

Packaging

Once dried and cooled, the hops are ready for packaging. Currently, large growers use sophisticated hydraulic presses to compress the hops into burlap-wrapped bales. This is an excellent primary stage of storage, as it compresses ordinarily very fluffy hops into dense blocks which can easily be cut apart into smaller quantities. The compression of baled hops keeps oxygen away from all but the surface layers, which slows the oxidation of oils and alpha acids. Burlap sacking is both cheap and breathable, and prevents moisture from accumulating in the bale. Lot numbers and grower identification can be easily stamped onto each bale, allowing for simple tracking of production.



Hops bales at Yakima Chief

These hydraulic presses are rather expensive however, and are beyond the economic reach of most small-scale growers. Fortunately, vacuum sealers do an admirable job of preserving hops, and permit the grower to package in quantities convenient for direct sale to the final market, whether that is home brewers or microbreweries. A good, industrial-quality vacuum packer is required, as home units often provide an inadequate seal. If possible, it is desirable to follow the lead of commercial packers like Yakima Chief, who first vacuum the air from the package, then inject a small amount of nitrogen back into the bag before vacuum sealing. This helps drive out any remaining oxygen and replaces it with inert gas, which aids in preserving the hop oils. It also results in a softer package, which may or may not be desirable.

Stay away from the light plastic bags sold for home vacuum packers. A barrier bag – that is, a bag which will not allow air to pass through the plastic – should be the first choice. If you find that you can smell the hops on the outside of the sealed bag, you need a different quality of plastic. The best option is to use an opaque barrier bag. This will keep the hops free of oxygen and light, which is critical to preserving those vital oils. These bags have a food-grade polyethylene liner, with a mylar or nylon opaque outer shell. Plain polyethylene bags, while they are food-grade, allow oxygen to pass through the plastic and should not be used. The best possible bags add an aluminium layer to the polyethylene/mylar combination, increasing the barrier by about 10 times.²⁵



Vacuum-sealed 5 oz bags from Freshops for the homebrew market.

Most homebrewers look for hops in 5 oz bags, while microbreweries require a minimum of 500g per package, and are accustomed to buying in 20kg lots. If a good relationship is established directly with a local brewery, hops can be packaged according to the amounts required for each batch of beer. While this is a bit more work for the hops grower, brewers appreciate the convenience and increased quality greatly, as they do not have to have open bags of hops deteriorating in their coolers.

Factors in hop storage

Hop oils deteriorate quickly in the presence of oxygen, light and warmth. Oxygen and light can be dealt with by vacuum packing in opaque barrier bags. Once packed, temperature comes into play. Hops should always be stored in a freezer or at least a cooler, as hop oils and alpha acids deteriorate much more slowly at lower temperatures. The rate of deterioration is halved for every 15°C drop in temperature.²⁶ Even hops which are baled in burlap must be stored below freezing to slow oxidation of oils and alpha acids.

The variety of the hops also determines how long it will last in storage. In general, bittering hops tend to store better than aroma hops, and some varieties will lose alpha acids more rapidly than others under the same conditions. This is due to the difference in lupulin from one variety to the next. Each hop variety has a different amount of natural antioxidants present, and some varieties' lupulin glands are more permeable to air than oth-

²⁵ p. 107 *Using Hops*, Mark Garetz

²⁶ p. 103 *ibid*

²⁷ p. 104, *ibid*

ers.²⁷ Oxidation of alpha acids creates the 'skunky' or 'cheesy' aromas of stale hops. Growers must be aware of the storageability of the different hops they are growing. Working directly with local homebrewers and micro-breweries allows the grower to encourage brewers to use first the hops which store less well.

Judging hop quality

The first thing to look for in dried hops is colour. Brown or streaky hops indicate sunburn, windburn or disease. Not all of these are fatal to high quality, but they are definitely indicators that a closer look is required. A clean green, tinged in very high-alpha varieties with lupulin yellow, is the goal. Windburned hops are still fine to brew with, but the colour may be off-putting to less knowledgeable buyers. Look also at the colour of the lupulin: is it



a bright, clear yellow or light orange? If it is a deep, dull orange, this may show oxidation, often due to too much heat in the dryer. Likewise, if most of the hops are broken, not still in cones, they may be too dry and oxidised.

Examine the hops for damage from insects as well - aphids, grasshoppers and spider mites don't just feed on the plants, they can damage the hops and reduce lupulin production.

The feel of hops is also vital. They should have a slight density, so that they do not simply crush to powder when handled. This is called 'cone stability', and it shows careful handling throughout the picking and drying process, as well as revealing how well the hops were dried.

Pressed or baled hops should not feel totally hard. Hardness is an indicator of too much moisture, which causes sweating and moulding over time. The handful should have a slight spring, and should fall apart when rubbed, but it should not powder. Lower alpha hops tend to break apart more easily than high alpha varieties, in which the lupulin makes the hops stickier. A handful should not display stems or leaves.

When crushed (and even before crushing), a handful of hops should have a distinctive aroma. While the specific aroma varies with the variety of hops, there should never be a sweaty, old-socks aroma, or a cheesy nose.

Whether the dominant note is floral, minty, grassy, citrus, herbal or woody, it should be clean and pure, without off-notes. Hay-like, straw-like, oxidized or musty aromas are indicators of poor quality hops. Smell the handful of hops several times. First, rub it lightly and sniff gently, to get the initial aroma. Then crush the sample thoroughly in your hands, feeling the lupulin glands break apart, and give this a long smell. Spend some time analyzing what you smell here, comparing it to other hops. Hold the sample for a while and smell it again. This releases more aromas, and may be the time to detect off-aromas. The aroma of the hops may change through the extended smelling process – this is fine! In fact, often the shifts in aroma are exactly what a brewer is looking for.²⁸

Finally, you can make a hop tea to determine what the hops will smell like in beer. This is a process usually performed by brewers, rather than hops growers, as it requires a sense of brewing beer and the ability to determine how initial aromas will age with the beer. However, it is interesting and educational for the hops grower, and ought to be tried at least once or twice. Ideally, conduct this test with a brewer, to help understand the process - not to mention cementing customer bonds! Making hop tea is still not as good as actually brewing with the hops, but it gives a better sense of how the hops aromas change through boiling. There is no single recipe for hop tea, but some effort should be made to approximate the conditions of brewing: therefore, the tea should definitely be boiled. One litre of water to a handful of hops is an easy quantity to handle. Bring them to a boil, and allow to simmer for several minutes before starting to evaluate the aroma. This allows the initial volatile compounds to dissipate, as they would in beer. Boil for about half an hour, evaluating the aroma at different times, right up to an hour and a half if you like. This will indicate how the hops will behave with different times in the brewing kettle. Be aware that not all the aromas will be pleasant, but this doesn't necessarily mean that the hops are not going to be useable, and indeed valuable. One of the most commonly used organic hops is Pacific Gem, which has a truly awful odor at certain times, but which also has a huge alpha acid content, and which, when properly handled, produces a fine, even bitterness.

Finally, if you are not sure if your hops are up to standard, get them tested. Brewers will require lab analyses of hop oils and acids in any case. There are a few labs across the continent which conduct hops analysis - ask your local hops broker for a contact, and check out the resource section for one lab in western USA.

²⁸ pp. 32-38 "The Good, The Bad, and the Hoppy" John Harris, *The New Brewer* Nov/Dec 1999

Post Harvest

After all the hops are in and packed, it is time to turn to the fields again. Before winter, any remaining long stems must be pruned off at ground level, and the hops should be top-dressed with compost and mulched well, especially in areas where winter temperatures stay below -20°C. This is also the time to drain the irrigation system and clean filters. Finally, summer green manures can be tilled in and winter crops planted, or perennial cover crops mowed for the last time. Sheep or chickens can now be allowed back in the yard to finish the fall cleanup. Harvested bines can be run through a chipper/shredder to be made into mulch, or added directly to the compost pile. Bines and biodegradable twine do not necessarily need to be shredded before composting, if the compost is very active.

Finally, some hops bines can also be turned into the basis for winter wreaths. Like grape vines, hop vines make admirable wreaths, either bare or as a base for seasonal greenery. These can become a lucrative value-added product for the small grower with good nursery connections and a little practice.



*A hop crown in the fall, showing green manure seeded around it, and the effects of tilling repeatedly both directions around the plant throughout the year. Only the stems which produced hops this year are visible, while the crown works on next spring's rhizomes.
From a Washington hopyard.*

Resources

Books & Magazines

All About Beer Vol 21 No 2, Organic beer feature issue

BC Organic Grower: Aphidoteles, Vol 4#4; *Ladybirds*, Vol 4#3; *Lacewings*, Vol 5#1

Brew Your Own, April 2001, Vol 7 No 4

“Culture, Drying and Baling of Hops” Herman C. Collins

American Agriculturist, Orange Judd, pub. New York, March 1865

Diseases of Fruits and Hops

H. Wormald, Crosby Lockwood & Son, pub. UK 1946

“Evaluating Hops” by John Harris, *The New Brewer* Vol 16, No 6, Nov-Dec 1999

“Growing Hops in the Home Garden” Miller, Gingrich and Haunold, OSU Extension Service Crop Science Report, www.oda.state.or.us/hop

Homegrown Hops

David R. Beach, self-published 1998 USA

Hop Variety Characteristics, Hopunion USA 1995

Hops and Hop Picking

Richard Filmer, Shire Publications Ltd., pub. UK 1998

“Hops in the Backyard: From planting to harvest and the hazards in between” Stephanie Montell, *Brewing Techniques*, May-June 1996 Vol 4 No 3

Oasthouses in Sussex and Kent: Their history and development

Gwen Jones & John Bell, Phillimore, pub. for the Hop Industry Research Survey, UK 1992

Organic Field Crop Handbook

Anne Macey, Ed. Canadian Organic Growers, pub. Canada 1992

“Readers Technical Notes” *Brewing Techniques*, July-August 1996 Vol 4 No 4

“The Hopvine” by Rupert Ponsonby, *The Grist* July-August 1995, Issue 65

The Pests of Fruits and Hops

A. M. Masee, Crosby Lockwood & Son, pub. UK 1946

“The Pursuit of Hoppiness” Don Put, *Brewing Techniques*, March-April 1996 Vol 4 No 2

Using Hops: The complete guide to hops for the craft brewer

Mark Garetz, HopTech, pub. USA 1994

Zymurgy Special Issue 1997

Zymurgy Special Issue 1990

Websites

www.freshops.com

Freshops – hops broker, supplier of rhizomes, and source of wonderful information on growing hops in the home garden.

www.nzhops.co.nz

www.nzhops.co.nz/products/pestfreehops.htm

New Zealand Hop Marketers Ltd. Brokers of organic and pesticide free hops. The sheep in hopyard picture is from their section on pesticide-free hops, which also has information on Integrated Pest Management for spider mites.

www.uvm.edu/~pass/perry/hops.html

University of Vermont, Plant and Soil Science Department

www.hort.purdue.edu/newcrop/afcm/hop.html

Alternative Field Crops Manual, Purdue University

www.hopunion.com

Hopunion is the biggest hops broker in the USA. They publish hops varietal specifications, as well as selling organic and non-organic hops. They also have great pictures of hops and some basic horticultural information.

www.realbeer.com/library/authors/smith-g/homebrew-hop.php

This is an excellent article on growing hops for the homebrewer.

www.hops.co.uk/abouthops.htm

Excellent information about hops in the UK, organic and conventional, as well as some basic horticultural information.

There are a lot more websites with information about growing hops, but they tend to be repeat postings of the material above, or to simply not have enough information for the serious grower.

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