Hops, Humulus lupulus

An investigation of agricultural practices and how producers are linked with business networks and consumers.

Report for
Canadian Nuffield Agricultural Scholarship Association

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Executive Summary

This Nuffield Report combines an examination of hop agricultural practices with an analysis of connections between business networks, consumers and hops.

The hop plant is profiled through botany, evolution, chemistry and human use. Outlines for agricultural requirements, associated costs and best practices for hop growing are included. Global hop market perspectives and producer comparisons are presented.

The objective of the scholarship study was to research the viability for hop production by Canadian farmers and to understand the hop market place domestically and internationally. The complex relationship between hops and beer brewing brought about the necessity to research the beer industry as well.

This report is a record of the findings of this study.

23 months were involved with research, preparation, travel and reflection. Farms, processing centres, research facilities and breweries were visited in 6 countries with interviews conducted at each location. The study is exploratory and the findings
should be read in that context.

The report suggests Canadian farmers considering hops as a potential crop must be aware of; best agricultural practices, high costs associated with production and processing, the volatile nature of the market with regards to supply and demand, competition with existing growers in a globally competitive market, trends in the brewing industry and the need for well formed knowledge about how and where crops intend to be sold.

The report concludes that Canadian farmers can grow high quality hops and that a focus on supplying local, small-scale brewing operations would be prudent when compared with trying to compete at a large and global scale.

The report has a supporting appendix providing visual references for hops and their evolution, hop products used by industry, hop and beer composition profiles as well as some common term definitions and measurements.

Acknowledgements

A truly heart-felt Thank You is extended to Mary Lou Morgan. Your message suggesting Nuffield Canada might be something I was interested in has proved to be life changing.

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Thank you to all the farmers, researchers and members of the brewing industry that have shared their hard earned knowledge, helping me to learn how much I really didn't know.

I offer thanks to scholars of Nuffield Canada and the extended Nuffield International groups for their dedication to agriculture and the support they provide our communities.

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1.0 The Study

1.1 Research

Hops are truly a global industry and my research required worldwide reflection. Selecting hops and related business networks as a study led to several areas of focus.

Production, processing and research each have global components but they also have traditional and very local connections. It was important to research the history of the hop world and also understand how the industry currently operates.

A farm in British Columbia involved with hops was a starting point to begin asking some questions. I next turned to the Internet searching for producers, processors, researchers and industry representatives for sources of information. Contacting many of these individuals and groups led to accessing written materials for recommended production methods, industry information, further research avenues and developing travel plans.

I spent a great deal of time reading about the global industry and narrowed my plans to focus on organic production and historical roots in the hop world.

Although I did discover links between Nuffield Scholars and hops, mostly through geographic proximity to production areas, I did not involve past or current scholars in my research or travel.

1.2 Travel

The hop industry has historical roots in only a few locations around the globe. The modern industry includes these traditional areas but also involves a small number of new areas. Even with only a few potential destinations I was limited by finances and was not able to travel to each location.

Germany and the Czech Republic are viewed as homelands for hops and are highly regarded within the industry. I felt compelled to visit both, as I could not imagine studying hops without experiencing these legendary locations. Alongside this living history I chose to investigate specific production techniques in Wisconsin, New Zealand and Poland.

Wisconsin, United States of America– April 9-11, 2010
New Zealand – December 22, 2010 – February 4, 2011
Poland – October 24–26, 2011
Germany – October 27-November 1, 2011
Czech Republic – November 2-5, 2011

I also took part in the Nuffield Contemporary Scholar's Conference that was held in Washington DC and Pennsylvania in the United States – March 6-14, 2010.

2.0 Hop Introduction

It was in 1753 that botanist Carl Linnaeus named and began the scientific documentation for the hop plant as, Humulus lupulus. He combined the Swedish word "humle" (hop) as the genus, Humulus, and the medieval Latin word for hop as the species name, lupulus. The hop plant was of course well known before this time but this was the beginning of its authoritative credentials.

Biological origins are attributed to China with divergent paths of development for the 3 recognized species that have since evolved: H. lupulus, H. japonicus and H. yunnanensis.

H. lupulus spread from western China and migration occurred at a high rate across Europe much as tree species spread after the last glacial period without human influence. This gave rise to what are now known as "European" or "Noble" hops.

H. japonicus and H. yunnanensis are indigenous only to Eastern Asia. The migration of these Asian populations spread through one migration from a single population or possibly from multiple migration events from distinct populations. This gave rise to what are recognized as genetically distinct hops. These wild hops have been crossbred with the "European" cultivars creating what are known as "North American" hops.

Of the 3 hop species, only H. lupulus is used for commercial trade with "European" and "North American" cultivars being used.

The two other varieties commonly known as Japanese and Chinese hops, do not produce the valued hop cone that H. lupulus does but they do possess genetic material that is increasingly being viewed as a valuable resource for future breeding with the commodity hop cultivars.

2.1 Taxonomy, Botany

Hop taxonomy traces through;

Family – Cannabaceae
Genus – Humulus
Species - Humulus lupulus

For a complete Taxonomical listing see Appendix 1.

Fascinatingly, the Cannabaceae Family contains 2 genera, Humulus and Cannabis. I write fascinatingly because both family members produce crops that are very commonly used around the world and no other plant family can lay claim to its members having such different, widespread presence in social circles.

The hop is a long-lived herbaceous perennial that remains productive past 20 years of maturity. It is dioecious (male and female are separate plants) and produces bines (twining vines) from a crown and over-wintering rhizome. These bines climb upwards of 5 metres. The bines develop each season and die to the crown following maturity each fall. Over time the perennial crown becomes woody and develops an extensive root system that can grow to a depth of 5 metres or more.

The growing season begins early in April with numerous bine shoots emerging from rhizome buds. The thin stalks are covered in trichomes or stem hairs and enable the bines to climb in a clockwise direction. At times they develop 8-12cm per day. Hop leaves form off the main bine and lateral branches, they are simple, heart-shaped to ovate, deeply lobed, and have serrate margins.

Around the summer solstice the lateral branches develop and flowers are produced in clusters. Both female and male inflorescence (flower clusters) form, but only the female flower or "cone" is wanted for commercial applications. As a result, commercial hop yards are planted entirely with females with possibly only a single male per 1,000 plants, if at all.

The female flowers develop into oval, cone-shaped strobiles and are commonly referred to as hops and they are what all the fuss is about.

See Appendix 2 for visual references of hop cones.

Their size ranges from 2-8cm in length and they are composed of yellowish-green scales. The interior surface of the scale bears small, yellow Lupulin glands that contain alpha and beta acids and essential oils that are key to commercial uses for hops.

2.2 Hop Uses; Beer and Medicine

Crop harvests from the "European" and crossbred "European" x "North American" cultivars are 95% used by a single industry; Beer Brewing.

The remaining 5% are used for a growing variety of medicinal purposes.

Hop compounds are released in the brewing process and contribute fundamental attributes of beer including aroma, flavour, body, mouth-feel, foam and head as well as preservative effects.

Hops are botanically diverse in their compound attributes. Each of the currently cultivated 150 varieties, has chemical profiles that are unique and lend themselves to different uses. The brewing customers may work with only a single type of hop or they may use as many kinds as they can access for many different styles of beer.

Beer is typically made with water, malt, yeast, hops and possibly herbs and spices. There are numerous varieties of each of these ingredients and beer production may involve a simple selection of these or a complex combination.

The different hop profiles provide a wide range of possibility for brewers and it is critical for hop growers to know what they grow and how they are used. The sheer variety sets up many questions as to farm and business strategy and management decisions.

Medicine

Although there is a long history of hop use for medicinal purposes exactly how they work within the body has not always been well understood. Wild hops have been traditionally gathered and incorporated into various remedies but sophisticated modern analysis is helping to focus the use of the varied compound groups used for medicinal purposes. Alpha and beta acids, essential oils and polyphenol compounds are all used and descriptions of these follow.

The major uses have been as sedatives, tonics and for soothing and claming effects on the body and mind. The bitter compounds are associated with the ability to strengthen and stimulate digestion and gastric secretions. There are wide uses as European folk remedies for treating bruises, boils, cramps, cough, cystitis, delirium, diarrhea, digestion, fever, fits, hysteria, inflammation, insomnia, irritability, jaundice, nerves, neuralgia, migraine, rheumatism, tumours, ulcers, worms and increasing the flow of milk for nursing mothers.

Outside of Europe hops have been noted as traditional remedies for many of these same conditions in China, Japan, and Korea. Several Arab health practitioners have used them for blood purification, reducing yellow bile and as an anti-inflammatory. Indian-Aryuvedic practices incorporate hops for restlessness, sedation, as a hypnotic and as an anti-bacterial. Native North American culture uses have been varied with the Cherokee using hops for an anti-rheumatic, analgesic gynecological aid for breast and womb problems and kidney and urinary issues, among the Delaware for earache and toothache, the Navajo for coughs and colds, the Dakota for wound healing and gastrointestinal disturbances and amongst the Fox as a sleep aid and for relaxation.

This is a long list of herbal remedies but primarily hops have been used for sleep disorders, to improve bladder function and to support digestion.

2.3 Hop Chemistry

Understanding the 3 chemical components of commercial interest found in hops is also critical for best management practices when growing hops. These elements are found within the Lupulin inside each hop cone with their importance being first, bitter compounds, followed by essential oils and then polyphenols.

The bitter compounds consist of alpha and beta acids.

The alpha acids impart the typical bitter taste in beer and they are the most critical for economic purposes. These compounds also support foaming stability in beers.

A wide range of acid composition and intensity exists with each of the approximately 150 individual hop cultivars having different alpha profiles ranging from 2-20%.

Hops have historically been divided into two types: “European/Noble” and “American”. The difference is based on the percentage of alpha acid content in each cultivar.

The “European/Noble” hops are associated with good aroma, are used as a conditioning or finishing hop when brewing, and their alpha range is roughly 2-7%. The “American” hops are mostly associated with bittering and are used as a foundation for a beer’s character and range from 7-20% alpha-acid.

Some varieties are considered dual purpose hops being used for bittering or for aroma.

Beta acids are aromatic in nature and also offer antimicrobial properties to beer helping preserve and keep fresh the brewer’s product. These acids also present options for alternative uses in the food industry as preservatives and as substitutes in the production of sugar and ethanol.

Individual hop cultivars also exhibit high variability within their essential oils. Approximately 300 of these compounds are found in hops. They deliver aroma to beer and a tremendous amount of research is focusing on understanding their make-up and interaction with each other in order to help breeding efforts create new cultivars. The essential oils also exhibit medicinal properties that are sedative in nature.

Polyphenols are secondary plant compounds and have antioxidant, anti-inflammatory, antibacterial and antiviral effects, as well as associations with cancer prevention and relieving circulatory ailments, diabetes and allergic reactions. The proportion of polyphenols in dried hops is between 2 and 8 %, with aroma cultivars generally containing higher content levels.

2.4 Hop History

100 years ago there were just a dozen hop varieties used by brewers worldwide. That number has increased to over 150 varieties today. Very few beers are made without the use of hops. It wasn't always this way though. Herbs and spices were used for roughly 9,000 years before brewers began using hops. Hops have become almost mandatory in beer production but herbs and spices still have their place in the beer world.

An abbey in northern France provides the first documented link between brewing and hops. In 822 Abbot Adalhard of the Benedictine monastery at Picardy in northern France wrote some guidelines for the running of the monastery and in this he covers duties and rules that include the gathering of hops (wild not cultivated). Hops had other uses at the time but he does distinguish that the hops were for beer production.

The preservation of beer through hops is first documented three centuries later at another Benedictine site at Rupertsberg, near, Bingen in the Rhineland Germany.

Around 1150, Abbess Hildegard, now known as St. Hildergard, healer and so called mystical philosopher, published a book called Physica Sacra ("The Natural World"). In this she warns of the hop not being very useful in benefiting man due to its melancholic effects but that its bitterness does benefit the preservation of drinks including beer.

Another famous historical figure associated with hop discovery is Pliny the Elder. He has been immortalized by one U.S. brewery with an infamous beer but unfortunately his fame is undeserved as it is based on misinterpretation and mistranslation of some of his writings.

Exact dates for the beginning of hops being cultivated for use in beer production are difficult to determine. There are some claims for the end of the ninth century in southern Germany around Hallertau but exact documentation is elusive. The strongest evidence points to northern Germany around the 1200s supplying trading areas around Hansa.

Geographical separation of growing areas existed and these boundaries supported a natural selection process where pollination occurred as a result of wind drift as male and female plants grew nearby one another. Growers worked with this process and selected promising seeds and rhizomes for new options.

These hops are the historical roots of modern hops and are recognized as "land races" with named references to the regions where they originated. Some examples include: Tettnang (Germany), Hersbrucker (Germany) Saazer (from the Zatec region of the Czech Republic).

New hop cultivars developed as growers tried to avoid disease and pests problems and increase yields but not necessarily to provide something new for brewers to work with.

Hops were being grown in what are now known as Belgium and the Netherlands in the 1300s and early in the 1500s Flemish weavers took plant material to England.

Identifying and naming hop cultivars developed in England with references for cone and bine characteristics such as Long White and Oval for the cones and Red Bine and White Bine for the stem. Growing regions and breeder's names also became mixed with new varieties with examples of regional references for Canterbury, Bramling, and Rodmersham and breeders such as Fuggle and Golding.

In 1629 English hops were introduced to eastern North America by The Massachusettes Company, and by 1646 commercial operations were underway. These hops eventually began cross breeding with wild North American hops and a particular variety known as Cluster accounted for over 95% of the commercial crop by the 1900s.

Morden, Manitoba, Canada has a notable role in the development of some significant North American hop cultivars. In 1916, Professor E.S. Salmon of Wye College, England collected seeds from wild hops growing along a creek running through the town and sent them back to the college. Around 1925, through breeding work with these seeds, a plant known as BB1 was developed. BB1 genetics became part of well-known varieties such as Brewer's Gold, Bullion and Northern Brewer.

Wye College developed many of the varieties that have been used to breed several of the most famous and popular hops grown around the world.

Other breeding work in North America led to a hop named Comet, and although not very popular it was one of the original uses for a North American wild hop developed into a new U.S. cultivar. The plant material was collected from Utah and crossed with an English hop known as Sunshine.

The first successful U.S. variety was named Talisman by Dr. Robert Romanko in 1968.

Also in 1968, the first harvest of another new cultivar occurred. But it wasn't until 1972 that USDA researchers at Oregon State University released the most famous U.S. cultivar, Cascade. It was an improved Fuggle cultivar bred to be resistant to downy mildew disease. The plant came from one seed selected out of over 7,000 in 1956 by another researcher, S.N. Brooks. It continues to be one of the most important hop cultivars used by brewers worldwide.

At the beginning of the 20th century it was realised that the soft resin content in hops, that is, the part that contains the alpha and beta acids, was responsible for

preservation of beer. Gradually brewers began to buy hops on their soft resin content, and growers began to plant varieties that contained a higher proportion of soft resins.

Sophisticated modern breeding work has led to the development of chemically induced tetraploids, which are used as breeding stock for triploid cultivars. Most hops are diploids, having 20 chromosomes, and these can be crossed with laboratory created tetraploids that have 40 chromosomes resulting in a triploid that has 30 chromosomes and two-thirds of the female parent's genetic characteristics.

The resulting triploid cultivars are most often sterile and seedless and this appeals to brewers and thus to growers (seeds can badly affect brewing). This breeding technique provides researchers with a higher degree of control when compared with traditional cross breeding and mass selection.

Hop varieties have expanded considerably from their wild roots. Hops with extremely high alpha-acid content, high-alpha hops with aromatic characteristics and seedless hop varieties are all very far from their ancestors. The characteristics expressed by these new plants offer a wide range of potential for brewers and other industries.

Although the number of options for growers is expanding many new varieties are protected property and grown exclusively in specific locations by private commercial interests.

2.5 Global Industry

Hops have been cultivated for commercial purposes for roughly 1,000 years. Hops are used around the world and producers face a globally competitive environment.

Production for local markets certainly exists but is subject to price and quality comparison with globally available product and this creates a challenging market for small producers.

Germany is considered the original production site with other notable historical sites being the Czech Republic, England and the Pacific Northwest in the United States.

European commercial production also exists in Poland, Slovenia, France, Spain, Russia, Ukraine and in minor amounts in several other locations.

China has entered the production market very quickly and Japan also produces some hops.

North America has had production in several areas but currently the absolute majority is grown in Washington State, Oregon and Idaho. Canadian hops have been grown in several places but without global significance.

Australia is the largest producer in the southern hemisphere but New Zealand, South Africa and Argentina also have production.

The hop industry can best be described as volatile. Production has developed, expanded and contracted at incredible rates. Challenges for producers revolve around disease pressures, yield, competition, over and under supply as well as contractual prices and spot market prices. A good harvest by no means ensures a good return.

Although early European cultivation of hops developed the notion that an acre of hops was more profitable than 50 acres of arable land, the idea that hop growing was more insecure than any other form of agriculture also developed. Annual yields traditionally swung wildly much as today's prices do for the crop. Hop growing has never been a stable industry.

An early rhyme from Kent, England rang out:
"First the flea, then the fly/Then the mould, then they die."

2.6 Current Market Data

		Change from 2009
Area Under Hop Cultivation	52,156 Hectares	-8.1%
Total Hop Production	99,879 Metric Tons	-12.1%
Total Alpha Production*	9,475 Metric Tons	-13.5%

Figure 1: Global Hop Production 2010, The Barth Report, Hops 2010-2011

* As noted earlier hops are divided into two categories, Aroma and Bittering. The bittering varieties account for the majority of hops that are grown and their alpha acid content is considerably higher than the Aroma varieties. Brewers use alpha acids as the foundation for their beers and thus require more of these compounds. This results in a critical data point being the total amount of alpha acid produced and available in the market.

Number of Countries	Number of Growers	Total Production (Hectares)	Yield (Metric tons)	% of Global Production	% of Global Crop
10	55	187	240	0.4	0.3

Figure 2: Global Organic Hop Production 2010, The Barth Report, Hops 2010-2011

	Number of Farms	Average Size (Hectares)	Total Hectares	Yield (Metric tons)
Germany	1,435	12.8	18,109	34,234
United States	73	174	12,662	29,707
Czech Republic	133	39.2	5,017	7,771
Poland	868	2.1	1,768	1,867
Slovenia	133	10.5	1,517	2,462
England	56	19	1,069	1,608
France	86	6.7	576.2	792
Spain	34	6 @ 50 28 @ 7	507	1,039
Ukraine	62	20	1,240	786
Russia	14	30	420	66
China	58	95	5,510	14,121
Australia	8	56	448	1,044
New Zealand	19	16	304	573

Figure 3: Global Hop Production, Country Comparisons 2010, The Barth Report, Hops 2010-2011

3.0 Production

3.1 Environment

Hop plants have a remarkable range for survival with varying climatic and environmental tolerances. They can be found in temperate areas around the world but specific conditions are necessary for the production of the commercially valuable chemical compounds used by commercial customers.

For the northern hemisphere the best growing conditions are found between the latitudes of 35N and 51N and across the equator in the south between 34S and 43S, and up to 1,000 metres in elevation.

Winter chilling is required with temperatures below 5C for 1-2 months and conversely 120 frost free days are needed.

Adequate production of flowers and cones require 8+ hours of sunlight and generally long day lengths. An annual temperature range of 5.6C to 21.3C is ideal. However, some varieties are heat sensitive, especially during flowering and cone formation, and although not entirely necessary for all varieties, the plants prefer a temperature range of 15-18C during the peak growing season.

Annual precipitation rates between 30-135cm are minimum requirements for healthy harvests and supplemental watering may also be necessary.

Warm days and cool nights can develop great crops come harvest time.

3.2 Soil Conditions

Hops can tolerate a range of site conditions but ideal soil conditions are alluvial, nutrient-rich, light, deep sandy or gravelly, well-drained loams with a pH range of 5.7 to 7.5.

3.3 Propagation

Plant propagation from seed is unreliable for hops. Vegetative propagation from rhizomes is standard for the non-research or non-breeding specific grower.

After several years of growing the perennial crown can develop into a mass the size of 1 metre x 1 metre x 5 metres deep. This crown has dozens and dozens of potential pieces for propagation. Once healthy growth after year two has occurred and care is given to ensuring the long-term health of each plant, many rhizomes can be cut in order to grow out more individual plants or for sale to other growers.

In the northern hemisphere in mid-March cuttings can begin to be taken. It is ideal for cuttings to be planted before normal seasonal growth advances too far, with April and early May being best.

Lateral bud bearing rhizome lengths of 5-15cm can be cut and planted directly into fields or potted and grown out in sheltered conditions such as a hoophouse or greenhouse. The rhizomes can dry out and whither to a point of death if not planted immediately and require cold storage in a moist environment to ensure survival.

The cuttings should be planted horizontally with buds up and be placed 2-5cm below soil level. More than one cutting can be planted together in order to ensure at

least one plant establishes but this is not necessary if the quality of the cutting is trusted.

Although rhizomes are most widely used, woody cuttings are also an option. Cuttings can be taken from stems with 1-2 nodes and two leaves with 5-8cm of wood beneath the node. These cuttings are often planted in pots or other temporary locations for one season before being placed in a permanent location.

3.4 Labour, Trellising and Seasonal Practices

Hop growing is very labour intensive. Mechanization and expensive equipment are used by large-scale commercial operations during the seasonal growth stages and for harvesting and processing.

People are still needed through all stages of the season but equipment can reduce labour requirement for individual jobs from 4, down to 1 person.

Underestimating labour needs is not a great idea and estimates vary for managing the different jobs through the year but generally two people are required for every acre and double this for harvest workloads.

The climbing nature of the hop requires trellis support for optimal growth. A hop yard can look truly incredible in full growth with row after row of 5-7 metre walls of vegetation towering above fields. The plants will climb just about anything, walls and trees included, but for commercial growing purposes, proper pole lines need to be established.

Trellis design and planting patterns vary from location to location. Typical trellis systems involve a grid system utilising wood, concrete or metal poles buried 1.5 metres in the ground and placed 8-16 metres apart with overhead hi-tensil or heavy gauge wire suspended between poles in a grid fashion. This set up is permanent and requires maintenance over time.

On average there are 800-1,000 plants per acre with each being planted 1 metre apart per row. Numbers of rows per grid varies from farm to farm with some planting a row every 1.5 metres and others planting every 3 or 4 metres. The variation depends upon the type of field maintenance to be performed and the kind of equipment being used by growers.

Plants are strung vertically to the overhead wire with 1.3mm iron wire or twine usually made of coconut fibre. These are annual wire/twine supports that are removed from the field with the harvest. Each plant may have one or multiple wire/twine lengths per season.

Each season hop plants produce dozens of bine shoots that will compete to climb. There is debate within growing circles as to how many bines per plant will produce

maximum yield and also how many bines should be allowed to climb each support wire.

One of the risky parts of growing hops involves the bine shoots themselves. If the growing tip of a shoot is broken during the early stages of development, flower, and therefore, cone development will not occur. A bine may continue to grow but the economic potential is lost. This sets up a risky decision for growers where they have to decide how many shoots to allow per plant and how many shoots to allow per vertical support wire/twine.

Industry often recommends 1 bine per vertical support and 2 bines per plant on 2 separate wires/twine. However, I have yet to meet a grower who only allows 1 bine per vertical support. The risk if it breaks is so high that most growers allow 2 and even 3 bines to grow up the same support. This does not double or triple the yield because the competition reduces the yield from each individual bine but the end result is a yield equal to one very healthy bine. I did meet growers who only allowed one group of bines per plant to grow but I also met growers who allowed 2-3 groups to grow. Each had their own personal reasons and all felt comfortable with their yields. All other bine growth must be removed.

During the early stages of growth the bines must be monitored to ensure they continue to work their way up the support wire/twine. Usually 1-3 visits through the yard over several weeks are necessary, as the leading growth tip will often fall away from the support wire/twine. However, windy or stormy weather and individual bine growth may create the need for further training. This process is critical as hop yields are day length dependent and reduced yields will result from insufficient growth.

As bines reach past 2.5 metres the lower leaves should be pruned away. The stripping helps with air flow and is also critical for improving yield. Removing this material from the field is ideal as hop yard sanitation is key to reducing possible disease development. In some countries sheep are used to perform this low level pruning and others simply strip by hand. When using sheep it is necessary that the bines have developed past their initial soft green growth to the point of being larger in circumference and almost woody, otherwise the sheep will munch through the soft tissue and the bine will be lost.

3.5 Fertility and Irrigation

Fertility: As with any field and crop management, soil tests are a critical starting point to understanding soil conditions and amendment needs. The nutritional needs for hop plants vary based on the soil conditions, growing region, varieties being grown and previous seasonal crops.

Nitrogen (N), Phosphorous (P) and Potassium (K) amendments are usual considerations especially with regards to replacing what was removed with a

previous year's harvest. The amount of material being removed from a hop yard can be considerable with roughly 1,000, 7 metre bines leaving the fields per acre.

Typically hops remove N – 120-140lbs, P - 60-100lbs, K - 80-150lbs per acre/per year and these figures need to be replaced in order to ensure successful future harvest.

Good quality compost and aged manure are considered great supplements to soil health as both macro and micronutrients will be worked into the soil. This will help with nitrogen and other nutrients being added to the soil over a long time period helping plants to access needed fertilizers throughout their growing cycle. 2,000 to 3,000 kilograms (2-3 tons) of compost or manure per acre is recommended for hop yards per year.

As hops are a perennial, using cover crops in open soil spaces between rows of plants can be an effective strategy for improving field and crop health. Some hop yards have no growth in the fields outside of the hops themselves, with bare soil existing between plants and rows of plants. Grower preference, equipment and field maintenance strategies can dictate whether or not cover crops are used.

Growers who use cover crops utilize a number of plants for different reasons including; building soil health, attracting beneficial insect populations, preventing soil erosion and conserving soil moisture.

Oats, vetch, red and white clover, buckwheat and mixed annual grasses are used on their own, or in combination, with mowing or plow down for incorporation also part of the strategy. Nitrogen fixation is a common goal for using cover crops, with white clover being a great option.

Irrigation: Different irrigation needs and strategies exist in different hop growing regions. Some areas do not water mature plantings at all, some water from 4-8 hours a day with drip irrigation and others use sub-soil monitoring devices that deliver water as soon as soil conditions begin to dry out.

Initial plantings of hop rhizomes require special attention as they establish. Heavy soaking of new plantings on a regular basis, daily or weekly, in the first year may be needed in order to ensure the rhizomes survive.

3.6 Insect Management

Two very well known insect/pest issues exist; Two Spotted Spider Mite and the Hop Aphid.

Spider mites pose real threats for hop growers. Feeding by mites on lower leaves in the spring ingests plant sap and causes leaves to yellow, shrivel and die. Cone damage can also occur resulting in "red hops" with brownish, brittle cones being the

result. The mites are pale yellow to red in colour and often have a dark spot on both sides of the body. Dry, warm weather can cause dramatic increases in populations. Problematic thresholds are considered at 10 mites per leaf.

Hop aphids feed directly on hop plant juices. Serious problems develop when the aphids enter cones and secrete honeydew (plant cell sap) causing a sooty mold in the cones. Overall plant health and yields are reduced. The aphids over-winter on Prunus species (trees and shrubs which include plums, cherries, peaches, apricots and almonds) and return to hop plants in the spring. The aphids are small pale and green. Controlling populations before flowering to prevent them from entering young cones is recommended. Problematic thresholds are considered at 8-10 aphids per leaf.

Natural control methods include encouraging mixed habitat and plant communities in order to attract beneficial predatory insects. Lacewings, ladybugs and syrphid flies can reduce aphid populations. Diatomaceous earth applications and lime and sulphur based sprays are effective. Growing ground cover mixes that include red clover will host predatory mites that prey upon spider mites.

3.7 Disease Management

Hop yards are particularly susceptible to several diseases that include;
Downy mildew *(Pseudoperonospora humuli)*, powdery mildew *(Podosphaera macularis)*, and Verticillium Wilt (*V. albo-atrum* or *V. dahliae*)

All varieties of hops exhibit varying levels of susceptibility to the potential diseases, from extremely low to very high, and in fact breeding efforts often focus on reducing susceptibility in new cultivars. Different climates, especially humidity, can increase disease problems as can excess fertilizers and irrigation. Grower choices regarding which hop varieties to grow are often made with an attempt to avoid disease issues.

Downy mildew occurs because of a fungus that over-winters in infected crowns and results in a “spike” or stunted bine/shoot that exhibits small, yellow, cupped leaves. The mildew may bloom in wet weather causing cones to become infected and become blackened and unmarketable. Heavy spring rainfall and warm temperatures, 15-21C, bring onset of the mildew. Stunted growth and reduction in cone production result. The basal spikes need to be removed from fields immediately and infected root crowns should also be removed. Pruning lower leaves can also help to improve air circulation reducing incidence of the mildew. Management practices include growing resistant varieties, ensuring fertilizer and irrigation are not over used, removing waste plant material from fields, copper based fungicides (organically certifiable), and Effective Microorganism (EM) spray applications.

Powdery mildew is also the result of a soil fungus. The mildew shows up on plants as white, powder-like splotches on leaves or stems. Growth blooms with damp and

humid weather in low-light conditions where minimal air circulation occurs. Young growth in overly fertile soils can be particularly susceptible. Growth of the mildew can thrive with temperatures in the range of 17-21C. Resulting effects can be stunting of the plants, reduced yields and cone shattering. Similar management practices for Downy Mildew should be followed but with sulphur based fungicides for Powdery mildew, as well as avoiding over-fertilization.

Verticillium Wilt is another fungus that lives in the soil and infects plants through their roots. Leaves turn yellow from the base and move up the plant. A "Tiger-stripe" pattern on leaves can be observed where the areas between veins are infected first. Internal examination of cut bines exhibits a brown tissue discoloration. Infected hop yards will diminish over time. Excessive nitrogen can increase rates of wilt. The planting of winter rye in alleys between plants can reduce wilt by up to 70%. Bacterial cultures that grow with the winter rye act to inhibit the wilt. However winter rye should only be planted every 2-3 years. Competition for water with hops is also a concern when growing winter rye. Planting resistant cultivars, removing infected plants and ensuring fertilizer and irrigation are not over used can help minimize infection.

Hops are susceptible to a wide assortment of viruses, diseases and insects. Each year, cultural practices are refined to better control their spread, and the damage they inflict on the crop. For a complete list of Pests and Diseases affecting hops view Appendix 7.

3.8 Weed Management

Competition for soil nutrients and moisture are important reasons for growers to consider eliminating weeds from hop yards. Pros and cons exist for common control methods such as mechanical and hand cultivation, and mulching. Equipment and labour costs are considerations as is soil erosion and decreased soil quality with repeated tillage.

Monoculture cropping, especially in perennial crops, can be very problematic over time with relation to decreased soil health and pest and disease issues.

I encountered a mix of strategies with some hop growers removing all non hop plants from their fields while others clear the alleys between plants but leave non hop growth in between the individual plants and still other growers use cover crops in alleys including oats, vetch, buckwheat, and red and white clovers.

4.0 Harvest and Processing

4.1 Harvest

Each hop variety matures at a slightly different time but generally harvest occurs in August to September. Timing can also be dependent upon the season. There are several factors to consider when deciding to begin the harvest and there is a bit of

art and science involved as well. Timing can be crucial as the lupulin content of the hops are in an optimal condition for approximately 1 week, give or take a few days. A harvest yield of 2,000 lbs per acre is considered standard with organic production typically being 1/2 – 2/3 of this.

As the season approaches harvest the cones themselves begin to dry down and this moisture content can be a good indicator as to when to begin. At this stage in the year the cone is green and plump and can feel quite vegetative. Ideal harvest time varies somewhat but it can be related to the cone drying to a slightly papery feel. Weather conditions and pest and disease issues may also influence a decision to begin harvest.

Taking the hops from the field too early may result in reduced quality of the acid and oil contents as well as reduced yields for both the current year and the following year. Allowing the cones to pass maturity may result in discoloration due to oxidation, reduced quality of the acid and oil content as well as advanced drying of the cones, which can cause them to shatter and be un-harvestable.

Several methods for harvesting exist depending upon the scale and investment in an operation. Highly specialized, very expensive equipment or simple tools and hands can be involved. The obvious consideration is scale and whether a hop yard is multiple hectares in size or if it is a yard that is much smaller.

Two stages of harvest are involved. The first is to cut the bines from their support trellis and the second is to strip the cones from the bines. The first can be relatively quick, even by hand. The second can be very quick if done mechanically but if done by hand can take many hours of labour. And that is a definite understatement.

Large scale farm practices involve specialized and expensive equipment. The units that remove the bines from the field resemble a high-sided wagon pulled by a tractor. There is a cutting tool at the front of the wagon that grabs and cuts the bine/wire/twine and then as the wagon moves forward the top of the bine/wire/twine is ripped from the top wire of the support trellis and the whole length falls into the wagon. The wagon can then continue through the fields until full and the crop can be off loaded to the site of the next stage.

4.2 Picking/Stripping

As mentioned stripping by hand is very time consuming but mechanical picking involves each individual bine being fed into a very large unit that strips the cones and vegetation from the bine. The cones and vegetation are separated through a series of belts and gravity resulting in the cones being sent for drying cleaned of debris and ready to be dried. These units are large and expensive but can process bines at an incredible rate of approximately 600-800 per hour with 8-10 acres being processed in single workdays. Estimates vary but it is thought that one picking machine is needed for every 250-300 acres of hops.

4.3 Fresh and Dry

Although "straight from the field" hops are used to make unique seasonal beers, currently only about 5% of hops are used fresh in the beer or medicinal industries. Fresh hop composition:

Alpha-acids, beta-acids, hard resins - up to 25% in total
Essential oils -up to 3%
Polyphenols - up to 14%
Cellulose - up to 50%
Water - up to 12%
Protein - up to 22%
Minerals - up to 10%
Lipids, waxes, pectins and carbohydrates - each 2-3%

These numbers vary depending on the variety, crop year and growing region. Immediately after harvest the volatile compounds that are critical to end-users begin to degrade. Preservation of these components is the goal of the various processing techniques, although, water is intentionally reduced for purposes of storage stability, space, and to reduce shipping costs.

Drying

Growers and processors handle thousands and thousands of kilograms of fresh hops and this results in a tremendous amount of material that needs to be stored and eventually shipped. Drying of the cones can reduce the weight and size of the material and this can also help to preserve the hops from mould and other storage issues.

Drying operations vary in different locales and are dependent upon scale. The different configurations for drying are quite varied and can involve a single stage or a series of layers that shift with belts and time. Essentially hops are piled approximately 0.25-1 metre deep and forced air (around 60C) is pushed through the piles for a varying length of time. The cones are ideally reduced from 80% to 10-14% moisture content and 30% of their original weight. The cones are then allowed to cool, air dry and condition for a day or more.

The dried cones can then be baled, with large industrial bales varying in size but approximately weigh 40kg. From here the dried cones can be packaged as whole cone hops where they are bagged and vacuum sealed. It is preferable to use a package type where the hops will not be exposed to light or oxygen.

The dried hops can also be pelletized.

4.4 Pelletizing and Extract Products

Pelletizing

Pelletizing is often performed by a contractor as pelletizing units are expensive and not exactly needed by each individual grower. About 60% of the annual harvest is converted into pellets. The cones are cut, milled, homogenized, and pressed into pellets. Again it is ideal that storage bags are dark and preferably vacuum sealed. Pelletizing can also reduce the bulk of material by a factor of 10 helping to reduce storage and transport requirements.

Two types of pellets are made, Type-90 and Type-45. The difference refers to the approximate yield from the volume of hops processed. If 100 kg of hops are processed into Type-90 the yield is approximately 90 kg. If the hops are processed into Type-45 the yield is approximately 45 kg. (Current processing techniques have advanced and this should have T-90 pellets being referred to as T-95 but the older reference persists.)

But there is a distinct difference in the pellets with Type-45 being a product with exact specifications in content and Type-90 a more general approximation. The difference between the two products lies in the technical processing.

Type-90 hops are cleaned, dried and then ground and retain all the compounds of raw hops. Type-45 pellets undergo a more complicated process where the hop powder is concentrated mechanically to a uniform end value.

Both pellet types contain all the substance groups of raw hops, but in different proportions.

Extract Products

Hop extract products are modern industrial options for customers. For the most part two types of extract processes are in use, CO2 and Ethanol. The method used determines which groups of substances are extracted.

CO2 extract is usually manufactured using supercritical CO2 with temperature and pressure controls enabling selection of compounds. The soft resins (i.e. alpha and beta acids and non-specific soft resins) and oils are removed and the hard resins and polyphenols are not extracted.

Ethanol extract uses a mixture of alcohol and water to extract all the groups of substances found in raw hops. Further processing separates the extract into pure resin extract (including all oils, soft and hard resins) and tannin extract (which includes all polyphenols).

In general, the most important aspect for the brewer is the content of alpha acid in the hops or hop product. There are new and distinct needs of customers that are

being met with increasing sophistication in processing methods. Some of the new options available include: variety specific hop oils, Isomerized Hop Extract, Tetrahydro Isomerized Hop Extract and Reduced Kettle Hop Extract.

5.0 Findings from Travel

5.1 Wisconsin, United States - April 9-11, 2010

I took part in a production workshop organized by Gorst Valley Hops. As I had very limited practical knowledge of hop growing I benefited a great deal from the organized structure and the opportunity to dialogue and ask questions of 3 experienced presenters. 30 workshop attendees also provided opportunities for me to learn as each had varying levels of experience and knowledge with starting hop operations. I received quite a bit of written material compiled by the organizers which I have returned to many times through my scholarship and during my two years of growing hops.

5.2 New Zealand – December 22, 2010 – February 4, 2011

New Zealand Hops

I met with Doug Donelan, Chief Executive at New Zealand Hops, at their facility in Richmond. All hop production in New Zealand is clustered close to Nelson, and Richmond is a small place just down the road from the bigger urban area of Nelson.

We discussed many issues including; NZ's total hop production (1% of global total), organic production numbers (1.5% of NZ production, with double the cost for producers and sale prices) and the industry as a whole. He also described the structure of New Zealand Hops the entity that is jointly owned by hop growers in the country. It acts as a contract processor for the growers (thus the growers are their own clients) as a single desk marketing agent for export sales (80% of production is exported) and also as an importer that sells foreign hops to the domestic brewing industry.

Doug toured me around the large processing and storage facility at New Zealand Hops where I asked lots of questions about quality control, capacity for processing, numbers of workers involved and long term viability of stored hops.

We then jumped in his car and toured some of the farms he thought I should see. Our first stop was to a farm where the first thing I encountered when getting out of the car was an infamous NZ sheep staring at me. New Zealand is well known for having loads of sheep all over the country and the hop growers famously make use of them for pruning duties in their crop. A great first encounter with New Zealand hop farms! The farm we were stopped at was the highest yielding producer in the country but unfortunately the grower was not available so Doug and I talked about production strategies used in the country and how the growers share information

(through field days where they gather with one another and researchers to share best practices and new information).

We moved on to another farm where once again the grower was not available for a tour but Doug and I walked around and talked about the export nature of most production where the crops are contracted for 3-5 years in advance with representatives of large multi-national breweries visiting and assessing farms and making arrangements based on variety selection and quality. This particular farm was over 100 acres in size with all related equipment and infrastructure, annual contracts with some of the largest breweries in the world and the farmer was in a position where none of his 4 sons wanted to take on the operation. Shocking and sad. So much effort had went in to building a highly regarded operation and the family wasn't interested in the legacy. Doug said that New Zealand Hops would probably begin to contract and manage the farm when the grower was interested in stopping.

We next paid a visit to a customer of New Zealand hops, Golden Bear Brewing Company. Doug was a professional brewer in Australia before joining New Zealand Hops so it was a great opportunity to ask questions of him and Jim Matranga, owner and brewer. We talked of how small brewers are interested in a range of hops so they can produce unique and flavourful beers, practical considerations for brewers about labels, bottles and equipment choices, the types of beers that are usually the most popular (70 % easy drinking lager styles), marketing directions where Jim felt the trend in the beer world of being irreverent can only sustain a brewery for so long and that at some point a degree of respectability probably has to enter the marketing strategy, practical sizes for successful small scale breweries and how adding a brew pub to a brewery can increase sales and margins dramatically. Doug wrapped up by expressing the notion that hops are similar to antiques – hard to find enough to sell - but you can sell them all once you have them.

We also sampled some of Jim's delicious beers.

This was the end of my tour with Doug and I was very grateful he was able to offer such a comprehensive introduction to New Zealand Hops and the local beer industry.

Hinetai Hops

I next visited with Dean Riley at Hinetai Hops in the Motueka Valley. Second generation growers with 54 hectares and 8 different varieties of hops along with 16 hectares of black currants on the farm as well.

Hinetai are organic producers and I was surprised to learn that only 2 NZ growers have organic production and neither is exclusively organic, they simply have isolated fields that are certified organic. Hinetai's total organic production is only 2 hectares but Dean told me they are some of his best quality hops and that he is

committed to growing more. I felt a keen interest from Dean for organic production and he certainly shared strong knowledge of organic practices.

The farm is spread out quite a bit so we toured the different fields in his truck and we talked about a wide range of issues including: their production strategies and challenges related to irrigation (all overhead watering), weeding (in the alleys between rows and between plants when possible), sheep (a neighbour rents them to Hinetai for a very small amount and moves them from field to field), trellis construction, seasonal training of bines up the trellis with contract workers (20 staff for 2.5 months paid on piece work for each plant strung up), that their entire production is under contract to major international brewers (MolsonCoors and Japanese brewers), when to harvest (testing is performed to measure the alpha content waiting for maximum values before harvesting and dry matter testing from leaves), yields (average 2.5 tons for high alpha varieties and 2 tons for aroma, but the high alpha are hard to sell due to international competition), employees (1 full time manager, 2 full time staff, 4 permanent casual workers and family members including Dean) and a thought from Dean that 20 hectares minimum would be necessary for a grower to sustain an operation as a result of the start up and equipment costs associated with hops.

He also took me to their processing area and showed me the Wolf Picker they use to strip the hops from the bines (20 bines a minute and 1/4 acre per hour), and the drying kilns they use (600-800 lbs of dry hops 5-6 times a day, taking 12 hours to dry). The boiler they use to heat the kilns is coal based.

A last comment Dean shared with me related to the pressure they feel from increasing real estate speculation in their area. The Motueka Valley is a beautiful area with a gorgeous river and stream system, wild landscape and mountain slopes mixed with farms and small land holdings. The price of land in their area has risen to between $20,000 and $70,000 per acre and despite his interest in expanding these prices make it very challenging.

Mike's Organic Brewery

Almost all hops are sold to brewers. Knowing the customer is critical for any business operation. When planning my trip to New Zealand I came across a listing for Mike's through WWOOF (World Wide Opportunities on Organic Farms). I had no experience with beer production but had known I needed to understand this important chain in the hop world and the opportunity to stay at an organic brewery a stone's throw from the Tasman Sea was a learning opportunity I could not pass up.

I was fortunate to stay here for a week and help inside the brewery and around the grounds. Father and son, Mike and Ron, Trigg, and their family relocated from South Africa and purchased the existing small scale brewery in Urenui. The business was established by a local named Mike and expanded for a number of years until the

Triggs' bought the facility and the business. Mike Trigg is not the original Mike but he is the new brewer.

I was well aware that almost all hops are used in the brewing industry but I had very little knowledge of beer production and what the industry was all about. I felt I needed to understand beer production but I remember feeling intimidated at the daunting task of trying to understand beer.

Brewing is an ancient tradition and beer is a large part of social customs in cultures the world over. I had never home brewed anything and felt very lost when trying to sort out how to approach the chemistry and specialized production involved with beer.

My time at Mike's was a breakthrough for my understanding of the beer world and thus the hop world as well.

I arrived just as a delivery truck was unloading bags of malt and after only exchanging names with the man receiving the delivery I was left alone to stock pile the bags of malt in a storage shed for the next hour. Later on that evening I was formally introduced to the folks at Mike's and was given a bed in a small cabin on the edge of an avocado orchard on the property. I was up first thing the next morning helping start a brew before breakfast.

For the next week I helped out anywhere I could as Mike and Ron answered any question I had and found work for me to do. (I will say they were impressed with my weeding abilities as they asked me to clean things up a bit around the property in advance of a wedding that was taking place the upcoming weekend.)

Next to the brewery Mike's has an old school house that has been converted into the pub and patio areas of their business. It was here that my real breakthrough into the beer world happened. After lunch on my second day there I picked up a magazine from a stack of reading material focused on the beer industry. The magazine, Beer and Brewer, is published in Australia and from it I was able to start really learning about the beer industry.

For the next week, at breakfast and lunch, while I was washing kegs (there are minutes of downtime in this process) after dinner and practically all other free time I was reading every issue of the magazine I could find. The crucial thing that the magazine offered was a mix of profiles of businesses in the brewing industry across Australia, New Zealand and some global companies. There were also profiles of local people who were professionally or personally involved with the beer world and technical articles relating information about brewing. There was such a wide range of articles I began to grasp the beer world.

Picking up that magazine was one of the pivotal moments in my scholarship. Beginning to understand the beer world helped me to understand the hop customer.

Before that I knew brewers wanted hops and I sort of understood why but with the reading I did at Mike's I was finally getting the real whys'.

Additional Brewery and Brewpub visits.

During the rest of my stay in New Zealand I sought out other breweries attempting to further understand the beer industry. I wasn't able to stay at any of these other businesses but I was able to arrange tours with brewers and ask many questions. I found each to be unique as they were small independent business selling into local markets.

After learning of my scholarship agenda, all of the brewers were extremely generous with their time and offered more information than I could process, good thing for notes! I won't detail everything I learned at the breweries but I will say my knowledge base grew exponentially with each conversation I had with the brewers.

One exception I will write about is the Sprig & Fern Tavern and head brewer Tracy Banner.

Historically New Zealand had two major breweries selling into every corner of the country through all points of sale. Around 20 years ago one family, the McCashins, in the Nelson area decided they were going to try and challenge the big players. They have been remarkably successful and helped kick-start a craft beer movement that is achieving a high level of success around the country as dozens of entrepreneurs have followed their lead.

One memorable Holiday Monday, Nelson Day in fact, I sought out one of the Sprig & Fern Taverns in Nelson, the one where I knew the head brewer was working. Tracy Banner, was the original brewer the McCashin family hired to begin their operations and she was also the first woman to head a division of the infamous Lion Breweries of New Zealand.

It was a bit of a sleepy mid summer holiday but the pub was busy. I introduced myself to Tracy as a Nuffield scholar and possibly through her ties to England she was aware of Nuffield. She opened up a bit after that and despite the busy atmosphere in the pub in between serving customers she fielded questions from me for the next several hours. I felt very lucky to have had the chance to talk with and learn from Tracy.

Additional breweries, brew pubs and specialty pubs I toured included: Founders, Renaissance, The Free House, Twisted Hop, Dux de Lux, Moutere Inn, The Malthouse, Hashigo Zake and the Mussel Inn.

Gladfield Malt

Along with hops, malt is a critical ingredient in beer production. Developing an understanding for the role malt plays alongside hops in beer production was a natural extension of my scholarship. Fortunately, New Zealand provided an opportunity for me to investigate these links with a visit to Gladfield Malt.

Most malt for beer is derived from barley. After harvest, grains are soaked, sprouted and roasted. The roasting process occurs with different temperatures and lengths of time, producing different types of malt from pale to dark, for use in the production of different styles of beer. Malting is a specialty process undertaken in very few places and most of it at a very large scale.

7 years ago, enterprising farmer, Doug Michael, began feeling that his growing of barley just wasn't going to be enough and decided to purchase some second hand malting equipment and outfit his farm with a new facility for producing malt on a small scale for sale to New Zealand brewers and possibly for export as well.

My timing wasn't so great when I arrived at Gladfield as it was the first day of barley harvest that season and Doug had almost no time to spare for me. He was apologetic but the harvest couldn't wait. He did however introduce me to his lab technician, Simon Bretherton, who graciously schooled me in the ways of Gladfield Malt, malt itself and their relationship with brewers and brewing.

I spent the better part of the day with Simon in his lab as he performed hour to hour analysis during harvest of the fresh crop. He was very helpful with providing technical information about malt and its relationship to beer as well as overviews of industry businesses and numbers. This gave me a fantastic opportunity to bring together information I had been learning about hops and beer with malt. It certainly helped that Simon was a professional brewer and had helped expand operations of some major craft brewing operations in Australia.

The operations at Gladfield involve production of 200 hectares of barley, all 2 row UK varieties, and malting this into 3 separate types of malt. They use 30 ton kilns and were also building a 5 ton kiln so they could produce small batches of specialty malts, they also bring in barley from other growers for malting. They bag and store the malt on site.

There is a great degree of technical analysis of the crop before, during and after malting. Expensive lab equipment was purchased, above $100,000, and they provide a certificate of analysis with their final products.

I was able to have a very quick lunch with Doug, as his wife, Gabbie, pulled him out of his tractor. I only had a few minutes to speak with him and he told me he realized there would be high costs involved with starting up his operation but he wanted to be involved for a long time and wasn't exactly concerned that money would not be coming in right away. He also told me he knew it would take some time for brewers to trust his product and that was why he invested in the lab and the equipment and

a qualified technician. He wanted to be able to prove to customers across New Zealand that they could use a local product and not import everything for their beers from abroad.

I was able to tour the storage areas and the kilns with Simon after lunch and watch the last of the harvest being brought in before moisture content in the barley crept up and things came to a stop. After this Doug and Simon needed some time for their work so I had a walk around the farm. A great visit and learning opportunity.

5.3 Poland – October 24–26, 2011

Unfortunately my notes from my stay in Poland are nowhere to be found. I am not sure how I lost them and despite searching everywhere I can think of, I have not come across them. I do have fond memories and some photos from my stay but this report will have to come from memory.

Researchers and producers in the hop world meet every two years at an international congress and while reading the proceedings from the 2009 International Hop Growers' Convention I came across some research that caught my eye. This prompted a visit with Dr. Ewa Solarska at the University of Life Sciences in Lublin, Poland.

Dr. Solarska's research involved pest and disease resistance in organic hop production that includes Effective Microorganism (EM) applications. I have some experience using EM and know many other farms around the world use EM effectively and I was interested to learn about their ability to manage the persistent and damaging problems that occur in hops.

EM consists of mixed cultures of beneficial and naturally-occurring microorganisms that can be applied as inoculants to increase the microbial diversity of soils and on plants. Research has shown that the inoculation of EM cultures to the soil/plant ecosystem can improve soil quality, soil health, and the growth, yield, and quality of crops. Its use was developed in Japan in 1991.

EM contains selected species of microorganisms including predominant populations of lactic acid bacteria, yeasts, and smaller numbers of photosynthetic bacteria, actinomycetes and other types of organisms. All of these are mutually compatible with one another and can coexist in liquid culture.

EM is not a substitute for other management practices. It is, however, an added dimension for optimizing our best soil and crop management practices that also include crop rotations, use of organic amendments, conservation tillage, crop residue recycling, and biocontrol of pests. EM can significantly enhance the beneficial effects of these practices.

Ewa is not a hop grower but rather a university based researcher. I stayed with her for three days and was able to have many conversations with her about a wide range of topics. Her research is not focused on organic or EM applications. She in fact also researches Biotechnology applications and a whole range of other agriculture based research. I have never met a researcher with so many different avenues of study.

Ewa performs many field trials for her research but she also works with other growers and brought me to some of these farms. I was able to tour an organic hop farm with Ewa that uses EM. Apparently the concept of EM was introduced to Poland about 5 years ago and it was quickly adopted across the country. In turns out the spread of EM use around Poland has occurred faster and to a higher degree compared with other countries.

The farm had adopted EM 4 years ago and has had great results. The crops have been disease free and their yields have improved. They have even begun to produce the EM solutions and are acting as a distributor in their area of the country.

This hop farm was 10 hectares in size and included processing facilities for drying and baling their hops. I was able to tour these and ask some questions about some of their field practices. Outside of the EM their management was similar to other organic hop growers.

One piece of research that Ewa shared with me that I had not come across was a management strategy for verticillium wilt in hops. I wrote about this earlier but will add this description here as well. Wilt can be a problem for growers and Ewa told me of her research with wilt and winter rye. Her research showed that growing strips of winter rye in the alleys between hop rows could reduce wilt by as much as 70%. It was her findings that soil bacterial cultures associated with rye help to control wilt. She did however caution only to grow rye every 2-3 years and that rye would create competition for water.

Ewa organized a tour one day for me to visit two other farms. I had an opportunity to visit an award winning organic goat and cow dairy operation. They were producing milk for sale locally as well as yogurt and cheeses. It is a small family operation with 2 staff members. The family transitioned to organic production when one of their daughters became ill as a child. Since adopting organic practices no one in the family has been sick. It has been 12 years.

The next part of the tour was to an organic vegetable operation. Again it was a family run business but at a much bigger scale. In season they have 15 plus staff as well as 4 family members working. They are producing 6 vegetables for export to Germany. I asked if they were worried about selling all their products to only one distributor and they responded that yes it was an issue and they have tried to find other distributors to work with but they had not found the right one yet.

5.4 Germany – October 27-November 1, 2011

Hop Homeland! I was looking forward to visiting the place where a global industry developed and is still home to the largest concentration of hop producers.

I arranged to meet with Florian Weihrauch of the Bavarian State Research Center for Agriculture, Institute for Crop Production and Plant Breeding, Hop Research Center, Hull.

Florian met me at a train station and then drove me through what he considered to be the most visually attractive areas for hop production. I had him stop several times so I could take pictures and even though the season was over and the fields were empty there were still some captivating sights. It was like walking through a forest in the winter and being able to see the trees and the lay of the land instead of losing everything to all the foliage.

We made our way to the Hop Research Center where Florian and his colleagues work. Florian's research is varied with his aim being to help German hop growers reduce rates of disease and pest issues and maximize yield. He shared with me some of the best practices they recommend to growers but unfortunately for me they would not be certifiable with organic practices. Florian expressed appreciation for organic production and we talked about the approaches for German organic growers. (These are much the same as the healthy soil practices described in the section relating to EM in the Poland descriptions. Although, he was not aware of any German growers using EM).

We also talked about current global industry issues; over supply of some varieties, not enough supply of others, and the demand for new varieties coming from small craft brewers. I asked him about the lack of a craft beer market in Europe and his thoughts were that the traditional brewers were producing the beers they know will sell in their markets and they weren't feeling much pressure to change. The drinking preferences of their customers are for the classic beers they are producing and that was okay with the brewers.

Florian then drove me to the farm of Georg Pichmail, a highly regarded organic grower. Georg grows three varieties of hops on 10 hectares and has been growing for decades.

My first impressions were for the contrast of the traditional architecture of the home and farm buildings and the presence of solar panels on nearly every building. Georg had twice invested in solar panels, but not for on farm use but as income generation. He was very happy with how things were working out. Georg toured Florian and I and showed his equipment used for harvesting and processing. Much of this was decades old but still operated as new. There isn't much wear and tear for hop equipment as it is only used for less than a month out of the year. Georg had

been modifying some of the equipment recently but only for minor changes and he shared that the seasons and harvests generally go as they always have.

We were called in for a late morning breakfast, 11 am, and joined Georg's two Polish farm workers for a very traditional Bavarian meal. Beer using their hops included!

We got out into the fields and had a discussion about his cultural practices, the labour he uses, equipment suppliers and the varieties he grows. We talked about how organic hop yields are under those for conventional growers with Georg telling me his are about 2/3 of some of his neighbours. He is okay with this though because he isn't interested in the health and environmental problems associated with chemicals. I asked him how he sells his crop and his certifier acts as a marketing agent. They buy his whole crop and work to sell it on their own. Georg wasn't even sure what price they were receiving. I asked him how much total acreage he thought was a minimum amount needed to grow and he laughed a bit and said it depends on the market prices and that sometimes all of his plantings aren't really enough and other years he has more than enough.

5.5 Czech Republic – November 2-5, 2011

I had arranged to meet with two people in the Czech Republic; Daniel Mourek of the Czech Environmental Partnership Foundation in Prague and Dr. Josef Vostrel of the Hop Research Institute, Zatec. Unfortunately, for different reasons, I was not able to meet with either. This was disappointing but something I had to accept. I attempted to find new connections but in the time I had available I was not able to make any appointments.

I did tour the hop growing regions in a car for a day but I did not have any connections with growers and was not able to meet with any farmers. This was my biggest disappointment of my scholarship. I will make my way back though. Some day.

I made up for this by touring breweries and brew pubs including; Prvni Pivni Tramway, Pivovarsky Dum, Zubaty Pes, Pivovarski Klub, Zly Casy, and the Prague Beer Museum.

6.0 Personal Involvement with Hops

Prior to being selected for my Nuffield Scholarship I had been researching hops but had no experience actually growing the crop. Several years before I had visited a farm with a hop yard and an on-farm brewing operation but the majority of my connection to hops was through reading, reading and more reading.

I began my scholarship studies in December of 2009 and that winter a friend agreed to establish a hop yard with me on the farm property I rent and where I operate my market garden business. I had always wanted to grow more than a couple of plants

but there is considerable expense involved and I hadn't been able to get things started before that. But my friend and I went ahead and scrambled over the winter to source rhizomes, 24 foot poles and related hardware for trellising, irrigation equipment and a few other odds and ends and with the arrival of spring we were able to get everything in the ground and set up.

Hops are a long-lived perennial and take at least two or three years to fully establish so we did not expect very much that first year. Nonetheless to be able to walk our field and move from theory to practice was a fantastic experience. We had a few rhizomes die but on the whole our first year was a successful learning opportunity.

Over the course of 2010 I was attending information sessions based around hops with a specialty crop advisor with the Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA). It seems OMAFRA had been receiving requests relating to hops and decided to offer information sessions to interested parties. A group of about a dozen people interested in hops emerged from these meetings and over the course of 2010 and 2011, started to meet independently of OMAFRA and have begun the process of forming an association of hop growers in Ontario. Experience varied amongst the group members with some having none at all and others having a few years of growing behind them. I have attended several events put on by this informal group including farm/hop yard visits, information sessions, meet and greet afternoons with local brewers and hop growers and some formal planning meetings aimed at developing the association. I am glad I have become involved as this network has become a great resource for information and in helping with developing business contacts for our crops.

During the 2011 growing season I volunteered our hop yard as 1 of 4 participating in a field study performed by researchers from Niagara College. A real lack of knowledge for hops as a crop in Ontario exists amongst the farming community, government agencies and educational institutions. The research aim was to visit existing hop yards in Ontario and perform soil and tissue samples along with some end of the year crop analysis in order to gather information to help growers and support future development of hop yards here in the province. Two researchers visited the farms 4 times over two months and a presentation of the findings is planned early this winter.

7.0 Current Industry Research

Although hop cultivation has occurred for at least 1,000 years, discoveries continue to surface. Modern science is facilitating a tremendous amount of analysis. As with most science, the exploration of one question leads to another.

Much of the historical research performed on hops was done through public institutions but that has shifted to mostly private interests around the globe. Private breeding programs are operating in several countries as domestic markets gather

together with the hopes of developing new cultivars that will provide a unique hop for the market place.

With demand for new hop options from brewers growing, and almost every grower facing competition from around the world, any new variety can provide real benefits. However, breeding work to bring a new hop cultivar to market can take 12-15 years.

Of the two types of hops grown, the high alpha varieties are often in over supply. Breeding research in the past has developed a strong supply of extremely high alpha varieties and this has resulted in fewer hops being needed to produce beer and also fewer hops needing to be grown.

The massive global brewing conglomerates are finding ways to brew beer with less and less hops and their preference remains these high alpha varieties because of reduced production costs. These brewers certainly have the majority of the beer market – approximately 85% - so high alpha hops remain in demand.

The result of the breeding work and the industry adoption of the new high alpha varieties has been a structural oversupply as growers rushed to fill the demand. This resulted in lowering financial returns and subsequent removal of hundreds and up to thousands of acres of plants as growers work at finding a balance in their fields and the marketplace.

However, the “Craft” and “Micro” beer markets are expanding faster than the demand for the mass-produced beers and this is driving much of the new research in breeding.

The craft beer world wants to work with as many hops, with as many different characteristics as possible. Aroma varieties have typically provided the greatest range of options for craft brewers and researchers are working to offer new cultivars for this innovative and experimental marketplace.

The U.S. market for craft beer is surging with demand and new breweries are opening every month with 700 projected to open in 2012. Other world markets are seeing this demand as well but some regions remain entrenched in traditional beer making styles and others have yet to fully embrace the potential of dynamic beer production.

A third category of hops is developing, “Flavour” cultivars. Research is revealing the hop’s ability to express more aromatic characteristics and these “next generation” cultivars are eagerly anticipated by brewers. Researchers are also working to match these new aromatics with disease and pest resistance and adequate yield.

New hop cultivars and brewing science are of course the focus for the majority of research but nutritional and medicinal research are also involved.

Current research is examining the functional compounds found in hops for use in food products, perfumery, pharmaceuticals, bio-remediation, waste processing and cosmetics. Some of the more promising research relates to hop compounds aiding in scavenging free radicals and their anti-cancer abilities as well as estrogenic properties.

The functional compounds of medical interest are the bitter acids and polyphenols.

The bitter acids, particularly the beta acids have antibiotic properties as well as anti-inflammatory effects beneficial for treating rheumatism and chronic inflammation. They may also have applications for treating tuberculosis, stomach disorders, acne and neurodermatitis. The alpha acids are also being examined for use in treating osteoporosis.

Polyphenols are being used to boost the immune system, protect against infections and inflammation, prevent coronary and vascular disease, as well as diabetes, and lowering the risk of cancer. The polyphenols are also being used as hormone preparations to address symptoms of menopause.

Xanthohumol is a substance being researched to a great extent. Cancer prevention properties have been confirmed as it is antioxidative, activating enzymes, which prevent tumour development, and inactivating enzymes, which encourage tumour growth.

8.0 Links Between Producers, Business Networks and Consumers

The dominant link between hop producers and their customers is through Hop Merchants, also known as, marketing agents, who buy hops from growers and sell to breweries. A producer will sell a season's crop to an agent who will then sell to various brewing customers but also to other smaller distributors. Quality testing and chemical analysis are performed by agents and further processing of raw hops into pellets or extract may occur, with the agents performing or contracting this processing.

There are examples of groups of growers forming selling agents so that their collective harvests can be managed from a single desk (i.e. New Zealand). However, the general practice is for growers to form an independent company that handles sales, instead of a formal Cooperative being formed.

Hop growers do sell directly to brewers but this is not the majority. Brewers like to have direct relationships with farmers and often seek crops from particular growers and locations. Although, these relationships are often established through Hop Merchants.

The majority of hops used for medicinal purposes are in the form of extract and Hop Merchants broker these sales.

The dominant link for consumer connections with hops is through purchasing the value added product, beer.

As for the hops used by brewers, Hop Merchants facilitate sales primarily through two methods, Forward Contracts and the Spot Market.

Forward Contracts

These contracts are variable in nature but are set up for 3-5 years, with a guarantee purchase price and an agreed upon volume for sale. The amount of hops in each contract diminishes with each year acting as insurance against over commitment. In general the forward contract permits some planning security for both producer and buyer. Growers may receive a price for their crop but may never know the final price to the end user, nor do they know who the customer may be.

The contracts haven't always been used but the volatility in the hop world over the last dozen years has brought back the long-term contracts. Recently there has been some restructuring of contracts where less hops are delivered in the first year and the total rate delivered is more balanced over the length of the contract. This is helping to balance the supply and demand in the market place.

Country	**2011**	**2012**	**2013**
Germany	85%	80%	70%
US	100%	90%	40%
Czech R	80%	70%	65%
Poland	45%	45%	25%
Slovenia	45%	35%	25%
England	80%	50%	30%

Figure 4: Forward Contract Rates, Country Comparisons

Spot Market

Hops not sold under contract find their way to the spot market. Traditionally many hops have been sold in this manner. There is no formal "market-place" for the spot

market, buyers and sellers simply search each other out. No set prices are involved and each party attempts to negotiate the best arrangement they can.

The spot market can set up favourable conditions for growers as supply and demand can create a seller's market. Most recently however, due to over supply, the hop world is definitely a buyer's market, and hops are being sold for less than the cost of production.

In recent years spot markets have not materialized as a result of the over supply in world production resulting in very little demand. Approximately 30% of the 2010 world crop sat without buyers. Producers who did not establish forward contracts around 2007/08 were the hardest hit as several crises had large scale customers scrambling to secure product for future years.

There is a high degree of volatility in annual crop volumes and prices received by producers. Risk is a major component for the spot market for both producer and buyer.

Farm to Brewery

Some really great relationships exist directly between hop growers and brewers. Agreements based on long term relationships or even on new found contacts can be quite favourable for both parties. A customer can have direct knowledge of a grower's farm and agricultural practices and a grower can benefit from a committed, long term customer and also by knowing exactly where their crop ends up.

Ongoing dialogue between both sides can develop understanding for annual issues that arise and for how these may affect production costs. A committed relationship between grower and brewer can allow for flexibility in pricing and crop volumes that may not be acceptable in a straight business arrangement.

Breweries Own Hop Yards

Hops are a mythical part of brewing and in many cases this has led to breweries big and small becoming producers of some or all of their own supply. There is a reverence for hops that carries over into people putting forward great efforts to be involved with their own hop production. Hops are expensive to establish and grow properly and it can be a challenge for anyone to produce enough hops for their brewing operations, so many still rely on purchasing hops from an outside source. But brewers love to get directly involved with growing hops.

9.0 Costs Related to Hops

On Average: 1,000 plants per acre - Yield: 1,000 - 2,000lbs/acre

Rhizomes	1000	$4-6 each	$4,000 - $6,000
Poles – 20 ft	100 approximately	$25 each	$2,500
Irrigation	Main lines, emitters, drip tape, connectors etc.		$1,000
Overhead Wires	3/16mm & 5/16mm, anchors, cables		$2,000
Twine	Coconut Fibre 16,000 ft	$0.15/ft	$2,400
Compost	1-2 tons		$1,000 +/-
Miscellaneous Supplies	Wire clamps, staples etc.		$250
Labour	Hole auger, pole setting, wire suspension		$2,500+/-
Total			$15,650 - $17,650*

Figure 5: Hop Yard establishment Costs – 1 Acre

*All costs are estimates depending upon suppliers and whether or not personal equipment and labour are used, or need to be rented or hired.

Equipment	**Cost**
Wolf (Picker)	$55,000 (used) $100,000 (new)
Hammermill & Pelletizer	$8,000 - $15,000
Vacuum Sealer	$2,000 - $2,500
Dryer	$12,000 +
Boom/Field Sprayer (Compost tea, EM applications, natural fungicides and pesticides)	$1,000
Cold Storage	Necessary?
Total	$78,000 - $85,500*

Figure 6: Hop Processing Equipment Costs

*Totals factor in a used Wolf Picker.

Approximate Production Set up, Equipment and Labour Requirements - 5 Acres of Hops.

Production set-up costs: $15,000 per acre – 5 acres = $75,000
Processing Equipment Costs - $100,000
One time costs - $75,000 + $100,000 = $175,000

Labour costs per year – $18,000*
*1.5 people per 2 acres - 5 acres = 3.75 people
3.75 people x $100 per day = $375
2 months working 10+ hour days = 48 days
48 days x $375 per day = $18,000

		Yield (lbs)		
		1,000 lb/acre (5,000 lbs)	1,500 lb/acre (7,500 lbs)	2,000 lb/acre (10,000 lbs)
Price per lb	$3.00	$15,000	$22,500	$30,000
	$6.00	$30,000	$45,000	$60,000
	$10.00	$50,000	$75,000	$100,000
	$15.00	$75,000	$112,500	$150,000
	$20.00	$100,000	$150,000	$200,000
	$25.00	$125,000	$187,500	$250,000

Figure 7: Potential Revenue from Potential Yields - 5 Acres of Hops

Approximate Production Set up, Equipment and Labour Requirements - 10 acres of hops.

Production set-up costs: $15,000 per acre – 10 acres = $150,000
Processing Equipment Costs - $100,000
One time costs - $150,000 + $100,000 = $250,000

Labour costs per year – $36,000*
*1.5 people per 2 acres - 10 acres = 7.5 people
7.5 people x $100 per day = $750
2 months working 10+ hour days = 48 days
48 days x $750 per day = $36,000

		Yield (lbs)		
		1,000 lb/acre (10,000 lbs)	1,500 lb/acre (15,000 lbs)	2,000 lb/acre (20,000 lbs)
Price per lb	$3.00	$30,000	$45,000	$60,000
	$6.00	$60,000	$90,000	$120,000
	$10.00	$100,000	$150,000	$200,000
	$15.00	$150,000	$225,000	$300,000
	$20.00	$200,000	$300,000	$400,000
	$25.00	$250,000	$375,000	$500,000

Figure 8: Potential Revenue from Potential Yields - 10 Acres of Hops

10.0 Conclusions

Hops are a niche product predominantly grown for a single industry, brewing beer, and their use can be traced back for at least 1,000 years. There is a narrow latitude range for optimal growing locations and hop production is primarily focused in just over a dozen countries, with 2 countries producing 65% of the world crop (Germany and the USA).

Hops are a long-term perennial crop with plants remaining productive upwards of 20 years. The crop is very susceptible to a wide range of diseases with Downy Mildew and Powdery Mildew being the most common. Pests are also a serious concern with Aphids and Two Spotted Spider Mites being of highest concern. Sound agricultural practices that are pre-emptive in nature, and have a focus on soil health can be very effective in controlling these problems. Organic production is not only possible but also very viable.

Hop yards are expensive to establish at $15,000 an acre. Additional equipment totaling almost $100,000 is also recommended for efficient production, harvest and processing. These are one time costs that are necessary but their utility remains for decades.

Crop quality is very important. Scientific analysis of a crop is essentially mandatory for being able to assure customers of what they are buying.

Organic hop production requires slightly different management practices when compared with conventional management but crop quality is not compromised.

Brewing customers are very interested in new cultivars of hops to work with but private interests operate the majority of new breeding programs. This limits some of the potential for growers to establish new plantings of new varieties. It takes about 12-15 years for a new hop cultivar to make it to market.

Hops are a globally competitive market place, with the largest producers having distinct advantages of economies of scale related to production and their ability to offer large amounts of product to the biggest customers. There is some semblance of mythical status for some varieties of hops based on their traditional growing regions and the characteristics of some of these hops that new growers will never be able to replicate.

The hop world is full of volatility relating to weather conditions, pest and disease issues, annual production yields, crop storage concerns and prices offered and received in the market place.

There are regular imbalances between production and demand creating unstable market environments with few ways for growers and customers to adjust. The market can swing erratically from a seller's market to a buyer's market and back and forth.

Forward contracts are being used again as buyers and growers look to find some stability and security with their operational planning. The spot market for 2011 saw prices that were below the cost of production due to over supply in the market.

Some production countries export the majority of their product and some actually sell the entire harvest to their domestic brewing market. Deciding where to sell may be based on scale of hop operations, ability for markets to absorb product as well as relationships between growers, their marketing agents and the brewers who buy their crops.

The small craft beer producers are gaining in popularity in some countries. They continue to chip away market share from the largest producers. In 2010 in the USA, the craft beer share of the market was approximately 5% by volume and 7.5% by revenue. However, these styles of beers are known to be more flavourful and creative and use more hops in their production resulting in estimates that the craft sector uses 10% of hops supplied to the US beer industry. There is increasing demand for more available hops from these smaller customers and for new varieties as well.

The largest brewing companies on the planet buy the majority of hop harvests but they are using science to help them brew beer with less hop content. Increasingly their products are being made by machines rather than by hand. This is lessening the demand for hops.

One of the truly amazing facts about hops is how small an amount is actually used for producing beer. Historically brewers have used on average approximately 4 grams of hops per 100 litres of beer. Some of the largest brewers are now using as

little as 1 gram per 100 litres. This is an incredibly small amount considering how much presence they have in each glass of beer. Pennies a glass!

Because brewers use such small amounts the overall cost per volume of beer is relatively low. A German hop farmer related to me a historical notion they have used that compares the cost of hops in each bottle of beer to the price of the cap. Now, he said, the cost of the hops is equal to the cost of the glue for the label on the bottle.

Historically hop prices have fluctuated between $3 and $25 per lb. But the difference in cost per bottle of beer is only pennies. Realistically this means that brewers can pay considerably more for hop crops and only have to pass on a slight increase in price to their customers. Paying more for any ingredient can seem to be a challenge for any producer but the brewers could do a world of good for farmers by paying higher prices come harvest time, with relatively small changes to their production costs.

Farmers considering hops as a future crop need to be aware of establishment costs associated with hop yards, processing equipment costs, customer demand for certain varieties, their ability to compete with existing growers and having well formed knowledge about where they intend to sell their crops.

Growers would be encouraged to develop relationships with local brewing customers who are interested in long-term relationships as a prudent strategy.

North American beer consumers are creating a large demand for locally produced, small scale beer that is creative and inventive and has connections to local farmers. This is creating opportunities for farmers to strategically produce hops.

Appendix 1: Hop Taxonomy

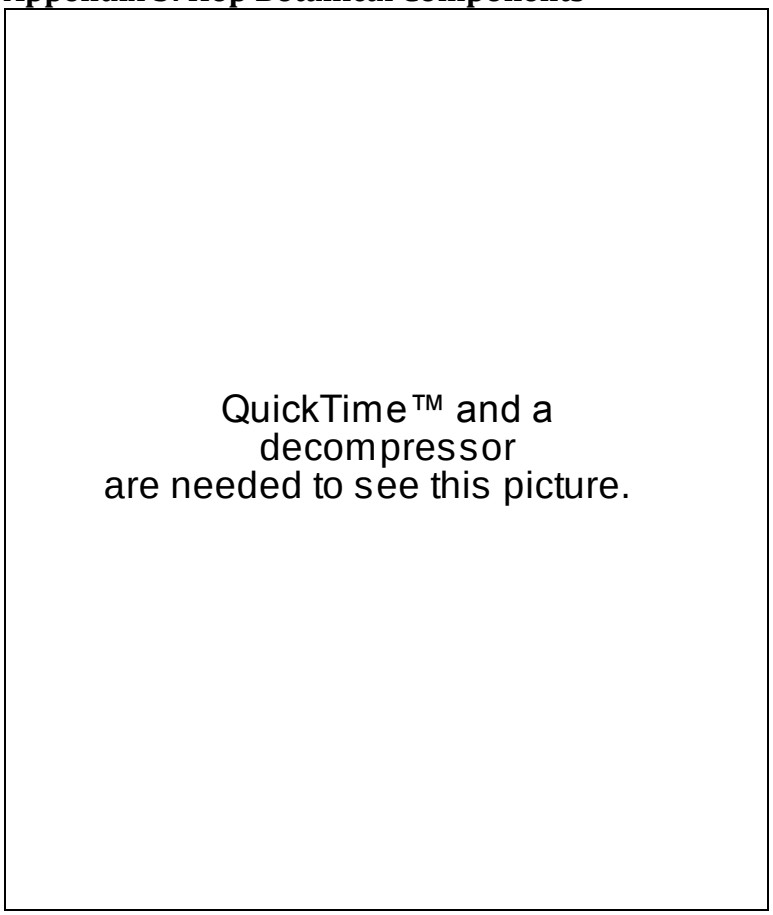
Humulus lupulus L. Taxonomic Serial No.: 19160

Kingdom	Plantae
Subkingdom	Tracheobionta
Division	Magnoliophyta
Class	Magnoliopsida
Subclass	Hamamelidae
Order	Urticales
Family	Cannabaceae
Genus	Humulus
Species	H. lupulus
	H. japonicus
	H. yunnanensis

Source:
www.itis.gov/servlet/SingleRpt/SingleRpt?search_topic=TSN&search_value=19160

Appendix 2: Hop Photos and Cross-Section

Appendix 3: Hop Botanical Components



Source: http://www.pfaf.org/user/plant.aspx?latinname=Humulus+lupulus

Appendix 4: "Hop" Translated for Other Languages

Latin: Strobuli Lupuli, Humuli
English: hops, hop, hymele
French: houblon
German: hopfen
Czech: chmel
Polish: chmiel
Dutch: hop
Chinese/Japanese: bijuhua ("beer flower"), pijuhua, shemahua, xiangshehau,
Spanish: lúpulo
Italian: luppolo

Source: www.ncbi.nlm.nih.gov/pmc/articles/PMC1852439/ and www.translate.google.com

Appendix 5: Genetic Diversity in Hop Varieties Used for Brewing

Source: www.barleyworld.org/620%20series/620/CSS620-Lecture1-ST.ppt

Each line represents a different variety of hops thus illustrating their shared heritage and evolution.

Appendix 6: Hop Flavours, Aromas and Bitterness for Use in Brewing

Source: www.hopschart.com

Each bar represents a different hop variety and the image illustrates the complexity involved for brewers when deciding which type to use and the related complexity a farmer has in choosing which ones to grow.

Appendix 7: Beer Flavour Descriptors

Source: http://beersensoryscience.wordpress.com

Each variety of hops can be used to illicit and compliment different beer flavour profiles.

Appendix 8: Hop Diseases and Pests

Infectious/Biotic Diseases:
Diseases Caused by Fungi and Oomycetes
Alternaria Cone Disorder
Armillaria Root Rot
Ascochyta Leaf Spot
Black Root Rot
Cone Tip Blight
Downy Mildew
Fusarium Canker
Gray Mold
Powdery Mildew
Red Crown Rot
Septoria Leaf Spot
Sclerotinia Wilt
Sooty Mold
Verticillium Wilt
Fungal Diseases and Pathogens of Minor Importance
Diseases Caused by Viruses and Viroids
Apple fruit crinkle viroid
Apple mosaic
Arabis mosaic
American hop latent virus, Hop latent virus, and Hop mosaic virus
Humulus japonicus latent virus (Humulus japonicus virus)
Hop latent viroid
Hop stunt

Arthropod Pests:
California Prionus Beetle
Damson-Hop Aphid
Garden Symphylan
Hop Flea-Beetle
Hop Looper and Other Lepidoptera
Root Weevils
Rosy Rustic Moth
Two-Spotted Spider Mite
Insect Pests of Minor Importance
White Grubs
Western Spotted Cucumber Beetle
Wireworms

Source: Compendium of Hop Diseases and Pests

Edited by Walter Mahaffee, Sarah Pethybridge, and David H. Gent

Appendix 9: Dried Whole Leaf Hops

QuickTime™ and a
decompressor
are needed to see this picture.

Source: www.grimalkinshearth.com

Appendix 10: Pelletized Hops

QuickTime™ and a
decompressor
are needed to see this picture.

Source: www.flickr.com/photos/32457792@N04/3688889461

Appendix 11: Hop Extract

Source: Photo - Myself.

Appendix 12: Definitions & Measurements

Ale - Beers distinguished by use of top fermenting yeast strains, Saccharomyces cerevisiae. The top fermenting yeast perform at warmer temperatures than do yeast's used to brew lager beer, and their byproducts are more evident in taste and aroma. Fruitiness and esters are often part of an ale's character.

Barley - A cereal grain that is malted for use in the grist that becomes the mash in the brewing of beer.

Barrel - A unit of measurement used by brewers in some countries. In Britain, a barrel holds 36 imperial gallons (1 imperial gallon = 4.5 liters), or 1.63 hectoliters. In the United States, a barrel holds 31.5 US gallons (1 US gallon = 3.8 liters), or 1.17 hectoliters.

Beer - Name given alcohol-containing beverages produced by fermenting grain, specifically malt, and flavored with hops.

Bitter - Bitterness of hops or malt husks; sensation on back of tongue.

Bitterness - The perception of a bitter flavor, in beer from iso-alpha-acid in solution (derived from hops). It is measured in International Bitterness Units (IBU).

Body - Thickness and mouth-filling property of a beer described as "full or thin bodied".

Bottom-fermenting yeast - One of the two types of yeast used in brewing. Bottom-fermenting yeast works well at low temperatures and ferments more sugars leaving a crisp, clean taste and then settles to the bottom of the tank. Also referred to as "lager yeast".

Cask - A closed, barrel-shaped container for beer. They come in various sizes and are now usually made of metal. The bung in a cask of "Real" beer or ale must be made of wood to allow the pressure to be relived, as the fermentation of the beer, in the cask, continues.

Cask-conditioning - Secondary fermentation and maturation in the cask at the point of sale. Creates light carbonation.

Conditioning - Period of maturation intended to impart "condition" (natural carbonation). Warm conditioning further develops the complex of flavors. Cold conditioning imparts a clean, round taste.

Conditioning Tank - A vessel in which beer is placed after primary fermentation where the beer matures, clarifies and, is naturally carbonated through secondary fermentation. Also called bright beer tank, serving tank and, secondary tank.

Dry-hopping - The addition of dry hops to fermenting or aging beer to increase its hop character or aroma.

Fermentation - Conversion of sugars into ethyl alcohol and carbon dioxide, through the action of yeast.

Hectolitre – 100 litres

IBU - International Bitterness units. A system of indicating the hop bitterness in finished beer.

Keg - One-half barrel, or 15.5 U. S. gallons. A half keg or, 7.75 U. S. gallons, is referred to as a pony-keg.

Lager - Beers produced with bottom fermenting yeast strains, Saccharomyces uvarum (or carlsbergensis) at colder fermentation temperatures than ales. This cooler environment inhibits the natural production of esters and other byproducts, creating a crisper tasting product.

Lagering - From the German word for storage. Refers to maturation for several weeks or months at cold temperatures (close to 0˝C /32˝F) to settle residual yeast, impart carbonation and make for clean round flavors.

Pitch - To add yeast to wort.

Saccharomyces cerevisiae - See Top-fermenting yeast.

Saccharomyces uvarum - See Bottom-fermenting yeast.

Saccharomyces carlsbergensis - See Bottom-fermenting yeast.

Secondary fermentation - Stage of fermentation occurring in a closed container from several weeks to several months.

Top-fermenting yeast - One of the two types of yeast used in brewing. Top-fermenting yeast works better at warmer temperatures and are able to tolerate higher alcohol concentrations than bottom-fermenting yeast. It is unable to ferment some sugars, and results in a fruitier, sweeter beer. Also known as "ale yeast".

Wort - The solution of grain sugars strained from the mash tun. At this stage, regarded as "sweet wort", later as brewed wort, fermenting wort and finally beer.

Yeast - A micro-organism of the fungus family. Genus Saccharomyces.

Yeasty - Yeastlike flavor; a result of yeast in suspension or beer sitting too long on sediment.

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