Sustainable Hop Production in the Great Lakes Region

MICHIGAN STATE UNIVERSITY EXTENSION

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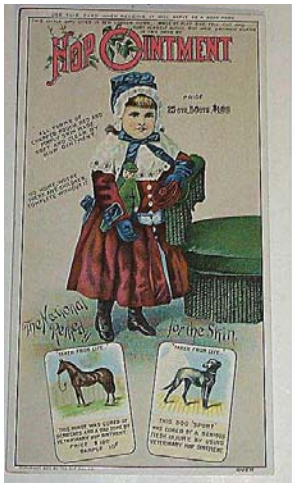
Introduction

Hops (*Humulus lupulus* L.) are an essential ingredient in beer production. The female flower "cones" of the hop plant contain lupulin glands with compounds important to the brewing process. These compounds, including alpha acids, beta acids, and essential oils, contribute to beer's bitterness and aroma. Recent hop shortages, growing appeal with specialty beers, and the desire for organic and locally sourced agricultural products have resulted in increasing interest in local hop production by farmers, brewers, and backyard enthusiasts. This bulletin is designed to provide an introduction to sustainable hop production in the Great Lakes Region.

History

Over the last 5000 years hops have been used for medicinal purposes, as a fiber for paper, as a salad ingredient, in pillows as a sleep aid, and of course as a preservative and flavor agent in beer.

Pliny the Elder (61-113 AD) in Naturalis Historia makes one of the first known references to hops. The first documented reference of the cultivation of hops is in the 8th century in the Hallertau region of Germany. Hop production most likely began before the 8th century in Eastern Europe and then spread to the rest of the continent.[1] The first description of using hops in beer was in 12th century Germany.



Though the British imported hopped Dutch beer in the early 1400s, commercial hop production did not begin in England before the early 1500s. European travelers transported the plant with them around the world and the hop was brought to the U.S. from England in 1629, though early settlers could harvest the native variety. Over time most east coast states became hop growing regions. Hops weren't grown for commercial production until 1808 in New York. Slowly the hop spread west, although New York remained the major producer until the crop was decimated by downy and powdery mildew in the late 1920's. Today the vast majority of hops in the U.S. are produced in Washington, Oregon, and Idaho.

Natural History and Taxonomy

Humulus is the genus of herbaceous climbing plants that most likely originated in China, but is indigenous to temperate areas of the northern hemisphere including Asia, Europe, and N. America. *Humulus* is

[1] Neve, R. 1991. Hops. Chapman and Hall, NY.

one of two genera in the Cannabinaceae family, the other being *Cannabis*. Though there are three distinct species *H. lupulus*, *H. japonicus*, and *H. yunnanensis* all commercial hops are of the *Humulus lupulus* (common hop) species.

Characteristics and Growth Habits

Hops are dieoecious (male and female are separate plants) perennial plants that produce annual bines from a crown and overwintering rhizome. With time the perennial crown becomes woody and can produce an extensive root system. In the spring, shoots surface from rhizome buds and aided by trichomes or stout hairs, hop bines grow in a clockwise direction and have the potential to reach heights of 25 ft in a single growing season (4-10 in. per day). Hop leaves form off the main bine and lateral branches and are simple, heart-shaped to ovate, deeply lobed, and have serrate margins. Around the summer solstice lateral branches develop and flowers are produced in cluster at the terminal buds. While hops produce both female and male inflorescence, only the female flower or "cone" is desirable for use in beer production. In fact, most commercial operations take great lengths to discourage fertilization by removing all male plants and sources of hop pollen. Female flowers form 0.5-4 in. light green, papery, cone structures (strobiles) that contain Lupilin glands, home to alpha and beta acids, and essential oils.

Hops Production and Growing Requirements

Environment and Climate

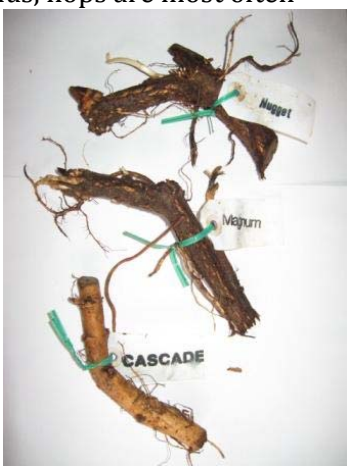
While the diversity of hop cultivars rivals their varying climatic and environmental tolerances, hops require long day lengths to flower and produce adequate cone yields. For optimal growth, hops also have specific chilling requirements (winter temperatures below 40 ^{0}F for 1-2 months) that are rarely satisfied below 35 degrees latitude. Therefore, most commercial production worldwide occurs at latitudes from 35-50 degrees. Ideal conditions for hop growth also include sufficient spring moisture followed by significant periods of summer sun and heat to ensure ample growth and full development of chemical compounds.

Soils

While the vast majority of hops in the U.S. are grown in the rich volcanic soils of Washington's Yakima Valley and Oregon's deep fertile glacial/volcanic soils, in general hops will produce well in well-drained, deep sandy loam soils with a pH 5.7-7.5. Heavy, poorly drained soils should be avoided. (See soil fertility for amendment information).

Propagation

Because hops are dieoceous, seed populations are extremely variable and will not produce offspring similar to a mother plant. Thus, hops are most often propagated vegetatively from rhizomes (see figure below) or softwood cuttings. Originating from the perennial hop crown, bud-bearing sections of lateral underground shoots or rhizomes, are typically cut into 6-8 in. lengths and transplanted directly into hopyards or potted and placed in greenhouses. If not planted immediately rhizomes should be stored in a cool, moist place. Softwood cuttings are typically taken from the stem with one-two nodes and two leaves, with 2-3.5 in. of wood beneath the node. Cuttings are usually planted and grown for one season before being transplanted into the hopyard the following year.



Agroecological Practices

Planting and thinning

Hops should be planted into recently tilled rows in early spring (late April-early May). Instead of tilling the entire field, many growers often leave alleys planted to ground cover to reduce the potential for soil erosion and enhance beneficial insect habitat. While there are several planting schemes, the most typical designs are 7 ft. x 7 ft. or 3.5-7 ft. x 10-15ft.,

with an average of 800-1000 plants/acre. Hops should be planted horizontally, bud side up 1-2 in. beneath the soil surface. When bines reach 1.5-2 ft., four bines are selected and the remainder are removed. Two bines are then trained (training) up each of the two coconut fiber support strings in a clockwise direction. In the spring of the 3rd year, after two-three weeks of growth many growers will hand-prune or mechanically prune the previous seasons old growth and current season's new shoots to control hop maturation timing, yields, and reduce disease incidence. Once bines reach 5-6 ft in height the lowest three feet of leaves and lateral branches are generally removed (stripping) to encourage airflow and reduce spread of downy and powdery mildew. Stripping can be accomplished manually, chemically, or even with livestock. The timing of both pruning and stripping are important in determining current and future year hop yields.

Trellising

While planting patterns vary, the vast majority of hops are trained on tall trellises (18-21 ft.) to maximize hop yields. A trellis system consists of hi-tensil or heavy-gauge wire suspended between poles that are set 3.5-

4 ft. deep, and spaced every 30-50 ft. Wires are then tightened and connected to earth anchors at each row-end. Strings are attached to the support wires, generally in a "V-shape" so as to leave a tunnel through which farm implements can drive. Because tall trellis systems require labor-intensive practices like training and stringing, USDA ARS researchers have been working to identify shorter-growth cultivars that would be well suited to low (10 ft.) trellis systems. Reducing labor costs would provide growers with significant cost savings.

Fertility and Irrigation

The best way to determine hop nutrient needs is to take annual soil tests to determine if supplemental hop nutrients are needed.

MICHIGAN STATE UNIVERSITY

MICHIGAN STATE UNIVERSITY
SOIL AND PLANT NUTRIENT LABORATORY
EAST LANSING, MICHIGAN 48824-1325
(517) 355-0218

SOIL TEST REPORT FOR:	CONSULTANT
ROB SIRRINE SUITE 107 8527 E. GOVERNMENT CENTER DR. SUTTONS BAY MI 49682	LEELANAU COUNTY MSUE 8527 E. GOVERNMENT CENTER DR., #107 SUTTONS BAY MI 49682 231-256-9888

DATE	LAB #	COUNTY	Previous Crop	ACRES	FIELD ID	SOIL
7/29/2009	108094	Leelanau	Cherry	1/2	Hops	Mineral

SOIL NUTRIENT LEVELS			Below Optimum	Optimum	Above Optimum
[1]Soil pH 6.8	Lime Index				
[2]Phosphorus (P)	100	ppm			
[3]Potassium (K)	102	ppm			
[3]Magnesium (Mg)	114	ppm			

ADDITIONAL RESULTS:					Optional Tests:						
Calcium (Ca) (ppm)	CEC (meq/100 g)	% of Exchangeable Bases K	Mg	Ca	Micronutrients (ppm) B	Cu	Mn	Zn	Fe	Organic Matter %	Nitrate-N ppm
668	4.6	5.7	20.9	73.4							

RECOMMENDATIONS:

Limestone: NONE
Tillage Depth: 6 inches
Target pH = 6.5
% Stand: 25

Plant Nutrients:					Micronutrient: (Optional)			
Year Crop	Expected Yield	Nitrogen (lb N/A)	Phosphate (lb P_2O_5/A)	Potassium (lb K_2O/A)	Boron (lb B/A)	Manganese (lb Mn/A)	Zinc (lb Zn/A)	Copper (lb Cu/A)
1 Barley	70 bu	45	0	20	0.0			

Hop nutrient needs vary depending upon soil quality, cultivars, and growing region. For nitrogen, it is useful to determine a budget and synchronize timing with plant uptake to estimate fertilizer timing and needs.[2] For example:

> N fertilizer required = hop N needs – N from green manure, cover crops, compost

In general, it is necessary to replace the amount of nitrogen removed with the crop during harvest. In hop production, around 100 lb/acre of nitrogen is removed on average during hop harvest[3]. Depending upon soil quality, cover crop N fixation, and amount and quality of compost, typical first year N rates are 75 lbs N/ acre (1.5-2 tons of compost/acre) and 100-150lbs N/acre (2-3 tons compost/acre) in subsequent years.

[2] Gingrich et. al. 2000. Hops. FG 79. Oregon State University. 5p.

[3] Carter et. al. 1990. Hop. Alternative Field Crops Manual.

Hops typically have low P requirements. As the hop crop usually removes 20-30 lbs of P/acre, hop P needs are generally lower than N or K. Typical P recommendations thus range from 20-30 lbs of P_2O_5/acre. Increasingly, over-application of P in agricultural and residential areas is leading to algal blooms in lakes and streams (eutrophication) and reductions in dissolved oxygen levels leading to "dead zones" such as that found in the Gulf of Mexico. Over the course of a season hops typically take up 80-150 lb K/acre[4]. In northern Michigan's sandy soils, optimal range for K is around 100 ppm. At this level, Potash K_2O is generally applied at 20 lbs/acre to replace the K taken up by hops during the season.

As the market for organic hops increases, the use of compost, cover crops, and other organic amendments will most likely become more prevalent. As long ago as 1877, P.L. Simmonds underscored the importance of compost, "In preparing the soil for this plant, care should be taken to thoroughly destroy the weeds…well-rotted dung must be applied with a liberal hand." Compost can be banded in the hop rows, which in addition to providing N and other nutrients over a longer time frame, may also provide weed control benefits as well. Depending upon compost and initial soil quality, two-three tons/acre should satisfy nutrient needs in organic systems. Michigan State Soil and Plant Nutrient Lab can provide compost quality determinations.

Micronutrients and pH

As mentioned, hops grow best in soils that are not overly acidic or basic. When fertilizers with ammonium have been applied for some time, soils will become more acidic (NH_3). As NH_3 is converted to Nitrate (NO_2), the hydrogen anions are released and Hydrogen anions are released making the soil more acidic. As soil pH decreases below 5.7, Mn levels can become toxic in hop tissues. If soils are too acidic, lime ($CaCO_3$) may be applied to neutralize the acid (H+ ion) to form CO_2 and H_2O. Soils with high pH > 7.5 are often associated with Zinc (Zn) deficiencies. If soils are too basic then ammonium sulfate fertilizer can be used. Hops have been shown to respond positively to Boron (B) as well if test values are below 1.5 ppm.

Irrigation is generally needed in most areas of the U.S. to satisfy hop water needs. Hops do not thrive in heavy, water logged soils, which can increase incidence of many diseases. While many systems exist, drip irrigation that can deliver water directly to plants tends to be the most efficient system. Researchers at the Northwest Michigan Horticultural Research Station have successfully employed a computer operated RAM tubing drip irrigation system with emitters every 2 ft. and an output of .42 gallons/hour. In this soil-moisture based system, underground sensors determine when water is needed and soil moisture levels are maintained at optimum levels. RAM tubing offers the benefit of having uniform output from each emitter, in spite of elevation changes or length of drip line. While this type of system has higher initial costs, it is more efficient in that it only operates when soil moisture levels are low, thereby accounting for wetting events.

Cover Crops

Cover crops have been used as a major groundcover management tool in many agricultural systems. Cover crops have proven particularly useful in perennial systems and offer several benefits. They have been shown to reduce fertilizer and pesticide costs, improve soil quality and crop yields, prevent soil erosion, conserve soil moisture, scavenge excess nitrogen,

[4] Gingrich et. al. 2000. Hops. FG 79. Oregon State University. 5p.

and provide beneficial insect habitat.[5] If improperly managed though cover crops can compete with primary crops, provide habitat for pests and rodents, and increase frost damage.

Insect Management

The most common pests in hops are hop aphids and spider mites, although less common pests such as cutworms and Japanese beetles can become problematic.

Hop aphid *(Phorodon humuli)*

Hop aphids are small pale green insect pests with two cornicles protruding from their abdomen. Hop aphids overwinter on Prunus species and return to hop plants in the spring. Infestations develop more rapidly during cool weather. Hop aphids feed directly on hop plants by sucking plant juices. Aphids should be controlled before or during flowering to keep them from entering the young cones. Once the aphids have entered the cones, they can secrete honeydew (plant cell sap) and cause a sooty mold in the cones. Aphids weaken plants and reduce yields and should be controlled before or during flowering to prevent aphids from entering young cones. Scouting is recommended and insecticide application recommended once the threshold of 8-10/leaf has been reached. Enhancing habitat to encourage beneficial predatory insects like lacewings, ladybugs, and syrphid flies can reduce populations of aphids.

Spider Mites (*Tetranychus urticae)*

Spider mites are serious pests of hops. They are pale yellow to reddish in color and often have a dark spot on each side of their body. Females emerge in the spring and begin feeding by piercing the lower leaf surfaces and ingesting plant sap, which causes leaves to become yellow, shrivel and die. Damage can occur on cones as well, which results in brownish, brittle cones-a condition growers call "red hops". Spider mites most often present a problem during long stretches of dry, warm weather. Mite predators include the western predator mite and the small black lady beetle. Scouting is recommended-the threshold before chemical application is generally required is 10 mites/leaf. Groundcover mixes that include red clover have been shown to host predatory mites that prey upon spider mites.

Weed Management

Like other crops, weeds have the potential to compete with hops for moisture and nutrients. As in many agricultural systems, there are different weed control options with tradeoffs in each. Mechanical cultivation (tillage), chemical control, and mulching are the most common methods of weed control. In mechanically cultivated systems, deep tillage (6-10 in.) should begin as weeds appear, followed by shallow cultivation (2-4 in.) until after lateral hop branches have developed. Over time cultivation has been shown to decrease soil quality and in hilly areas can lead to erosion problems. Many growers use no-till systems with herbicides to manage weeds. Only a few herbicides are labeled for hops and growers must be careful with application timing and rates to prevent damage to hop plants. Mulch has been shown to suppress weeds in hop systems and over time and can increase moisture retention and improve long-term soil quality.

[5] Managing Cover Crops Profitably, 3rd ed. offers an excellent overview of cover crops.

Disease Management[6]

There are several diseases of concern that affect hops and are sure to be more prevalent in the humid Great Lakes Region. Major diseases include downy mildew (*Pseudoperonospora humuli*), powdery mildew (*Podosphaera macularis*), and Verticillium Wilt (*V. albo-atrum* or *V. dahliae*) amongst others. In fact, downy and powdery mildew were responsible for the decline of hop production in the eastern U.S. in the 1920's. The first step in disease management is selecting resistant or tolerant cultivars. The USDA ARS maintains a database of these cultivars.

Downy mildew (*Pseudoperonospora humuli*)

Downy mildew is a serious disease of hops in most hop growing regions of the world and can threaten profitability if not controlled. Losses from downy mildew vary depending upon cultivar susceptibility and climate and are greatest in areas with heavy spring rainfall and favorable temperatures (60-70^0 F). The fungus overwinters in infected crowns and results in a conspicuous stunted shoot or "spike" that typically has small, yellow, cupped leaves. Spike formation results in stunted growth and reduction in cone production. If bloom occurs in wet weather, cones are likely to become infected, resulting in blackened, unmarketable cones. Downy mildew management requires multiple practices including planting of resistant varieties, field sanitation, and fungicide application. Rhizomes should be disease-free, basal spikes should be promptly removed, and infected root crowns removed from the field as well. Pruning or stripping of the lowest leaves after training will help improve air flow and reduce inoculum density. While Cluster is the extremely susceptible, moderately resistant cultivars include Cascade, Fuggle, Perle, Tettnanger, and Willamette.

Photo by Cynthia M. Ocamb, 2002

Photo by David H. Gent, 2006

Powdery mildew (*Podosphaera macularis*)

Powdery mildew requires control in most hop producing regions as it is a serious disease in hops. Symptoms include white, powder-like splotches on leaves or stems. Powdery mildew thrives in damp, hi-humidity, low light areas with minimal air circulation. The fungus also favors young growth in overly fertile soils. Optimal temperature for growth and infection occurs between 64-70 ^{0}F. In susceptible varieties cones can become infected resulting in stunting, cone-shatter, and reduced yields. As with downy mildew, control options include cultural and chemical. Plants should be thinned, and after stringing, lower leaves should be stripped to improve airflow. Excessive fertilization should be avoided.

Photos by Cynthia M. Ocamb, 1998.

Verticillium Wilt (*V. albo-atrum* or *V. dahliae*)

Verticillium wilt lives in the soil and infects hundreds of woody and herbaceous through their roots. In an infected plant, leaves will turn yellow from the base and move upward. As the areas between veins are often the first to dies, leaves tend to demonstrate a "tiger-stripe" pattern. Infected bines, when cut, will show a brown discoloration of the woody vascular tissue. Infected hopyards will slowly decline over time. Cultural control measures include eradication of infected plants, planting of resistant cultivars, and

[6] The Compendium of Hop Diseases and Pests, Mahaffee, Pethybridge, and Gent (eds.) 2009. offers a comprehensive overview of pest and disease management in hops.

maintenance of adequate but not excessive fertilization and irrigation.

Several diseases are caused by viruses and viroids as well including apple mosaic virus, hop latent virus, hop mosaic virus, and hop latent viroid. The best management strategy is to only plant healthy and/or virus-free material.

Harvesting, Picking, and Drying

Harvest timing is cultivar and management dependent, but in general harvest occurs between mid-late August through late September. Harvest date decisions depend upon several factors including cone moisture content, weather, pest, and disease issues. Proper timing is essential as hops are in prime harvest condition for only 7-10 days. Premature harvest can result in losses in yield and flavor in the current season and potentially reduced yields in subsequent years. Harvesting after peak ripeness can result in reduced aroma and brewing quality, shattering, and discoloration due to oxidation.

Although all hops were once picked by hand, in most commercial operations today, at peak ripeness hop bines are cut at the base and transported to picking machines. Picking machines strip the cones from the bines and separate leaves and stems, which can then be composted for future use. Cones are subsequently cleaned to remove debris.

After harvest the vast majority of hops are dried to reduce cone moisture from around 80% to 8-12% for storage. Drying reduces the potential for spoilage in storage. After drying cones are allowed to cool and then baled and pelletized.

Establishment Costs

Though establishment costs vary depending upon current market conditions and choice of trellis systems, irrigation, and growing methods, in general costs range from $6000-$15,000/acre. Tall trellis systems recently established in Michigan and Colorado averaged around $14,000-$18,000 per acre. (See figure).

2009 Michigan Standard Trellis Establishment Cost/Acre		
Northwest Michigan Horticulture Research Station		
Standard Trellis Establishment per acre		
Rhizomes	800	$3,200.00
Misc. Hardware & Supplies		$250.00
Poles (21' treated, lodge pole pine)	100	$3,200.00
Post hole augering and pole installation		$1,000.00
Crushed Stone for setting poles	4 yards	$550.00
Hop Twine (coir: coconut husk fiber)		$125.00
Ground Anchors (Manta Ray and Duck Bill)		$2,200.00
Drip Irrigation Materials		$800.00
3/16" wire		$1,200.00
5/16" wire		$525.00
Skytrack rental for wires		$800.00
Labor		$2,400.00
Compost		$1,000.00
Total Establishment Cost/Acre		$17,250.00

Economics, Markets, and Brewer Needs

In 2007, after years of oversupply and stagnant prices, there was a "perfect storm" of events that dramatically changed the hop industry. As a result of over a decade of poor returns, many farmers had been pulling land out of production-in the U.S. hops acreage declined by over 1/3 since 1996. When combined with a 2006 warehouse fire that destroyed 4% of U.S. production (50% of the total U.S. crop is exported on average), and poor yields globally in 2007, demand outpaced supply for the first time in years. Consequently, prices sky-rocketed ($5-$50/lb in Michigan) and the needs of small-scale breweries took a backseat to large scale beer producers who hold long-term contracts for 80% of U.S. hop production. As prices increased, interest in hops production nationwide grew and farmers in many Great Lakes States planted hops for the first time in over 100 years. Washington State producers have responded by increasing acreage by over 35% (see figures below), which will most likely stabilize prices in the years ahead. Regardless, because of growing interest in the "buy local" movement and organic production, there may be an opportunity for small scale producers to satisfy the needs of many Great Lakes microbreweries. A 2008 MSUE survey of brewers in Michigan found that 100% of brewers surveyed were interested in establishing a contract with a small, local grower. Seventy-five percent of brewers were either slightly or definitely concerned about the market

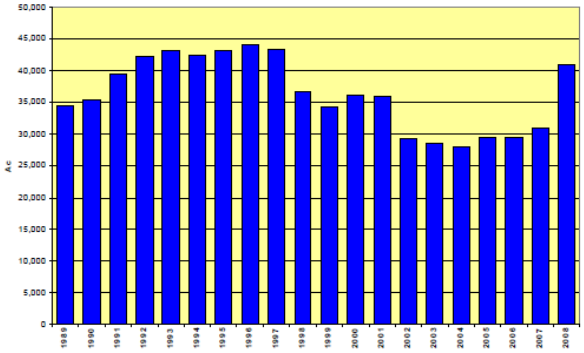
security of hops. Eighty percent of brewers were slightly to definitely interested in purchasing organic hops. And, importantly 55% of brewers would pay a 1-10% premium for locally grown, organic hops. If growers are savvy and diversify their marketing to include the medicinal, herbal, and home-brew markets they may be able jumpstart a regional hop industry.

U.S. HOP ACREAGE BY STATE 1998 – 2008 (IN ACRES)

YEAR	WASHINGTON	OREGON	IDAHO	TOTAL
1998	26,573	6,161	3,909	36,643
1999	25,076	5,822	3,362	34,260
2000	26,980	5,819	3,321	36,120
2001	26,339	6,103	3,469	35,911
2002	20,333	5,577	3,399	29,309
2003	19,492	5,748	3,429	28,669
2004	19,382	5,107	3,253	27,742
2005	21,013	5,163	3,287	29,463
2006	21,532	5,036	2,797	29,365
2007	22,745	5,270	2,896	30,911
2008	30,595	6,370	3,933	40,898

SOURCE: USDA-NASS. Prepared by HGA.

U.S. TOTAL HOP ACREAGE 1989 – 2008 (20 YEARS)
Source: USDA-NASS. Prepared by HGA.



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http://www.usahops.org/userfiles/file/2008%20Stat%20Pack-final.pdf

http://www.hort.purdue.edu/newcrop/duke_energy/Humulus_lupulus.html

http://www.ipmcenters.org/CropProfiles/docs/orhops.pdf

http://www.tricity.wsu.edu/~cdaniels/profiles/Hops3PM.pdf

http://oldmissionhops.com/

http://www.gorstvalleyhops.com/

Weed Control: http://uspest.org/pnw/weeds?15W_LEGL14.dat

Rhizome sales:

www.homebrewing.org/ Adventures in Home Brewing (Taylor, MI)

www.hopunion.com/

www.hoptech.com/

www.midwestsupplies.com

www.thymegarden.com

www.freshops.com/

www.Ebrew.com

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