DEVELOPING A SUSTAINABLE APPROACH TO HOP PRODUCTION IN THE NORTHEAST[1,2]

USDA ARS/SARE Project Number FNE 95- 79

Report to United States Department of Agriculture,
Agricultural Research Service,
Northeast Region Sustainable Agriculture Research and Education Program.

The development of a regional brewing trade over the past decade has generated interest in reviving the production of hops (the dried inflorescence of female *Humulus lupulus L.*) in the Northeast US. The establishment of commercial hop growing regionally is severely constrained by the absence of realistic cultural and management experience and expertise, as well as technical infrastructure. To address some of these challenges, this study utilized a maturing planting of hops and established overhead wirework trellis system to initiate a comprehensive environmentally benign and sustainable management approach to hop growing. The strategies that evolved include a restorative soil improvement program based primarily on stable, slow release naturally-derived nutrient sources; a fertilization program for hop exploiting graded solubilities of mineral nutrients; rigorous soil and water conservation and reduced weed control costs by the use of a cover crop and vegetative mulch and minimal tillage; enhanced economic opportunity through experiments with interplantings of marketable secondary crops; and improvement of productivity and field efficiency through beginning to adapt and implement cultural techniques and appropriate technologies of stringing and training of hops to overhead wirework. By these means, this work met objectives of beginning to restore and maintain a diverse, vital and healthy ecosystem while producing the first field grown hops in nearly a century in the Northeast for the commercial brewing trade.

BACKGROUND

hopCulture began in 1993 as a field trial of hop on a second bench of the Upper Connecticut River Valley straddling the states of Vermont and New Hampshire, USA. This trial has been intended as a stage in development to a economically viable scale of operation, but is currently considered to be the largest area of overhead trellissed hops in eastern US.

The grower brought to this work twelve years of prior agricultural experience with specialty field crops and has introduced varieties of dry edible beans, flax and grain, to US and Northeast field production . Technical background has included the construction of the only combine for internally seeded vegetables and fruits currently in use in New England. In addition to practical agricultural experience, graduate studies and college teaching experience in molecular biology and biochemistry provides some literacy in attempting to understand the complex mysteries and subtle chemistry of the hop.

In May of 1993, a suitable site was located, and was leased on a long term basis. Preliminary inspection indicated a stone free sandy loam to loam soil with sandy subsoil. The agricultural land has been in more or less continuous production since 1794. The property has been in the ownership of one family since 1920's and supported a parttime dairy through the 1930's. As late as twenty years ago, neighbors recall, four crops of alfalfa per year were

harvested. By the nineteen eighties, however, careless cropping had resulted in a production of no more than twenty bales of hay per cutting. Preliminary inspection indicated significant depressions and a sandy subsoil mostly devoid of vegetation in two rectangular areas of about 0.1 acre on one side of the field, consistent with a pattern of intentional damage.

The site is located at 43°49' N, 72°13' W adjacent to the village of East Thetford, Orange County, Vermont USA. Classified by survey as Hadley Silt Loam, a potentially highly productive soil type predominant in the river valleys of New England, the first soil samples, tested in May of 1993, indicated 2.5 to 3.3% organic matter but depleted of major nutrients. The field, and entire farming operation, under trellis in an imperfect rectangle of ratio 3:2, and lands devoted to headlands, machinery, supply and compost storage areas, and some land under development for expansion of trellissed hops.

The site presents best and worst case scenarios for hop growing in the Northeast. In late summer and early autumn heat from the adjacent river combined with cool nighttime temperatures, regularly causes fogs from after midnight until mid-morning which provide significant frost protection, extending frost-free season as much as one month compared with low lying areas in uplands. However, mist borne fungal spores may spread mildews in late summer more rapidly than drier upland sites. The field is well exposed to the east and south, bounded by a low tree line to the north and a line of 40 foot black locust in the northwest corner, providing refreshing summer shade.

Original planting materials were supplied, in May of 1993, by a researcher in western US for a replicated varietal trial of nine varieties. Remaining rhizomes were purchased from trade suppliers for commercial field trial, and were initially planted between May 24 and June 10, 1993. The field was laid out in an atypical rectangular quadratic spacing . Uneven quality of planting materials from shipment over long distance, as well as reselection of appropriate cultivars and individual clones has resulted in replanting some sections up to three times.

In 1994, the planting became a fulltime responsibility in order to replant to five varieties, construct an overhead wirework trellis of 16 foot height, and maintain an extensive nursery. Stock and supplies were purchased with the assistance of two small local brewers.

Maturation of the existing planting to economic yields and selection of appropriate cultivars may easily require 3 to 4 years. Development of appropriate technologies and scaling to an economically viable operation is expected to require an additional 5 to 10 years.

Our working hypothesis in these studies centers on the notion that although the river valleys of the Northeast produced economically viable crops of hop on soils of near-virginal quality in the eighteenth and nineteenth centuries, these same soils would require significant remediation to be equally productive in the late twentieth and early twenty first centuries.

METHODS

Fertilization. To meet goals of restoring and conserving soil and water resources, the program of soil remediation and fertilization of hops relies principally on slow release naturally derived sources. Prior to the beginning of this study, 105 yd3 [87.5 m3] of leaf and grass compost was obtained (courtesy of Lebanon, NH solid waste facility). Analysis in fall of 1994 indicated a finished compost with adequate levels of organic matter and major nutrients. This material was spread by tractor and manure spreader, at the rate of 40 wet tons per acre. A 41 h.p. , 4 wheel drive tractor, John Deere model 1070, (courtesy of Deere & Company, Columbus, Ohio, and Blackmount Eqpt., N. Haverhill, N.H.), modified with 12.4" x 28" rear tires, rear work lights, and flexibly mounted rear warning lights; and supplied with a quick- attach loader (JD model 440), was used for all field work through the season. High magnesium limestone was applied by spreader truck at the rate of 2.5 tons per acre. These materials were incorporated by tillage with three shanks of a field cultivator set to a depth of approximately 12 in [30 cm], leaving approximately 50% of applied materials on the surface.

In April 1995, 90 yd3 [75m3] of a blend of topsoil, cow manure compost, and spent greenhouse media was supplied by neighboring grower to replace topsoil removed during his lease of the field. By test results from Agricultural Testing Lab, UVM, this material was judged consistent with the quality of compost previously used. Approximately 45 cubic yards were applied by bucket loader remedially to the areas known to have been stripped of topsoil. The remainder was applied by manure spreader throughout the field to equilibrate any nutrient imbalances in the material.

Following primary application of compost, 250 lb/acre [275 kg/ha] of a specially blended 12-4-12 (calcium nitrate, diammonium phosphate and muriate of potash) was broadcast by 3 point hitch spin spreader (courtesy of Bob and Marilyn Stone). An additional 300 lb [136 kg] was used as starter for potatoes. Subsequent mineral fertilizer applications were hand applied to individual plants in three application, resulting in (per acre [hectare]) a total mineral application of 191 lb [212 kg/ha] N as calcium nitrate and ammonium sulfate, 40 lb [44.4 kg/ha] P as diammonium phosphate, 221 lb [245.3 kg/ha] K as muriate of potash, sulfate of potash, and sulfate of potash magnesia, 119 lb [132.1 kg/ha] Ca from calcium nitrate, and 50 lb [55.5 kg/ha] Mg from sulfate of potash magnesia, with incidental amounts of zinc, copper and boron. Fertilizer applications were timed to immediately precede tillage or cultivation operations.

In July, 150 yd3 [125 m3] of two years aged cow manure (gift of Rita LeMountain) was hauled onto site, stacked for composting and covered with woven black polypropylene. Compost was applied (tractor and spreader courtesy of David and Jody Horan) in late October

at the rate of approximately 40 tons per acre [90 tonnes per ha], and incorporated with 5 shanks of a 66" [167 cm] Pittsburgh spring trip field cultivator to a depth of approximately 12" [30 cm].

Conservation tillage, weed control and cover cropping. To conserve soil and water resources and minimize environmental and health risks by obviating herbicide use, bidirectional cultivation was eliminated and interrow cultivation was significantly reduced. This was achieved by the use of an interrow cover crop, regular mowing and reduction of cultivation for weed control. After primary fertilization with compost/top soil amendment, the field was conventionally tilled in both directions using Pittsburgh spring trip chisel, fitted with five shanks. Several days before seeding, interrow lanes were tilled with a 59" [150 cm] rotovator (courtesy of Bob and Marilyn Stone) to produce a finished seed-bed. A nurse crop of oats and Japanese millet, 100 and 15 lb/a, [111 and 16.6 kg/ha] in combination with sweet clover and white Dutch clover, 15 and 3 lb/a [16.65 and 3.3 kg/ha], was seeded on April 29 in interrow lanes (north/south) using a 63" [160 cm] Brillion seeder (courtesy of Tim and Janet Taylor). In early May, just prior to stringing and training of hops, cultivation of hops for weed control was first performed using a three point hitch cultivator, modified by removing all but 2 pairs of outside springteeth, leaving an ~4.5 ft [123 cm] swath of cover crop undisturbed. Cover crop was mowed on approximately two week intervals with a 5 ft. [152 cm] rotary mower (courtesy of David and Jody Horan), with side plate removed on left side to discharge plant residue at base of hop plants. In early June, after completion of stringing and training of hops, to sweep soil to base of hop plants, two standard duck foot cultivator shoes were modified by welding a one foot length of automotive leaf spring at about 25° to the horizontal. Remaining weeds within the hop rows were mowed in late June using a Stihl hand held weed trimmer (courtesy of David and Jody Horan). With the exception of several rows of new plantings, hoeing was eliminated.

Market Intercropping. Interplantings of the perennial hops with annual secondary market crops, addressed goals of improved economic opportunity of hop growing enterprise through diversification or in early establishment years. In conformity with a planned three year internal rotation, every third interrow lane was reserved for interplanting vegetable crops. For comparison, additional areas were planted on field boundaries and treated identically. Potatoes and onions were selected to interfere minimally with seasonal labor requirements of hop production and to determine adaptation in terms of shade tolerance, complementary nutrient requirements, disease and insect resistance and possible effects on hop production.

Primary tillage was performed as described above. Furrows for potatoes were made with double disk hillers mounted on three point hitch tool bar in reversed position. Seed potatoes of five varieties were obtained from a local supplier, hand cut to 1.5 to 2 oz. [42 to 56 g] pieces and hand planted at approximately 6 in [15 cm] spacing. Fertilizer (12-4-12, as above) was applied at the rate of about 3 lb per 100 row feet [4.5 kg per 100 m]. Seed was covered using a three point hitch Dearborn spring tooth cultivator. The same cultivator was used prior to, and at emergence, modified with a 38" [97 cm] gang of a tine weeder to rake out sprouting annual weeds. Potatoes were hilled twice with double disk hillers. Remaining weeds were hand pulled on a random basis. No herbicide, fungicide, or insecticide was used through the season.

Beds were prepared for onions by making furrows with three point hitch cultivator with spring teeth 11" apart. Onions were planted as sets, 3 to the foot, and covered with a rake. Approximately 1500 row feet were handled in this manner. Some beds were planted as seed (gift of Johnny's Selected Seeds) by hand. Weed control was performed mechanically with tine weeder as described, onion hoe, and wheel hoe. Onions were pulled by hand or dug with potato digger and field windrowed to dry.

Stringing and Training. Construction in 1994 of the first field scale trellis and overhead wirework in New England offered this first opportunity to adapt and refine training system with a maturing hop planting. A crowsnest was constructed from a scrap tire changing cage by a local welder, and was mounted onto JD 440 bucket loader by chain and binder. Coir rope, clips and special tool were obtained from a commerical supplier. Beginning May 10, a worker was driven through field in tractor crowsnest (this procedure does not conform to manufacturer's safety standards and is not recommended) to tie coir strings (2 per plant) to overhead wirework. Strings were fixed into the ground at hop crowns using clips and special tool. Manual training of hop shoots began immediately thereafter. First training was completed May 24. A second training was begun June 1.

In mid-June, as hops approached full height of wirework, strings were tied (arched) at ~4.5 ft. [1.37 m], lower leaves were stripped to reduce spread of mildew. Approximately one third of plants were stripped by hand, a third by back-pack propane flamer, and the remainder left unstripped. No fungicide was used.

Hops were hand picked beginning August 18 and continuing through October 3. Drying was performed using a forced air bed dryer with ambient temperature or occasional heat supplied by a wood stove. Hops were sacked in burlap and stored at ambient temperature. For analysis, hops were hand sampled from the center of each bag. A late variety was field sampled at approximately six foot height [2 m] just prior to harvest.

Hop analysis was performed by Brooke Martin, MSc, and Kent Sudgen, PhD (courtesy of Dept of Chemsistry, Dartmouth College, Hanover, NH. Bittering acids were extracted from ground hops by a modification of the alkaline methanol method of the American Society of Brewing Chemists and analyzed by spectrophotometric assay. Organoleptic (sensory) analysis of aromatic properties was performed by local brewers.

OBSERVATIONS and RESULTS

Fertilization. In mid-April, annual weeds of cultivation, lamb's quarters or smooth pigweed (Chenopodium sp.) and redroot or rough pigweed (Amaranthus sp.) were observed emerging from strips of unincorporated swaths of application of leaf and grass compost. Previously these weeds have not been observed until late May or early June. No emergence of these weeds was seen in tilled areas of bare soil at this time.

Reliance on compost as complete nutrient sources was modified in late April with the emergence of hop shoots and the appearance of visible deficiency symptoms, notably of calcium and magnesium. Applications of mineral fertilizers followed. Under drought conditions through the first half of the growing season, and without artificial water applications, mineral fertilizers were often observed to have remained undissolved. Moderate phosphorus deficiency symptoms appearred on some varieties after flowering early July and remained throughout the season.

Conservation Tillage, Weed Control and Cover Cropping. The absence of significant rainfall from late April through mid June resulted in a poor stand of the seeded cover crop of oats, Japanese millet, and sweet and white clover. In mid through late June, these strips of cover crop were supplemented by the germination of the endogenous supply of lamb's quarters, redroot pigweed and crab grass. Due to the unsteady growth of the cover crop, it was not entirely possible to abandon cultivation and rely entirely on mowing this vegetation as a source of mulching material for weed and moisture control among hop crowns. Nonetheless, regular mowing of these strips delivered a steady supply of decaying vegetation to the base of hop plants.

Cultivation with a standard two bar Dearborn cultivator equipped only with 2 pairs of outside spring teeth and equipped with an outside pair of custom built extended sweeps provided some measure of weed control within hop rows, and with minimal damage to hop plants. Weed control within hop rows was nearly complete in places, but in some rows required some mowing with hand held rotary mower.

Intercropping. Interplantings of potatoes and onions in lanes between trained hops were found to be technically feasible. Labor requirements, timed to precede hop training and precede harvest, did not substantially conflict with labor requirements for hops.

Management of potatoes among hops posed no significant problems. Simultaneous cultivation of hops and potatoes, with a hybrid tine weeder-springtooth cultivator, was 95% effective in preemergent control of annual weeds. Similarly, hilling of both potatoes and hops could be performed with a single implement simultaneously. No spray for Colorado potato beetle was used. Beetles appearred first on control strips of potato plants in a sandy, exposed slope and spread to other control strips. Potato rows interplanted with hops were affected last.

Harvest and marketing of potatoes coincided with defoliation by Colorado Potato Beetle. Early potatoes were hand dug beginning the first week of July. From late July through mid-August, a one row PTO driven potato digger (John Deere, Ca. 1940) was used, with only minor damage to adjacent hop vines. Digging potatoes was completed a week before onset of hop harvest. Potatoes were marketed through local produce retailers, directly to visitors, or supplied (or fed) to volunteer hop pickers.

Under drought conditions, emergence of directed seeded onions failed. Red onion sets were of poor quality and emerged unevenly and were turned under. Yellow set onions grew successfully and matured beginning late July and were dug and removed by the middle of August, a week prior to the beginning hop harvest. Onions were marketed or distributed in the same manner as potatoes.

Control strips of potato and onion along field boundaries matured, or were defoliated, and removed prior to interplantings. Consequently, direct yield comparisons would not be valid and were not recorded.

Stringing and Training. Strings were tied to overhead wirework by single worker operating from platform attached to bucket, and elevated by loader frame of tractor. Training followed and was completed within the projected time frame.

Stripping proceeded simultaneously with tying bines (arching) in mid-June. Angular leaf spot, symptomatic of powdery mildew was noted in some varieties in early June. Stripping alone, by flame or hand, failed to entirely control mildews.

The first hop bines reached the top of trellis (16 ft) [4.9 m] by the 10th of June and were noted at that time to be growing as much as six inches [15 cm] per day in areas with adequate soil moisture. First burrs were noted the first week of July. Bines grew as long as 27 feet [8.23 m], and were regularly measured at approximately 20 feet [6.1 m].

Hand harvest was, as expected, interminable, but not unpleasant. Assistance was ably and consistently supplied by dependable evening and weekend hop pickers, Phoebe Tzou, Dr. William Steinhart, Brooke Martin, Dr Kent Sudgen, Lori Bushway, Mary Poulsen, and Ana DePina, and many others.

Consistent with customary and reasonable practice, and regulatory assurance in the hop producing states, of the confidentiality of individual proprietary statistics, yield and analytical data are not reported. However, of five varieties, of mixed ages, one to three year old plants, yields were significantly less than reported yields in established growing regions. Overall, 50% damage from downy and/or powdery mildew is reported, with 90% loss of one variety included in that estimate. As this planting has not yet reached full maturity, and in the absence of sufficient funding to begin an effective program of plant protection, these data are not conclusive.

Pests. While insect and disease control were not specifically addressed in this study, and lacking adequate funds for a parallel study of plant protection methods, observations were nonetheless made throughout the season. As a result of steady growth of bines up a string , compared with growth on poles or baling twine as used previously, crimping of bines and consequent entry and damage from hop bine weevil (presumably, fam. *Cossidae*) was minimized, and was not considered to have reached an economic threshold. Damson hop aphids (*Phorodon humuli*) rarely exceeded 6 per leaf. Red spider mites (*Tetranychus urticae*) were occasionally observed, but similarly did not pose an economic hazard. Twice, personal contact with a caterpillar (fam.*Notodontidae*) with a cryptoxic defense mechanism, possibly formic acid, resulted in a clinically significant injury, blistering of the skin.

DISCUSSION

Early season nutrient stresses predicted by lab results, indicated that domestic yard residue compost and an enriched compost-based soil amendment broadly applied did not supply adequate levels of major nutrients in rooting zone of hops. General improvement in plant health later in the season, indicated by robust hop growth and reduction of deficiency symptoms, may be attributed to improved availability of nutrients from composts under warmer soil temperature or mineral fertilizers, or both. Absence of insect damage, suggestive of a healthy plant from a balanced nutrition, supports the evolution of a rational mixed approach to hop fertilization, exploiting a range of materials with different solubilities. Late season appearance of nutrient deficiencies in some plants indicates a required adjustment. An ample supply of soluble nitrogen may have predisposed one cultivar to widespread mildew damage.

Other effects of the use of compost for field hop production are noted. Where compost remained on the surface, early appearance of certain weeds indicated an increase in early spring soil temperature. The addition of large volumes of organic material, via composts, may have also resulted in improved moisture retention, as evidenced by undeterred plant growth during a prolonged drought period in the first half of the growing season. Positive effects on vigor of hop from auxins, growth hormones and humic acids present in compost, can only be assumed.

Wind borne soil loss was significantly reduced as a result of interrow cover crop and minimal cultivation for weed control, coincidentally (subjectively) improving working conditions and local aesthetics. Similarly, a cover crop combined with minimal cultivation has, by observation, moderated extremes of day and night temperatures, particularly in areas tending towards sandy character, and may have contributed beneficially to steadier growth of hops. Further improvements in in-row weed control and cost savings may be made in coming seasons by more careful timing and skillful cultivations.

Adoption of use of coir rope and stringing from a elevated and moving platform made for a modestly efficient first use of overhead wirework, compared with a previous use of baling twine and stringing from the ground. Downsizing to suit a limited scale, a single row was strung at a time requiring two people, compared with as many as four people stringing from a trellissing trailer in the Northwest. Completion of training in the projected time frame permitted improved uquality of life in late spring and early summer.

Interplantings between hop rows, of secondary market crops, potatoes and onions, were found to be technically feasible. Improvement in economic potential of hop growing enterprise in early years was achieved through this diversification, indeed it may easily be concluded that market intercrops may be of equal economic value to the marginal commodity value of hops, and without the extensive capital investment of trellis, delayed productivity and specialized equipment. Delayed infestation by Colorado Potato Beetle in potatoes interplanted between hop rows suggested an inhibitory effect of hops on the migration of the beetle. Further study would be required to verify this observation.

Cumulatively, these practices have resulted in the first harvest of field grown, commercial quality hops for the brewing trade in New England in nearly a century. Quality standards, evidenced by analysis for bittering acids and sensory examination by professional brewers, compare favorably with hops grown in established growing regions. Yield data may be regarded as inconclusive, but suggest that some improvement in cultural methods and rigorous selection of varieties may made before direct economic comparison can be made with established hop growing regions. As expected, downy and powdery mildew diseases may prove refractory to control by cultural methods alone.

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Outreach

A. Field Days for Brewers, General Public, and Affiliated Professions were held on August 18, 19, and 21, 1995, approximately 50 people attended.

B. Article was published in Valley News, Lebanon, NH, September 10, 1995.

C. Same article (through wire services) reprinted in Portland (Maine) Sunday Telegram (distributed throughout Maine) in mid September.

D. Article in Seven Days, Burlington, VT area, with reference to first commercial brewing underway (middle October).

E. Copy of report will be submitted to Hop Research Council, Salem, Oregon for possible inclusion in annual report to hop growers, researchers and industry.

F. Copy of report will be submitted to Washington State Hop Commission for possible inclusion in grower's bulletin.

G. Slide show presentation will be available to
Maine Brewers Guild
Vermont Brewers Association.

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hopCulture
East Thetford, VT
February 6, 1995

ADDENDA Soil and Compost Test Results*

	Soil Test 5/93	Mun. Comp. 11/94	Soil Amend. 4/95	Min. Appl. 4/-6/95	Comp. Man. 11/95	Total (lbs) (per acre)	Retest Spring 96
		40 t/a	15 t/a		45 t/a	100 t/a	
O.M.(%)	2.7	15.0 %	6.2 %	0	23.5%	-	
added		5583#	1240#	0	12,572#	19395#	
C.E.C.	3.9	9.4	9.7	n/a	n/a		
pH	6.35	6.9	6.9	n/a	6.9		
C/N		14.8	n/a	n/a	11.6		
N	-	227#	n/a	191#	214	632	
P	4.6 ppm	44#	97.6 ppm	40 #	128	212	
reserve	166 ppm						
K	75 ppm	97#	760 ppm	221#	198	516	
Ca	662 ppm	510#	1110 ppm	119#	289	918	
Mg	50 ppm	212#	263 ppm	50 #	348	610	
Na	10.5 ppm	11#	99ppm	unk	10	21	
Cu	0.35 ppm	1.5#	0.2 ppm	@1#	1.2	3.7	
Zn	0.75 ppm	6.4#	2.2 ppm	@1#	4.0	11.4	
Fe	3.1 ppm		3.6 ppm				
Mn	2.9 ppm	21.0#	5.2 ppm	28.0#	49.0		
Bo	0.15 ppm	1.7#	0.5 ppm	@1#	3.0	5.7	

* Does not include @ 5 tons compost sidedressed in spring 1994, @ 40 wet tons/acre of haylage, waste hay and horse manure applied as mulches 1994 and 1995, and @ 2.5 t/a dolomite limestone applied fall 1994.

For sources of mineral nutrients, see text.