2017 Hop Germplasm Study

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HOP GERMPLASM STUDY

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Until now, commercial hop (*Humulus lupulus* L.) production has not occurred in the northeast (NE) region of the United States for 150 years. Vermont production peaked in 1860 when the state produced 289,690 kg of dried hops (Kennedy 1860). A combination of the spread of hop downy mildew, the expansion of production in western states, and prohibition laws from the 1920's contributed to the decline of the 19th century NE hop industry. Today, the Pacific Northwest states of Washington, Oregon, and Idaho remain the dominant hop production sites of the U.S. However, hop production in non-traditional regions is growing and now accounts for over 2% of the total U.S. hop acreage (George, A., 2014). Nationally, there has been recent and unprecedented growth in the craft beer sector which has dramatically increased demand for local hop production.

Hops are native across North America, but European hops and North American landraces were cultivated in northern states from colonization to prohibition. Genetic markers have been used to classify wild NA germplasm (Bassil et al., 2008; Peredo et al., 2010). Wild or naturalized hop plants are in the Vermont landscape, yet they are not grown on a commercial scale. Downy mildew disease pressure is currently one of the biggest concerns in NE hop production. It is possible that naturalized plants have evolved arthropod and disease pest resistance traits allowing them to persist in the environment. It is critical that we begin an active evaluation of existing wild cultivars and emerging hop varietals to explore their potential to increase NE hop production. Furthermore, assessment of germplasm could aid with the discovery of novel and unique hop characteristics and flavor profiles that could be made widely accessible to producers and brewers.

MATERIALS AND METHODS

Wild hop plants were initially collected from eight locations within Massachusetts, New York, and Vermont in the fall of 2016 (Figure 1, Table 1). Multiple rhizome cuttings, approximately 6" in length, were taken from each site, placed in plastic bags and kept in refrigerated storage. Cuttings were occasionally inspected for spoilage and any compromised samples were discarded. After three months of cold storage, the remaining cuttings were planted into 4" pots with Fafard 3B potting media (Kent, New Brunswick) at the UVM greenhouse. Mother plants were produced from the cuttings, maintained at a temperature of 65-70° F and watered as needed by greenhouse staff. Vegetative cuttings were taken from the mother plants to obtain additional plant stock. Cuttings consisted of approximately three nodes and were treated with Hormodin 1™ (Mainland, Pennsylvania) rooting hormone prior to planting into 4" pots with vermiculite. The plants were removed from the greenhouse and placed outside to harden off in mid-May. The plants were transplanted on 20-Jun and 21-Jun 2017 at Borderview Research Farm in Alburgh, VT. Approximately 14-18 individuals from each of the 10 wild hop varieties were planted totaling 163 plants overall. Plants were spaced 3' apart and planted into weed barrier fabric. Each plant was strung up on 26-Jun using a single coir string leading up to the top wire.

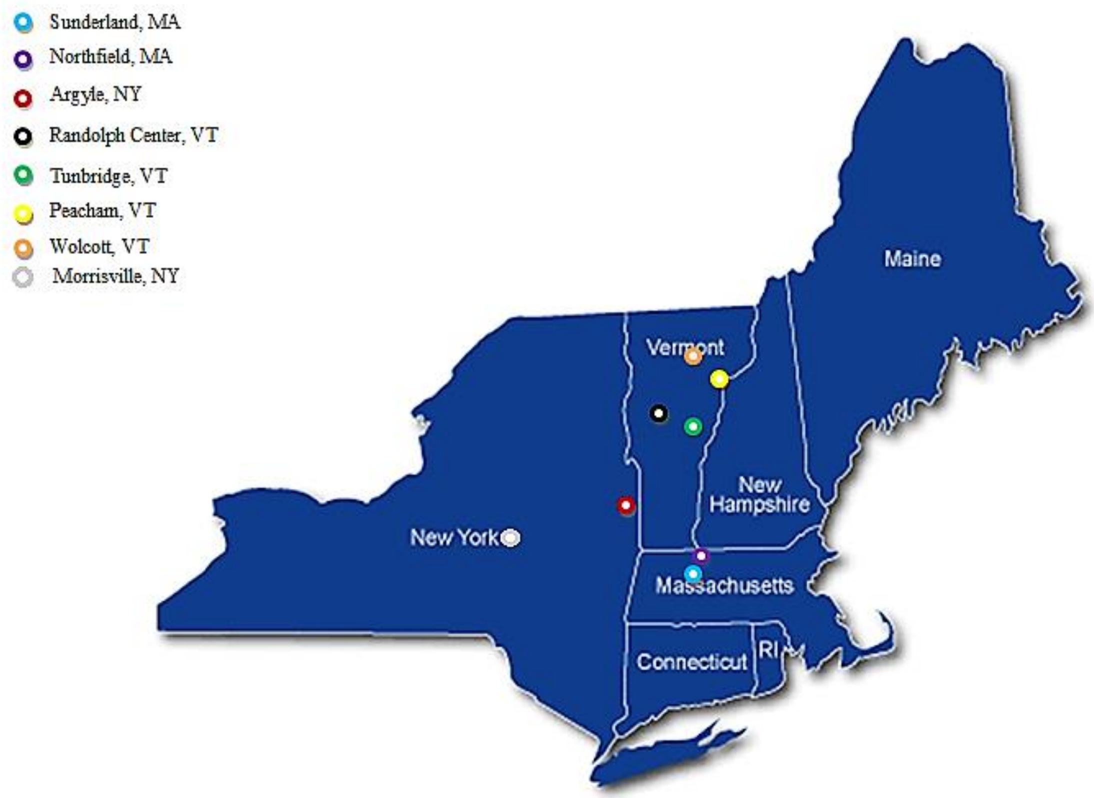

Figure 1. Map of original wild hop rhizome collection sites.

Table 1. Wild hop varieties and collection location.

Plant	Total Plants	Town, State	Latitude	Longitude
Northfield 001	14	Northfield, MA	42.715015	-72.465087
Northfield 003	15	Northfield, MA	42.715015	-72.465087
Peacham 001	16	Peacham, VT	44.38361111	-72.18638889
Peacham 002	18	Peacham, VT	44.38361111	-72.18638889
Wolcott 001	16	Wolcott, VT	44.54416667	-72.41861111
Wolcott 002	16	Wolcott, VT	44.54416667	-72.41861111
Mount Toby	18	Sunderland, MA	42.503834	-72.531131
Argyle	17	Argyle, NY	43.237972	-73.495185
Kingdom 001	17	Tunbridge, VT	43.9218136	-72.5718315
Kingdom 002	16	Tunbridge, VT	43.9218136	-72.5718315
Morris	16	Morrisville, NY	42.832964	-75.567996

Plants were scouted weekly for pest and beneficial insects beginning in June and continuing through August. Three random leaves within each plot (variety) was visually inspected. The number of potato leaf hoppers (PLH), hop aphids (HA), two-spotted spider mites (TSSM), and mite destroyers (MD) present on each leaf was recorded.

Due to various growing conditions and hop characteristics, not all plants were harvested this year, and higher yields should be expected in subsequent years. In total, six varieties were harvested and total yield and quality data were obtained. Plants were harvested using a Hopster 5P (HopsHarvester LLC, Honeoye, NY) hop harvester. The number of individual plants harvested and total cone yield was recorded for each line in the germplasm collection. Cone samples were weighed and dried to determine dry matter content. Cones were also rated in browning severity on a 1-10 scale where 1 indicates low browning and 10 indicates severe browning.

Samples of harvested varieties were vacuum sealed and frozen for later analysis. These samples were sent to Alpha Analytics (Sunnyside, WA) for standard quality analysis as well as minor oil profile and total oil content.

RESULTS

The germplasm lines appeared to differ in their susceptibility to pests (Figure 2). Although these data were not analyzed for statistical differences, it is worth noting the observed differences in pest populations across the varieties. Two-spotted spider mites were only observed on two of the varieties while HA and PLH were present on all varieties. The variety Wolcott 001 had the highest populations of PLH averaging 2 insects per leaf while the next highest variety, Wolcott 002, averaged only 0.5 insects per leaf. The highest HA populations were observed on the variety Morris which averaged about 4.5 aphids per leaf. As we continue the study, we plan to continue to measure the impacts of these various insects on hop quality and yields, and hope to observe any variations in cultivar susceptibility.

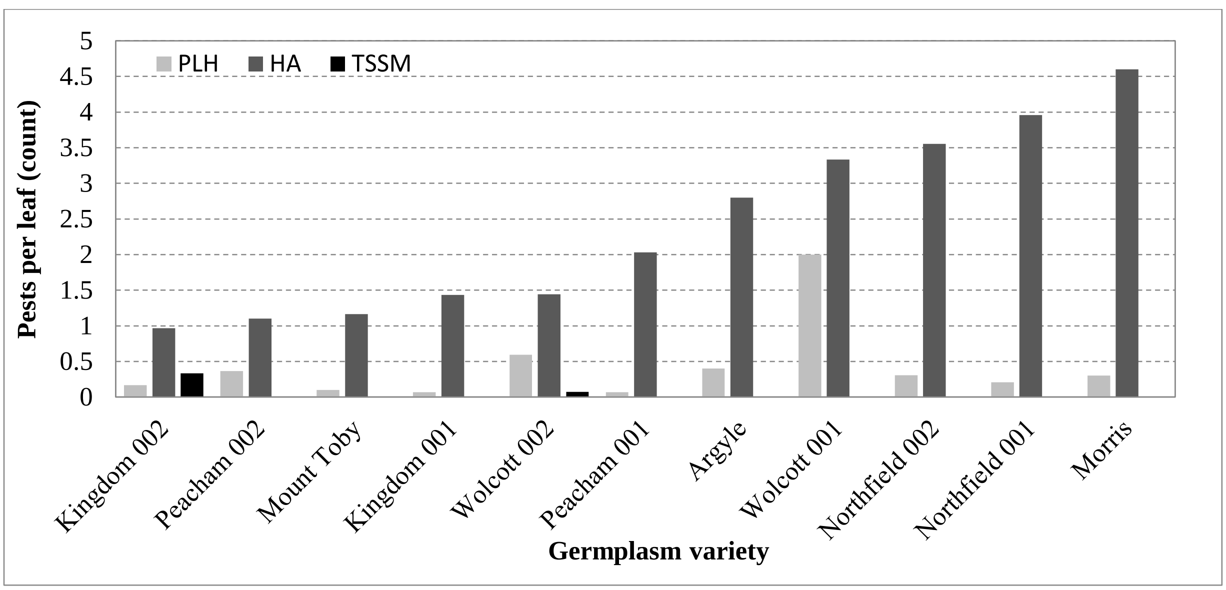

Figure 2. Average number of PLH, HA, TSSM per leaf on each germplasm line, 2017.

This year, we also experienced adverse reactions to a combination of pesticide applications which resulted in severe plant damage to a large portion of plants. Champ was sprayed at 2 lbs ac^{-1} in conjunction with Regalia at 1qt ac^{-1} diluted in 50 gal of water. This resulted in severe leaf and cone damage, impacting the survival of a number of the wild hops (Figure 3). While each of the wild hop varieties were adversely affected by the combination of these two fungicides, the hops growing as part of our commercial variety trials showed no phytotoxic effect. This may indicate that these hop varieties are far more susceptible to phytotoxicity caused by certain types of fungicides.

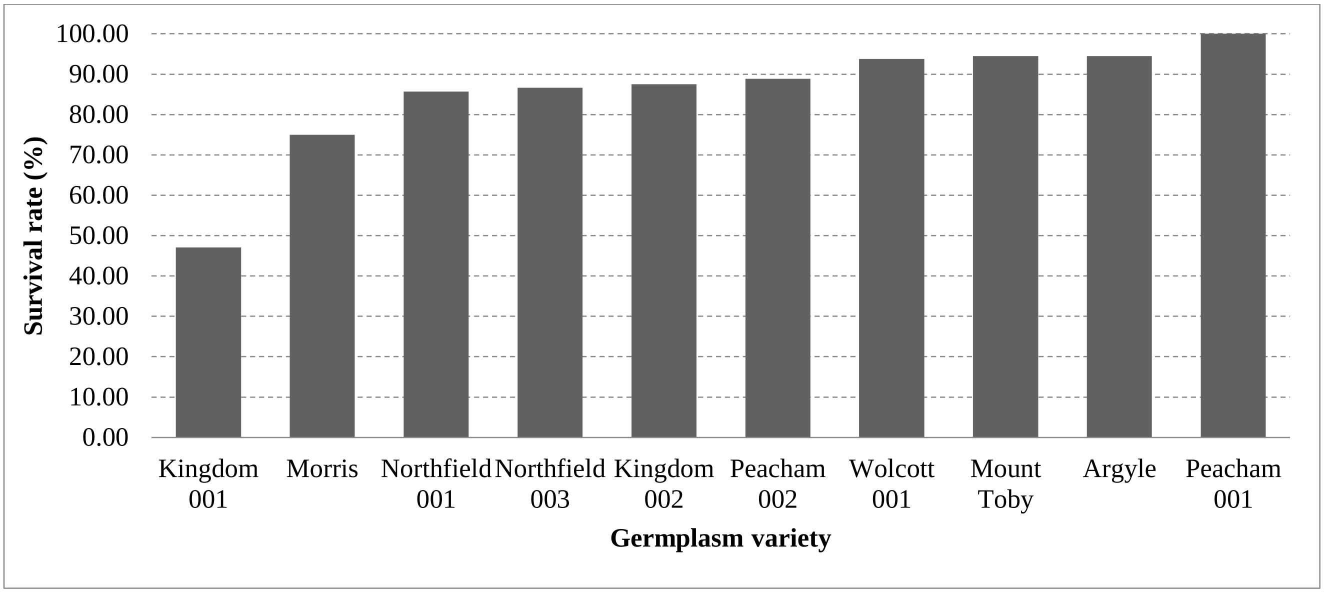

Figure 3. Survival of wild hop variety following application of fungicide.

Hop varieties also differed in yield and harvest characteristics (Figure 4, Table 2). While all plots were harvested at similar dry matter contents, the varieties Wolcott 001 and Northfield 001 were harvested one week earlier than the others suggesting faster maturation rates. The highest yields were obtained from the variety Morris, which produced approximately 456 lbs ac^{-1}. Although these data were not analyzed for statistical differences, it is interesting to note the observed differences in first year production across the varieties. Wolcott 001, although reaching maturity about 1 week earlier than the other varieties, produced less than 100 lbs ac^{-1}. Varieties Wolcott 002, Kingdom 001, Kingdom 002, Northfield 003, and Peacham 002 were not harvested.

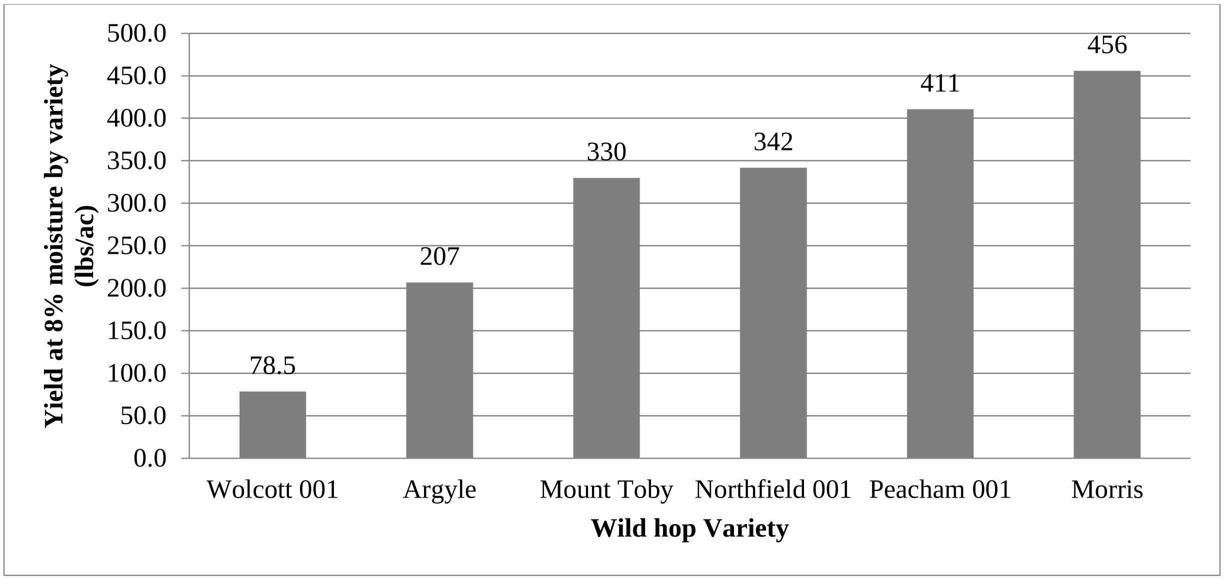

Figure 4. Yield of hop germplasm lines, 2017.

Interestingly, the varieties Morris and Mount Toby produced relatively high yields but also exhibited severe cone browning and damage. We will continue to monitor these differences as plants are monitored in future years.

Table 2. Harvest characteristics by variety.

Variety	Total plants	Harvest date	Yield @ 8% moisture lbs ac^{-1}	Dry matter %	Cone Disease Severity (1-10) +
Wolcott 001	10	7-Sep	78.5	22.6	4
Argyle	6	7-Sep	207	22.4	3
Mount Toby	8	15-Sep	330	21.4	10
Northfield 001	6	15-Sep	342	21.1	2
Peacham 001	9	15-Sep	411	22.4	8
Morris	8	15-Sep	456	22.6	4

+ Cones were also rated in browning severity on a 1-10 scale where 1 indicates low browning and 10 indicates severe browning.

Hop varieties also varied dramatically in acid content and oil profiles (Table 3 and Table 4). Wolcott 001 and Argyle had similar concentrations of alpha and beta acid while Morris had significantly more alpha acid than beta acid. The opposite was true for Peacham 001 and Northfield 001. Argyle and Peacham 001 also had about double the oil content of the other varieties.

Table 3. Wild hop variety acid content.

Variety	Alpha %	Beta %	HSI
Northfield 001	3.60	6.70	0.249
Wolcott 001	3.80	5.00	0.280
Morris	6.00	3.40	0.241
Argyle	5.00	3.90	0.271
Peacham 001	3.00	8.60	0.264

In addition to basic quality parameters, the varieties also differed in oil profile (Table 4). Argyle and Morris produced the highest alpha levels compared to the other varieties. Peacham produced the highest beta acid levels and total oil concentrations.

Table 4. Hop aromatic oil profiles.

Variety	**Oil %**	**b-pinene %**	**Myrcene %**	**Linalool %**	**Caryophyllene %**	**Farnesene %**	**Humulene %**	**Geraniol %**
Wolcott 001	0.3	0.83	64.02	0.71	5.82	0.07	9.07	0.24
Northfield 001	0.4	0.43	41.05	0.46	5.55	0.05	18.09	0.15
Morris	0.3	0.58	46.21	0.34	5.37	0.17	15.44	0.39
Peacham 001	0.8	0.21	11.24	0.33	5.7	8.77	25.41	0.18
Mount Toby	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Argyle	0.7	0.68	52.87	0.25	4.23	0.08	12.45	0.41

Table 4 summarizes the aromatic oil profiles of the harvested varieties. Each harvested variety has distinct oil compositions, which has the potential for new uses or substitutions in the brewing process. Table 5 provides a brief sensory description of individual oil characteristics.

Table 5. Oil characteristics.

Oil	Associated Scents
β-pinene	Piney, green
Myrcene	Citrus, bright, green, resinous
Linalool	Floral, orange, citrus
Caryophyllene	Woody, spicy
Farnesene	Floral, herbal
Humulene	Piney, woody, herbal, spicy
Geraniol	Floral, bright

DISCUSSION

As the project continues to develop, we hope to obtain additional wild hop samples from across the Northeast to build a database of genetically distinct cultivars of our wild hop species (*Humulus lupulus* var. *lupulus* and *Humulus lupulus* var. *lupuloides).* Wild hop varieties could provide new and distinct flavor profiles through variable acid and oil profile combinations for use by brewers. With the aim to build this database, new varieties could become available to regional hop producers that are more suitably adapted to our growing region through greater resistance to downy mildew and other prevalent and damaging pests and diseases. Ideally, this would lead to improvements in the quality and consistency of hops for our growers and brewers in our ever expanding craft brewing industry in Vermont and the rest of the NE.

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