STRATEGIC PLAN

FOR THE

HOP RESEARCH COUNCIL

Prepared by the Strategic Planning Committee

Revised August 9, 2005

CONTENTS

Introduction

The Strategic Planning Committee (SPC) of the Hop Research Council (HRC) was founded as a standing committee in 1995. The SPC prepared a strategic plan (SP) based on a survey of priorities among the membership. Additionally a mission statement was prepared. In 1997, with the breakout of powdery mildew in the USA, the plan was appended and updated for 1998. In 2003, at the suggestion of the HRC president and members, the SPC held discussions to update the SP, with consideration of quickly emerging tools from molecular biotechnology and with a perceived need for concordance with research occurring in the EU and elsewhere. Additionally, in 2003, a survey of Washington Hop Growers, conducted by the Commission, informed the membership on grower directives.

The original SPC mission statement calls for a repeat of the member survey every 5 years. This document is an updated strategic plan which reflects the results of the 2005 survey of priorities among the membership.

Mission

- The purposes of the Hop Research Council are to
    - Solicit and provide funds for scientific investigation and research related to the agricultural production and quality of hops in the United States; and to
    - Serve the needs of all segments of the hop industry by maintaining a membership which covers the entire industry and by supporting research that meets the needs of its members.

Research Program Core Values

The results of the 2005 priority survey identified three key areas of research, or “Core Values” important to HRC membership (detailed results of the priority survey can be found in the Appendix).

1. **Improvement of agronomic and quality traits of U.S. hops.**
2. **Lower cost of production and processing of U.S. hops.**
3. **Elimination or control of diseases and pests of U.S. hops.**

Determination of funding priority for new and existing projects should adhere to the Core Values. Projects with objectives which do not support these Core Values should be considered only as special projects if funding is available.

The following summary reflects concerns and issues regarding the research program and operating guidelines from past and present priority surveys.

- The key strategic focus should be to maintain and enhance the HRC research base, organization, research program, funding and direction by:
    - Ensuring the HRC has a role in selecting new researchers, setting program priorities and doing formal program reviews.
    - Maintaining adequate investment from brewers to ensure brewers' needs are met.
    - Ensuring adequate research positions by appropriate lobbying of public officials and other means.
    - Consider international concordance and promote harmonization.
    - Addressing the issues of finances, membership, relationships and planning as dealt with in following sections.
    - The HRC is generally supporting research in line with members' wishes and priorities. Most, but not all, current research programs, priorities and funding are satisfactory.
    - The HRC should continue to maintain an emergency reserve (contingency fund) of $30,000 per year for such projects.
    - The HRC must assure that all members' needs are met. The Strategic Planning Committee should act as a forum for members who have concerns with regard to projects and priorities.

Financial

- The major threats to HRC's financial health and thus ability to continue funding research programs are loss of membership and loss of public funding. Therefore:

- Membership should be well informed of HRC researcher's progress and impact.

- The major approach to ensure continued public funding is for the HRC executive and researchers to maintain regular contact with the appropriate public officials and provide them with at least annual information on the benefits to the industry by the publicly-funded research programs. See below regarding these key relationships.

- The HRC must be creative in developing other sources of funding (see Appendix for examples).

Membership

- The keys to continued healthy HRC finances are keeping our existing members and adding new members, by

    - Ensuring the HRC keeps members advised of progress of researchers and identifies direct benefits of sponsored research. Periodically review goals and accomplishments to membership.

    - Ensuring the HRC keeps its existing members by assuring that the needs of all members are met and by defining and promoting the benefits and return on investment of HRC membership.

    - Informing potential members of benefits of HRC membership and actively invite participation.

    - Suggestions for recruiting new members are presented in the Appendix, item No. 3

Key Relationships

- The HRC must maintain and / or develop key relationships and key contacts with members, researchers, university departments, university administrators, state officials and federal officials.

- A plan for maintaining and / or developing these relationships and contacts must be developed.

The Strategic Planning Process

- Maintain the Planning Committee as a standing committee.
- The key functions, duties, responsibilities and mandate of the Planning Committee are to
    - Conduct an annual review of the strategic plan and establish an annual plan.
    - Recommend how to implement the HRC Strategic Plan.
    - Survey the members at least every five years to identify changes in research priorities.
    - Set priorities for research projects and make recommendations to the other committees.
    - Address strategic issues not covered by the other committees, including setting priorities, deciding which issues to raise with the members, and determining how to implement the solutions.
    - Provide a formal mechanism for progress accounting of sponsored projects and report impact assessments to membership.
    - Consider and recommend changes in structure of the Council to the membership.
    - Seek and employ external advice and assessment expertise as needed.

APPENDIX TO THE HRC STRATEGIC PLAN

LAST REVISION: August 9, 2005

HRC Strategic Planning Committee Members as of the 8/9/05 revision:

- Darwin Davidson
- John Henning
- Paul Matthews
- Jason Perrault, Chair
- Kevin Riel
- Mike Wood

1. THE HOP RESEARCH COUNCIL (HRC) RESEARCH PROGRAM

Based upon the 2005 priority survey results and SPC discussion, the Strategic Planning Committee has the following comments/suggestions to add:

- There is continued interest in most current HRC funded projects.
- There seems to be less interest in some specific areas of research such as new uses and sensory research.
- There is increased interest in finding additional sources of funding.
- The membership seems to favor shorter term research which benefits the brewer and the grower.
- The highest priority items have not changed considerably since the last priority survey, thus the development of the "Core Values."
- There have been some changes in HRC priorities since the last revision of this strategic plan. At the August 13, 1997 meeting of the HRC Strategic Planning Committee, it was agreed that, in view of the 1997 outbreak of hop powdery mildew in the Yakima Valley, the HRC must address hop powdery mildew both as an emergency, short term project and as a strategic, long term project. It is apparent from the surveys that the view of powdery mildew as an emergency has changed. This Appendix has been modified accordingly.
- In support of the mandates of the planning committee a survey has been developed to assess research projects.
- Hop breeding has consistently had high priority with the members of the HRC. The U.S. hop industry has the unique and beneficial position of supporting both private and public breeding programs. Therefore it is the suggestion of the SPC that an official meeting between the public and private hop breeders occurs at each winter meeting in an effort to facilitate further communication between the programs.

2. FINANCIAL

Following are additional details on this aspect of the strategic plan.

- The HRC needs to be creative in developing other sources of funding, for example
    - Consider sharing projects with other commodities.
    - Consider grant programs and / or funding.
    - Consider matching endowed research positions.

3. MEMBERSHIP

Following are additional details on this aspect of the strategic plan.

- The Strategic Planning Committee recommends the HRC take a more aggressive approach to the recruitment of new members, including but not limited to
- Consider the development of alternative membership categories. For example group memberships for micro/craft breweries, allied industry memberships, etc.
- Approaches to recruiting new members include
    - Develop a package of promotional information demonstrating the strengths of the HRC and the benefits of membership.
    - Stress the leverage of HRC research dollars.
    - Select new officers from new members to demonstrate the benefits of membership.
    - Define and promote return on investment of HRC funds.
    - Stress achievements of the HRC. Maintain a current list of publications by researchers supported by HRC.

4. RESULTS OF MEMBERSHIP SURVEY ON PRIORITIES OF HRC RESEARCH

The following provides a summary of the results of the 2005 membership survey on priorities of HRC research.

The major work areas and objectives within major sections are listed in order of descending priority.

The priorities are presented as an average priority value calculated from all submitted surveys to facilitate comparison. The values were based upon a 1 (high priority) to 10 (low priority) scale.

A blank copy of the survey containing definitions and descriptions of all survey items can be found in section 5.

4A. SECTION PRIORITIES

	Response #							
Section Description	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Average**
Quality	1	1	2	4	1	3	2	**2.0**
Breeding and IPM	4	1	4	3	1	1	4	**2.6**
Production Costs	4	1	3	1	1	2	7	**2.7**
New Uses	6	1	10	4	1	10	5	**5.3**

4B. GROUP PRIORITIES

Section: Quality

			Response #							
Group	**Item**	**Description**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Average**
1	1	Prebreeding interaction of breeders with HRC membership	1	1	2	2	1	1	1	**1.3**
1	2	Interaction of breeders with growers.	2	1	1	2	1	2	1	**1.4**
4	1	Molecular diagnostics for varietal identity or purity.	1	4	2	4	6	3	6	**3.7**
1	4	Interaction of breeders with handlers and brewers.	4	1	9	6	4	1	6	**4.4**
2	1	Analytical methods in processing.	1	4	9	6	4	5	6	**5.0**
1	3	Interaction of breeders with brewers and food scientists.	3	4	10	9	3	5	3	**5.3**
2	2	Improvements to sensory evaluation.	2	4	10	7	7	5	6	**5.9**

Section Production Costs

			Response #							
Group #	**Item**	**Description**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Average**
1	1	Increased federal and state monies directed to lower input costs.	1	3	7	1	1	3	2	**2.6**
2	2	Process improvements at pre-harvest and harvest.	5	3	3	1	4	2	8	**3.7**
2	1	Post harvest processes	5	3	3	4	4	1	7	**3.9**
1	2	Increased funding to agronomics at public research institutions. Write grants.	7	3	10	2	1	2	7	**4.6**

Section Breeding and IPM

			Response #							
Group #	**Item**	**Description**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Average**
2	1	Screen and characterize cultivated and wild accessions heritable disease resistance.	2	1	1	3	1	2	2	**1.7**
1	1	Integration of program goals across disciplines.	3	1	8	1	1	1	3	**2.6**
2	5	Early disease/pest detection	4	1	7	2	1	3	5	**3.3**
2	2	Screening assays for resistance to pathogens and pests.	5	1	3	5	2	1	7	**3.4**
2	4	Identification of genes involved in disease resistance.	4	1	5	3	5	2	4	**3.4**
3	1	Expansion of germplasm diversity.	6	5	2	2	1	3	8	**3.9**
2	1	Natural predators for control of pests and diseases.	3	1	8	4	2	5	4	**3.9**
2	3	Identification of DNA sequences as either selectable markers or resistance genes.	4	1	10	4	5	1	4	**4.1**
3	3	Development of a genetic system and breeding	8	5	4	4	5	2	7	**5.0**

		performance data.								
3	4	IPM	6	1	10	7	2	5	6	**5.3**
3	2	Phylogenetic reconstruction and genetic diversity of hop germplasm.	10	5	10	5	5	3	8	**6.6**
4	1	In vitro reproduction	9	5	9	5	5	4	9	**6.6**

Section New Uses

Response #

Group #	Item	Description	1	2	3	4	5	6	7	Average
1	1	Identify and foster extramural funding for research on health benefits of hops.	6	1	10	3	4	8	5	**5.3**
3	2	New use for harvest and process by-products.	5	8	10	4	6	5	5	**6.1**
2	1	Chemical content	5	5	10	6	6	7	5	**6.3**
3	1	New chemical accumulation	5	8	10	7	8	10	5	**7.6**

5. 2005 PRIORITY SURVEY: SECTION, GROUP, AND ITEM DEFINITIONS

Place a priority rank from 1 (high priority) to 10 (low priority) in the box or blank, send back to Michelle

Section Quality
_____Quality traits of hops

Goal Definition: HRC Membership can request of the Hop Breeders new hop varieties that fulfill the flavor and economic requirements of certain beer types. HRC shall foster communication and interaction between Breeders, Growers and End-users.

Regardless of whether or not the requested new hop varieties are aroma, dual, or bitter type, the Hop Breeder can select from agronomically- and economically-sound cultivars to match the HRC Members request.

The desired goals are for the Hop Breeders to provide new hop varieties to the

HRC Membership that will satisfy their particular brewing requirements, while at the same time provide healthy and economical hop varieties for the Hop Growers to produce.

☐ **Section Quality**
_____**Group 1 Priority** Foster interaction among Breeders, Growers, Processors and Brewers.
Item 1. Pre-breeding interaction of Breeders with HRC Membership
Examples 1:

- Promulgation of minimum set of required traits for brewing
- Promulgation of minimum set of required traits for agronomics
- Promulgation of minimum set of traits for processing

Time to Impact 1: 5-12 years
Comment 1: Different Brewers, Handlers and Growers may specify needs to HRC membership. HRC functions to facilitate communication among the various interests and to the Breeding Programs. Examples of dictums may include: prescriptions for evaluation processes, for methods evaluation and for required traits, among others.

☐ **Section Quality**
_____**Group 1 Priority** Foster interaction among Breeders, Growers, Processors and Brewers.
Item 2. Interaction of Breeders with Growers
Examples 2.

- Field trials and evaluations of agronomic performance, disease resistance
- Evaluation of seasonal consistency
- Evaluation of time-of-training
- Evaluation of pick-ability and kilning properties

Time to Impact 2: 7-12 years
Comments 2: Extensive field-testing in a variety of locations and under a variety of harvest systems over several seasons is necessary to assure agronomically-sound varieties. Candidates that show agronomic promise in small plots, meet a minimum set of pre-set standards of the Brewer, Processor and Grower may advance to commercial scale test plots after chemical trait evaluation, hand-rub tests and discussion with the Breeder.

☐ **Section Quality**
_____**Group 1 Priority** Foster interaction among Breeders, Growers, Processors and Brewers.
Item 3. Interaction of Breeders with Brewers and Food Scientists
Examples 3:
Evaluation and review of chemical traits
Evaluation and review of olfactory traits (hand-rub evaluation)

Pilot brews
Flavor evaluations
Comment 3: HRC may serve as a interface for reviews and testing of varieties. For example, hand-rub evaluations occur at semi-annual meetings. Breeders should take care in preparing samples appropriately for these evaluations. HRC serves as one mode of introduction of varieties to Brewers and Food Scientists.

☐ **Section Quality**
_____**Group 1 Priority**
Item 4. Interaction of Breeders with Handlers and Brewers
Examples 4.

- Evaluation of pelletization
- Evaluation of extractability
- Evaluation of isomerization properties
- Evaluation of storage and combustibility

Time to Impact 4:1-5 years
Comments 4: Varieties developed in collaboration must also meet the needs of the Brewer's need in processing.

☐ **Section Quality** Control and process
_____**Priority Group 2**. Improvements to quality control and process
Item 1. Analytical methods in processing
Examples 1:

- Development of consistent moisture content analyses, especially in bales
- Real-time, in-line analytical methods in process (e.g., videometrics, scanalytics, IR)
- Bitter acid determination
- Polyphenol determination (LCMS2)
- Oil analyses (e.g., SPE, headspace, GCMS, GCO)

Time to Impact 1: 3-5 years
Comments 1: Improvements in analytics are supported.

☐ **Section Quality**
_____**Priority Group 2**. Improvements to quality control and process
Item 2: Improvements to sensory evaluation
Examples 2:

- Improvements in evaluation methods
- Improvements in application of statistical methods
- Application to Brewer's concerns in quality development and control

Time to Impact 2: 2-5 years
Comments 2:

☐ **Section Quality**
_____**Priority Group 4.** Verification of root stock and products

Item 1. Molecular diagnostics for varietal identity or purity
Examples 1: 3-5 years

- DNA fingerprinting
- Oil composition profiling
- Polyphenol and flavonoid profiling

Time to Impact 1: 3-5 years
Comments 1: Methods exist for identification of some varieties by PCR and/or chemical evaluation. While these methods are relatively inexpensive to develop, routine analyses would be a further cost burden to the industry. These methods can also be applied to reconstruction of hop pedigree, where information is lacking.

Section Production Cost
_____Lower the Cost of Production of U.S. Hops

Goal Definition: Currently hop growers in the United States produce 115 million dollars worth of product each year. The average cost to produce an acre of hops is estimated at $4,000. The U.S. hop industry contributes unique assets to the brewing industry world wide with its selection of hop varieties, and its attention to detail. Brewers depend on U.S. hops to produce quality beer in each and every year. Growers in the United States are increasingly under pressure by foreign countries to maintain their market share. U.S. growers have to contend with European countries that have been growing hops for centuries, and at times the tradition that has been established with some brewers is difficult to overcome. Emerging countries also present challenges for the U.S. grower. The cost of their labor is so low that U.S. growers find it difficult to compete with them.

There is need for research to help U.S. growers lower their cost of production, so that they can compete in today's competitive world markets. Growers find it economically difficult to conduct research on their farms to discover methods to lower their production costs. The usual mistakes, which are inevitable in research, cannot be tolerated if a grower is expected to stay in business. He must compete against his fellow growers in each and every growing season, all the while trying to be innovative in order to insure his long-term success along with other U.S. growers in the world market.

In order to insure long-term survival of the U.S. hop industry, the industry must reduce their input costs by 10% over the next 5 years. This will enable U.S. growers to stop the current deterioration of their world market share. Further efforts will be needed if this first goal is met. To make the U.S. grower a viable long-term supplier to the world brewing industry, he will need to lower his costs by 25% over the next 10 years. Pressure from Asian suppliers will mandate increased efficiency.

The obvious benefits are attained by the U.S. Grower, but the Brewers world-wide, and particularly U.S. Brewers, would greatly benefit from such research. Brewers are continually looking for areas to lower their input costs as well. Many brewers place a high value on the ability to source hops from

differing locations from around the world. Lowering the cost of production for U.S. growers will enhance any brewery's ability to source hops in the United States. Finally, the consumer derives the ultimate benefits. The consumer will be able to purchase a quality beverage at a reduced cost.

Priorities.

Section Lower Cost of Production
Priority Group 1. Identify sources of funding and mechanism for increased agronomic research.
_____**Item 1.** Increased federal and state monies directed to lower input costs
Examples 1.

- Hop Research Initiative and Hop Economic Viability Initiative
- Growers compete for grants administered by HRC
- Other funding agencies?

Time to impact 1: 1-10 years
Comment 1 . U.S. federal and state monies could be appropriated for the purpose of lowering the input costs of the growers. These monies could be allocated in one, or both, of two ways. Firstly, individual growers could apply for grants to conduct this type of research on their farms in a true commercial environment. A panel of growers, brewers, and university researchers (possibly the Hop Research Council) could evaluate these grants and appropriate the funding to the best uses.

Section Lower Cost of Production
_____**Priority Group 1.** Identify sources of funding and mechanism for increased agronomic research.
Item 2. Increased funding to agronomics at public research institutions. Write grants.
Examples 2.

- Hop Research Initiative
- USDA-ARS
- Other funding agencies?

Time to impact 2: 1-10 years
Comment 2. A second method of allocating these monies would be to have them designated to specific universities, who could hire professional researchers to conduct the studies. These researchers could choose to collaborate with individual growers, if they so desire.

Section Lower Cost of Production
_____**Priority Group 2.** Quality improvement at the farm.
Item 1. Process improvements post-harvest
Examples 1.

- Kilning practice
- Moisture determination, instrumentation and practice

- Baling, materials and methods

Time to impact 1: 1-10 years
Comment 1. Includes cost-avoidance in labor and materials as well as direct benefits in reduction of Alpha losses, reduction in rejected product, and reductions in insurance costs and other human liabilities.

Section Lower Cost of Production
_____**Priority Group 2.** Quality improvement at the farm.
Item 2. Process improvements at pre-harvest and harvest
Examples 2.

- Reduction in propagation and planting labor
- Improvements to training ergonoimcs
- Mechanization of vine loading to harvester or picker
- Mechanization of treatments and pruning
- Improvements to trellis system (low-trellis?)
- Cost reductions in twining (new material, i.e., polyethylene?)

Time to impact 2: 1-10 years
Comment 2. Includes cost-avoidance in labor and materials as well as direct benefits in reduction of losses, in insurance costs and other human liabilities. Creates higher-skilled jobs, sustainability.

Section Breeding & IPM
_____**Elimination of pesticides and control of disease**

Goal Definition: Breeding and Integrated Pest Management (IPM) to reduce and, where possible, eliminate chemicals used to control diseases and pests. This objective involves three different disciplines: genetics, pathology and entomology. In each discipline, modern techniques that have proven successful in other crops should be developed and deployed for reducing or eliminating pesticide applications.

Priorities:
Section Breeding & IPM
_____**Priority Group 1.** Integration of program goals across disciplines: genetics, pathology, entomology. Integration of research goals and research progress within the international community, communication and coordination of AHRC and EUHRC.
Item 1. Coordination of activities across disciplines and substantive deployment of knowledge to the crop improvement programs, the growers, and processors.
Examples 1.

- Extension service training of growers in IMP protocols
- Modeling, prediction, and information service of disease epidemiology

in relation to chemical application management
- Production, collection, archiving and distribution of data and biologics for agricultural genomics: diversity data, phylogenies, DNA libraries, sequence data, molecular maps and markers, and molecular diagnostics

Time to impact 1: 1-10 years

Comment 1. As the amount of disparate disciplinary information increases, so does the need for responsibility in integration, deployment and application of knowledge. HRC and its sponsorship have an increased responsibility to growers and processors to deploy technologies. Strong leadership can have a large impact on our relatively small constituency. Integration and practical dissemination need be developed and encouraged. Co-ordination and harmonization with the international community is essential in a *niche* crop, where limited resources are available. This is especially true of agricultural genomics development, which is too costly for any one country or interest to pursue.

Section Breeding & IPM

_____**Priority Group 2.** Identify superior germplasm.

Item 1. Screen and characterize cultivated and wild accessions for heritable traits of value to disease control

Examples 1: Some specific traits that germplasm development should focus on are as follows (in order of importance or priority):
- Resistance to powdery mildew (caused by *Podosphaera macularis* spp. Humuli).
- Resistance to downy mildew (caused by *Pseudoperonospora humuli*)
- Resistance to spider mites (*Tetranichus urticae*)
- Resistance to hop aphid (*Phorodon humuli*)

Time to impact 1. 2-12 years

Comment 1. While varietal development is a critical requirement for the continued success of USA hop growers, there is some concern that public breeding programs should not be involved in the development and release of varieties. Several private breeding companies actively work towards developing and releasing public and proprietary varieties grown with the support of a marketing system that helps growers sell their product on the world market. In almost all other crops, public breeding programs no longer serve as the major developer of varieties but do serve as developers of germplasm containing a specific trait or traits. Germplasm developed by public programs is then utilized by private breeders for use in the development of superior varieties-the better the germplasm, the better the varieties that are ultimately made. Goals for germplasm development are centered on one or a few traits, while selection for a variety requires the identification of a line or lines that have excellent characteristics for many traits. As a result, much fewer offspring are required for selection in germplasm development in comparison to varietal development where up to 10X the number of offspring are required for successful identification of a variety containing all the desirable traits necessary for making a new and

better variety. In some cases, new material may be fortuitously developed that contain enough superior traits to warrant release as a variety. It is important to note that variety development will not be the focus of HRC support but may be pursued by individual members of the HRC utilizing private funds.

Section Breeding & IPM
Priority Group 2.

☐ _____**Item 2**. Further development of assays and screens for resistance to pathogens and pests.

Examples 2:

- Powdery mildew*. In vitro*, detached-leaf powdery mildew screening system using defined monosporic isolates
- Downey mildew. Misting, dew chamber, or *in vitro* method of disease assessment
- Behavioral screens for insect resistance
- Chemical correlates of phago-stimulants and -deterrents

Time to impact 2:

Comment 2. A system of maintained and characterized monosporic isolates of mildews and a deployable system to apply the isolates in progeny screens is essential to the development of durable (horizontal) resistance in hops. Under sponsorship of HRC, the universities could supply the groundwork and biologics to establish efficient screening tools to their own programs and also to industry programs. Similarly, an efficient, controlled and deployable system for screening progeny for insect resistance, either directly or indirectly, would be a great value to germplasm improvement and variety development programs.

Section Breeding & IPM

☐ _____**Priority Group 2.** DNA sequences as either selectable markers or resistance-conferring genes

Item 3. Identification of DNA sequences as either selectable markers or resistance genes.

Examples 3.

- Cloning and sequence characterization of known disease resistance genes from hops
- Development of high-frequency transformation for American breeding lines
- Over-expression of monogenic resistance (to mildew, mites, aphids) genes in hops
- Over-expression of known antimicrobial or anti-herbivory gene factors from other species
- Core molecular maps
- Correlative mapping of molecular polymorphisms to monogenic resistance loci in recombinatorial progeny (molecular maps)
- Applications of molecular polymorphisms in parent and progeny selections (MAS) for disease sensitivity and resistance

- Pyramiding of resistance genes by MAS
- Targeted introgression of alien traits followed by reconstitution with MAS recursive backcrossing

Time to Impact: 5- 12 years

Comment 3.

Molecular tools are means of speeding up and making more efficient the process of germplasm development. In addition, with the near-future advent of successful genetic engineering of currently desirable hop varieties, molecular means of genetic improvement for specific traits (under single gene control) will be accomplishable. While some of the currently available molecular tools have successfully been adapted for use in hop, a number of newer techniques have not been attempted. The development and application of molecular tools in hop requires specific tools and instruments that are not generally available to private hop breeding programs. These tools and instruments are either in the possession of, or readily available to, the public breeding programs. Therefore, HRC believes that members should take advantage of these capabilities by funding the application of molecular tools at the public research institutions towards their use in germplasm development. The application of molecular tools having the greatest chance of success towards implementation in germplasm development should have priority funding. Nevertheless, funding for new applications in hop germplasm development should not be restricted if success of the new tool has been proven in other crops. Finally, genome characterization should be encouraged through the funding of USA scientists working with international collaborators. A hop genomics effort is too expensive to be maintained or deployed by any one interest. It is anticipated that non-USA scientists would obtain funds to pursue their collaborative work from sources other than HRC.

Section Breeding & IPM

Priority Group 2.

_____**Item 4.** Identification of specific genes involved in the disease resistance pathway in the interaction be between hop and pathogen

Examples 4.

- Identification and isolation and sequencing of infection-response genes from hop and hop pathogens
- Genomics of pathogens, sequence-based molecular diagnostics development
- Integration of hop pathogen molecular detection systems, multiplex pathogen profiling
- Molecular diagnostics of virus- and viroid-free production systems and of commercial impact studies of virus-free systems
- Molecular diagnostics of host-vector-pathogen interactions

Time to Impact 4: 1-5 years

Comment 4. Research on plant genetics involved in resistance to specific diseases should be simultaneously accompanied by molecular investigations on the genetic control of disease induction for specific fungal and viral pathogens.

This research would not be limited to studies on single genes but would include genome sequencing and gene identification. Being a much simpler organism, a fungal pathogen can be sequenced along with gene identification on a much quicker scale than that for hops. Identification of genes involved in the induction of disease in plants would aid towards the ultimate goal of identifying hop genes responsible for resistance response.

Section Breeding & IPM

_____**Priority group 3**: Expansion of germplasm diversity

Item 1. Collection, archiving, characterization and distribution of elite and wild germplasm.

Examples 1:

- Collection of native American Hops
- Collection of international elite, landrace, and wild varieties to the USDA archives
- Characterization of key traits, e.g., mildew resistance, insect resistance, etc
- Virus-free production for archives of accessions

Time to Impact 1: 5-20 years

Comment: Aspects of hop reproductive biology and breeding history have lead to deployment of a very narrow germplasm for hop cultivation. Although there is no direct evidence in hops, narrow germplasm is generally thought to predisposition widespread crop failure due to new abiotic and biotic challenges for two reasons: (1) Widespread host susceptibility due to homogenous genetic background and (2) slow breeding-response time due to lack of allelic potential in current breeding populations. While most elite and wild hops are unlikely candidates for immediate parents of viable, American cultivars, introgression of diverse germplasm into pre-breeding stocks is a long term goal of any crop improvement program, especially with respect to sustainable, natural disease resistance and to elimination of pesticide use.

Section Breeding & IPM

Priority Group 3.

_____**Item 2.** Phylogentic reconstruction and genetic diversity of hop germplasm.

Examples 2:

- Molecular polymorphism-based determination of genetic distance
- Reconstruction of pedigree history
- Relationships among species
- Evolutionary history and biogeography

Time to Impact 2: 5-10 years

Comment 2. Understanding evolutionary and genetic relationships is essential the cost efficient integration of alien germplasm into current pre-breeding stocks. Phylogenetic and biogeographic knowledge is necessary for collection strategies and rational parent selection.

Section Breeding & IPM
Priority Group 3.

☐ _____**Item 3.** Development of a genetic system and breeding performance data

Examples 3:

- Determination of molecular genetic maps and allele distributions in breeding populations
- Heritability estimates (breed-ability) of key traits
- Determination of resistance loci expressivity and penetrance in various target backgrounds
- Measurement of inbreeding depression and out-crossing heterosity (hybrid vigor)
- Application of genetic distance data for choosing wide-germplasm (more likely heterotic) crosses
- Empirical searches for good (heterotic) combining ability in pre-breeding lines

Term 3. 5-20 years

Comment 3. Hops researchers largely lack any empirical genetic data to guide rational choice of parents and progeny. Although a genetic system is a long term goal, it is now time-tenable (5 years development) by virtue of molecular technologies. In the long-term it is cost effective because rational selection criteria speeds breeding time, increases breeding efficacy and reduces breeding costs for the obligate, progressive maintenance of an environmentally sound, sustainable, and competitive crop.

Section Breeding & IPM

☐ _____**Priority Group 4.** Reproductive system manipulations.

Item 1. In vitro and reproductive technologies development

Examples1:

- Microspore culture, double-haploid production
- Tetrapoild and tripoid production, flow-cytometric cell sorting
- Mutation breeding
- Protoplasts and para-sexual systems
- Determination of barriers to wide-species crossing

Time to Impact 1: 5-20 years

Comment 1. Breeding systems in hops are determined and limited by its reproductive behavior. Experimental modification of this behavior can open potential to exploit breeding strategies that are well proven in other crop species.

Section Breeding & IPM

☐ _____**Priority Group 2**. Beneficial or Predatory Organisms for the Control of Plant Pathogens and Insect Pests (IPM)

Item 1. Identification and implementation of introduced or natural predators for fungal diseases or natural predators for insect pests.

Examples 1

- Evaluate pesitcides for pest specificity
- Biology, behavior and physiology of pests and beneficials
- Develop in vitro methods of insect culture and propagation
- Behavioral and epidemiological observation among relevant American hop varieties
- Examine host's chemical correlates of pest's and beneficial's feeding behavior

Time to impact 1. 3-5 years.
Comment 1. Many pesticides used in prior years are no longer available or have lost their effectiveness for target pests. Pesticide use is not desirable from the perspective of most consumers. With these facts in mind, it would be desirable to support research that utilizes natural means of control which have no impact on the end-product. Natural means of control includes the use of evolutionary-sound mechanisms such as the introduction of natural predators or the enhancement of predators already present in hop-growing regions.

Section Breeding & IPM
Priority Group 3
☐ _____**Item 4.** Identification and use of natural plant products as means of controlling or significantly reducing fungal or insect damage.
Examples 4.
Olfactometric studies of insect pheromonal communications
Comment 4. The use of naturally derived plant products with no proven toxicity to humans.

Section Breeding & IPM
☐ _____**Priority Group 2:** Early Detection of Diseases and/or Pests
Item 5: Identification of new and more accurate means to determine pest population (infestation) in fields-both pathogens and insects.
Examples 5:

- Identification of economic thresholds for pest population (infestation)-both pathogen and insects.
- Studies correlating pest population (infestation) to timing of spraying and/or spraying rates with the sole objective of reducing pesticide use.
- Insect trapping, suction
- Molecular diagnostics
- Behavioral studies and epidemeology

Comment 5: Effective control of pathogens and insect pests requires early notification of population increases before levels of infestation are too high. If levels of infestation become too high, then control becomes increasingly problematic with higher pesticide rates and/or more frequent applications required to bring levels down to non-economic thresholds. Methods to accurately determine non-economic thresholds should be identified for both disease and insect pests. Methods that have proven most effective for other crops but not yet implemented in hop should receive priority in funding. On a lower priority but still fundable, are studies to correlate pest populations to timing of spraying and

spraying rates. With these goals in mind the funding priority for HRC grants are as follows (listed in order of importance or priority)

Section New Use

☐ **_____New Uses of Hops and Hop By-products**

Goal Definition Expansion of the value of hops by recognition, improvement or addition of value-added traits. The goal includes (1) study and promotion of the positive health aspects of hop use in beer, (2) cost-avoidance by finding new uses for harvest and processing by-products and (3) promoting the expansion of hop uses, hop markets and hop growing, by development and promotion of enhanced and new beverages and by new-use of hop biochemicals for cosmetics, preservation and pharma/nutraceuticals.

Priorities:

Section New Use

☐ **_____Priority Group 1.**

Item 1. Identify and foster extramural funding for research on health benefits of hops

Examples 1:

- Metabolism of humulones, lupulones and prenylflavanoids (*in vivo* studies)
- Clinical trials of lupulones as antimicrobials and food additives (e.g., toothpaste, Palmolive patent)
- Clinical trials of prenylflavanoids (xanthohumol)

Time to impact. 1-5 years to identify additional funding sources and partners

Comment 1. What are potential routes to extra-mural funding?

- HRC to promote hop researchers and interactions within funding agencies
    - Dialogue with NIH
        - DIETARY SUPPLEMENT HEALTH AND EDUCATION ACT OF 1994
            - Office of Dietary Supplements **ODS**
            - National Center for Complementary and Alternative Medicine **NCCAM**
                - Purdue University, ID
                - University of Arizona
    - American Cancer Society, others?
- Recruit hop interest from funded medical researchers (iso-xanthohumol *vs*. resveratrol studies)
- Funding for international efforts; technology transfer; AHRC, EUHRC

Section New Use

☐ **_____Priority Group 3.** Use of By-products

Item 2. New use for harvest (leaves and stems) and process by-products (spent hops)

Examples 2:

- biofuel, compost systems, phytoremediation, fodder, litter
- polyphenol extracts
- novel, value-added traits

Time to Impact 2. 2-15 years
Comment 2: Cost avoidance in waste handling and processing, value of waste pays for disposal

☐ **Section New Use**
_____**Priority Group 2.** Crop improvement for new value-added traits
Item 1. Chemical content
Examples 1:

- Polyphenol content
- Xanthohumol content

Time to impact 1: 2-12 years
Comments 1:

- Routes to crop improvement include:
- Assessment of germplasm for variation in chemical content
- Assessment of heritability of chemical content
- Conventional breeding for chemical content
- Development of molecular marker maps of American hops and core anchor maps across populations
- Determination of quantitative trait loci (QTL) (e.g., high beta, high xanthohumol, low CoH) in American hops
- Testing and applying marker assisted selection (MAS) for chemical content in American hops
- Molecular genetic dissection of metabolism
- Gene isolation and functional analyses
    - Structural genes (aromatic prenyltransferase)
    - Regulatory genes (*myb*-domain transcription factors)
- Genetic transformation-based proof-of-concept of altered metabolism
- Convention breeding based on metabolic concepts (MAS or Elite selection)
- Metabolic engineering to enhance known chemical traits

☐ **Section New Use**
_____**Priority Group 3.** Value-added trait addition
Item1: new chemical accumulation
Examples1: Stilbene synthase addition – resveratrol, phytoalexins, etc.
Time to impact 1: 5-7 years
Comment 1.
Genetic modification can be used to add a large variety of chemical traits that are compatible with the structure and metabolism of glandular trichomes

The HRC does not seek to limit research to the above priorities and accepts proposals from the scientific community.