NORTHWEST CROPS & SOILS PROGRAM

2019 Hop Nitrogen Fertility Trial

Dr. Heather Darby, UVM Extension Agronomist
John Bruce, Scott Lewins, and Ivy Luke
UVM Extension Crops and Soils Technicians
(802) 524-6501

Visit us on the web: http://www.uvm.edu/nwcrops

THE UNIVERSITY OF VERMONT EXTENSION

2019 HOP NITROGEN FERTILITY TRIAL

Dr. Heather Darby, University of Vermont Extension
heather.darby[at]uvm.edu

Until now, commercial hop (*Humulus lupulus* L.) production has not occurred in the northeast (NE) region of the United States for 150 years. 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. Nationally, there has been recent and unprecedented growth in the craft beer sector, which has dramatically increased demand for local hop production.

There are more than 400 acres of hops in the Northeast with hop yards ranging in size from 0.25 to 25 acres. Hop yields in the region are often limited by pest damage and nutrient deficiencies. This is a reemerging industry in the Northeast and growers are asking for research to determine practices that will help them optimize hop yield. Yields reach 1500-2000 lbs/acre in other production regions yet most NE growers are below 800 lbs/acre. The investment to start a hop farm is significant and higher yields must be achieved to help growers be successful and profitable. The goal of this research project was to identify proper nitrogen (N) rate and timing to optimize hop yield and quality.

MATERIALS AND METHODS

The experimental design was a randomized complete block with split plots and 4 replicates. The main plots were fertility treatments (Table 1) and the split plots were hop varieties Cascade and Centennial. Nitrogen was applied in the form of calcium ammonium nitrate (CAN) 27-0-0 during a base spring application (10-May) and an 8 week split application period from 23-May through 10-Jul (Table 1). Calcium ammonium nitrate was dissolved in water and applied directly to individual plots based on nitrogen application rate.

Table 1. Nitrogen fertility treatment application rates, 2019.

Treatment Total lbs N ac^{-1}	Spring base application lbs N ac^{-1}	Weekly application total lbs N ac^{-1}	Weekly application rate lbs N ac^{-1}
100	100	0	0
150	100	50	6.25
200	100	100	12.5
250	100	150	18.8
150	50	100	12.5
200	50	150	18.8

Hills were strung between 13-May and 21-May using a double coir string leading up to the top wire and trained 30-May. Beginning on 24-May, the entire hop yard was sprayed with Champ WG (Alsip, IL) at a rate of 1 lb per acre, and diluted in 100 gallons of water, and was sprayed on a weekly basis through 28-

Jun. During this period, plots were scouted weekly for downy mildew basal spikes and aerial spikes. Plants were additionally scouted on a weekly basis starting 17-Jun for pest and beneficial insects through 19-Aug. Two plants and three random leaves per plant within each plot (variety) were 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.

Throughout the growing period, plots were sampled every other week for leaf petiole nitrates from 13-Jun to 31-Jul. Thirty-five leaf petioles were collected per plot during each sampling period from 5-6' height range including each plant within plots. Collected petioles were sent to Dairy One in Ithaca, NY to be analyzed for total nitrogen throughout the entire sampling period. Leaf petiole samples were also tested for nitrates on-farm using Horiba Laquatwin Nitrate Meter (Irvine, CA) during the last three sampling events 7-Jul through 31-Jul. Half of collected petiole sample was run through the meter, after using a garlic press to extract sap, and analyzed for petiole nitrates.

Hop harvest was targeted for when cones were at 21-27% dry matter. At harvest, hop bines were cut in the field and brought to a secondary location to be run through our mobile harvester. Centennial plants were harvested from 30-Aug through 5-Sep and Cascade plants were harvested from 13-Sep through 16-Sep. Plants were harvested using a Hopster 5P hop harvester (HopsHarvester LLC, Honeoye, NY). The number of individual plants harvested and total cone yield was recorded for treatment. Four bines from each plot were chipped, dried, and sent to Dairy One in Ithaca, NY to be analyzed for whole plant nutrients. 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 as a result of disease. All hop cones were dried to 8% moisture, baled, vacuum sealed, and then placed in a freezer. Hop samples from each plot were analyzed for alpha acids, beta acids and Hop Storage Index (HSI) by the University of Vermont's testing laboratory. Yields are presented at 8% moisture on a per acre basis. Per acre calculations were performed using the spacing in the UVM Extension hop yard of 872 hills (1744 strings) ac^{-1}.

Variations in yield and quality can occur because of variations in genetics, soil, weather and other growing conditions. Statistical analysis makes it possible to determine whether a difference among varieties is real, or whether it might have occurred due to other variations in the field. At the bottom of each table, a LSD value is presented for each variable (i.e. yield). Least Significant Differences (LSD's) at the 10% level of probability are shown. Where the difference between two treatments within a column is equal to or greater than the LSD value at the bottom of the column, you can be sure in 9 out of 10 chances that there is a real difference between the two varieties. Treatments that were not significantly lower in performance than the highest value in a particular column are indicated with an asterisk. In this example, A is significantly different from C but not from B. The difference between A and B is equal to 1.5, which is less than the LSD value of 2.0. This means that these varieties did not differ in yield. The difference between A and C is equal to 3.0, which is greater than the LSD value of 2.0. This means that the yields of these varieties were significantly different from one another. The asterisk indicates that B was not significantly lower than the top yielding variety. Within the trial there were no significant variety x treatment interactions so data was pooled across varieties and is presented based on nitrogen treatment impacts.

Treatment	Yield
A	**2100***
B	1900*
C	1700
LSD	300

RESULTS

Table 2 shows a summary of the temperature, precipitation and growing degree-day (GDD) summary. In the 2019 growing season, there were an accumulated 2322 GDDs, 157 less than the historical 30-year average with greatest deviations from the norm occurring in May and July. The 2019 growing season experienced a wet spring followed by a dry summer with well below average precipitation occurring during the month of July. Supplemental irrigation was applied to plants at a rate of 4500 gal ac^{-1}, however drier summer months and limited well capacity resulted limited the ability to provide adequate water to the crop.

Table 2. Temperature, precipitation and growing degree day summary, Alburgh, VT, 2019.

Alburgh, VT	March	April	May	June	July	August	Sept
Average temperature (°F)	28.3	42.7	53.3	64.3	73.5	68.3	60.0
Departure from normal	-2.79	-2.11	-3.11	-1.46	2.87	-0.51	-0.62
Precipitation (inches)	1.36	3.65	4.90	3.06	2.34	3.50	3.87
Departure from normal	-0.85	0.83	1.45	-0.63	-1.81	-0.41	0.23
Growing Degree Days (Base 50)	9	59	189	446	716	568	335
Departure from normal	-13	-52	-103	-36	86	-14	-25

Based on weather data from a Davis Instruments Vantage Pro2 with WeatherLink data logger. Historical averages are for 30 years of NOAA data (1981-2010) from Burlington, VT. (http://www.nrcc.cornell.edu/page_nowdata.html).

Within the trial, fertility rates appeared to have little to no impact on observed pests with the exceptions of hop aphids (Table 3). Aerial spikes were observed throughout the study yet fertility treatments appeared to have no impact on spike incidence when looking at nitrogen treatments alone. In general, hop aphids appeared to be present in much larger populations in 2019 compared to past years as a result of weather conditions favorable to aphids. The highest average populations were observed on one of the higher nitrogen application treatments, 100_100 lbs N ac^{-1} with an average of 6.65 aphids $leaf^{-1}$ compared to lowest populations observed on the 100_50 lbs N ac^{-1} treatment at 2.17 aphids $leaf^{-1}$ and a trial average of 3.59 aphids $leaf^{-1}$. That being said there were also some "hot pockets" within the hop yard in which with some single leaf populations exceeded 100 aphids $leaf^{-1}$ and a number of weekly scouting populations exceeding some proposed action thresholds of 5-10 aphids $leaf^{-1}$.

Table 3. Average insect pest and disease scouting incidence for nitrogen fertility rates, Alburgh, VT, 2019.

Treatment Spring_Summer lbs N ac-1	**Total applied N**	**Aerial spikes $plot^{-1}$**	**Basal spikes $plot^{-1}$**	**HA $leaf^{-1}$**	**PLH $leaf^{-1}$**	**TSSM $leaf^{-1}$**
100	**100**	0.471	1.16	3.52 a †	2.32	1.18
100_50	**150**	0.395	1.04	2.17 b	2.32	0.757
50_100	**150**	0.326	0.692	3.03 ab	2.68	1.05
100_100	**200**	0.214	0.946	**6.65 a**	2.72	1.02
50_150	**200**	0.400	0.754	2.70 b	2.58	0.479
100_150	**250**	0.414	0.821	3.46 ab	2.69	0.146
LSD (0.10) ‡		NS ¥	NS	3.70	NS	NS
Trial mean		0.370	0.901	3.59	2.55	0.772

HA= hop aphid. PLH = Potato leaf hopper. TSSM = two-spotted spider mites.
†Within a column treatments marked with the same letter were statistically similar (p=0.10). Top performers are in **bold.**
‡LSD –Least significant difference at p=0.10.
¥NS –No significant difference between treatments.

Throughout the growing period, plots were sampled every other week for leaf petiole nitrates from 13-Jun to 31-Jul (Table 4). Collected petiole samples were analyzed on-farm for nitrates and sent out for total nitrogen. Basic guidelines have been proposed for determining plant nitrogen requirements, yet there are no current recommendations based on these in-field nitrate readings. Collected leaf petiole samples may fall into three categories including Low: 0-6000ppm, Normal: 6000-10,000ppm, and High: 10,000+ppm.

Throughout the sampling period (2-Jul through 31-Jul), treatment differences between petiole nitrates were significant within the 16-Jul and 31-Jul sampling dates. Most notably, the 100 lbs N ac^{-1} treatment (lowest in the study) was significantly lower than the other treatments in these two dates, whereas those receiving a minimum 50 lbs N ac^{-1} extra, were sustaining similar levels of petiole nitrates. Overall nitrate levels followed decreasing trends over the course of the sampling period with highest values observed in 200 and 250 lbs N ac^{-1} treatments.

Total percent N followed similar trends over time, but some more consistent differences were observed between application rates. The 250 lbs N ac^{-1} treatments was consistently the highest percentage total nitrogen and the 100 lbs N ac^{-1} treatment was consistently the lowest percent total nitrogen. While the differences were slight between equal total nitrogen treatments (at the 150 and 200 lb rates), those receiving higher summer application totals appeared to have slightly higher total nitrogen within petioles. Application rates over 200 lbs N ac^{-1} did not further increase % N concentrations in the petioles.

Table 4. Leaf petiole nitrates and total nitrogen over sampling period, Alburgh, VT, 2019.

Treatment Spring_Summer lbs N ac-1	Total applied N lbs ac-1	2-Jul ppm NO^{3-}	16-Jul ppm NO^{3-}	31-Jul ppm NO^{3-}	13-Jun % N €	2-Jul % N	16-Jul % N	31-Jul % N
100	**100**	7550	6213 b †	4125 b	3.76 b	2.97 c	1.86 d	1.41 d
100_50	**150**	8400	7363 a	5963 a	3.86 b	3.19 b	2.16 c	1.55 cd
50_100	**150**	7550	7100 a	5988 a	3.87 b	3.22 ab	2.22 bc	1.66 bc
100_100	**200**	8963	**7888 a**	5900 a	3.99 ab	3.33 ab	2.35 ab	1.80 ab
50_150	**200**	9338	7688 a	6088 a	4.17 a	3.34 ab	2.44 a	1.83 a
100_150	**250**	8975	7625 a	**6325 a**	**4.18 a**	**3.37 a**	**2.45 a**	**1.92 a**
LSD (0.10) ‡		NS ¥	851	806	0.296	0.159	0.171	0.156
Trial Mean		8463	7313	5731	3.97	3.24	2.25	1.70

†Within a column treatments marked with the same letter were statistically similar (p=0.10). Top performers are in **bold.**
‡LSD –Least significant difference at p=0.10.
¥NS –No significant difference between treatments.
€ Percent nitrogen presented on a dry matter basis.

Whole bines were processed for nutrient analysis (Table 5). There was a significant difference across treatments for nitrogen, potassium, phosphorus, magnesium, manganese, iron, and zinc. Nitrogen, magnesium and manganese all showed increasing plant concentration trends with increased N rates from 100 lbs N ac^{-1} to 250 N ac^{-1}. Peak whole plant N and magnesium concentrations were observed at the highest 250 N ac^{-1} rate, whereas manganese concentrations peaked at the 200 N ac^{-1} rate (50_150 N ac^{-1} treatment). Conversely, phosphorus and potassium showed peak values at lower N application rates and lower concentrations at higher N application rates. In most cases, nutrient concentrations were maximized at 150 lbs N ac^{-1}. A number of these factors may have been impacted by soil available nutrients as well as changes in pH that may have resulted from the increasing rate of fertilizer within the trial. Nitrogen management of soil is closely linked to the plant uptake of a wide number of nutrients. The trial results indicated that application of N can help to improve the availability and subsequent uptake of other essential nutrients but highest rates may reduce the uptake of some.

Table 5. Whole plant nutrients at harvest, Alburgh, VT, 2019.

Treatment Spring_Summer lbs N ac-1	Total applied N	Nitrogen	Potassium	Phosphorus	Calcium	Magnesium	Manganese	Iron	Copper	Boron	Zinc
		%	%	%	%	%	ppm	ppm	ppm	ppm	ppm
100	**100**	2.02 c †	1.60 a	0.382 ab	2.40	0.378 b	58.5 b	94.4 b	82.9	37.1	17.9 b
100_50	**150**	2.10 bc	1.59 ab	**0.393 a**	2.49	0.423 ab	66.3 b	106 ab	71.8	41.5	25.0 ab
50_100	**150**	2.17abc	1.58 ab	0.375 ab	2.47	0.406 ab	77.0 ab	152 ab	69.4	39.2	**30.5 a**
100_100	**200**	2.26 ab	1.54 ab	0.361 abc	2.58	0.434 ab	91.5 a	122 ab	77.9	37.5	23.7 ab
50_150	**200**	2.30 ab	**1.61 a**	0.347 bc	2.40	0.431 ab	**97.8 a**	**283 a**	72.6	39.8	23.7 ab
100_150	**250**	**2.38 a**	1.49 b	0.338 c	2.62	**0.467 a**	92.8 a	103 ab	75.3	40.3	21.6 ab
LSD (0.10) ‡		0.221	0.102	0.039	NS ¥	0.069	24.4	182	NS	NS	9.73
Trial mean		2.20	1.57	0.366	2.49	0.423	80.6	143	75.0	39.2	23.7

†Within a column treatments marked with the same letter were statistically similar (p=0.10). Top performers are in **bold.**

‡LSD –Least significant difference at p=0.10.

¥NS –No significant difference between treatments

At harvest, 100 cone weight, diseased cone percentages, disease severity, harvest dry matter, and yields were recorded (Table 6). There was no difference across treatments for 100 cone weights or yields, however there were significant differences in the percentage of diseased cones, disease severity, and harvest dry matter. Disease was least prevalent in the 100_100 lbs N ac^{-1} (200 lbs total N ac^{-1}) treatment at 54.5% and with a relatively low disease severity rating at 2.63. It also appeared that, with equal total nitrogen application rates, higher amounts of nitrogen applied in the summer months during the vegetative period may increase chance of disease and the severity. This can be seen specifically when comparing the 200 lbs N ac^{-1} treatments with lowest severity in the 100_100 lbs N ac^{-1} treatment and highest severity in the 50_100 lbs N ac^{-1} treatment. Fertility treatment did not significantly impact yield.

Table 6. Fertility trial yields and cone quality, Alburgh, VT 2019.

Treatment Spring_Summer lbs N ac-1	Total applied N	100 cone weight	Diseased cones	Disease severity	Harvest dry matter	Yield at 8% moisture
		g	%	1-10 €	%	lbs ac^{-1}
100	**100**	50.8	68.3 b †	3.38 ab	24.3 abc	973
100_50	**150**	46	65.4 b	3.13 ab	25.0 a	820
50_100	**150**	46.8	68.0 b	3.25 ab	24.8 ab	911
100_100	**200**	48.2	**54.5 a**	**2.63 a**	23.4 c	812
50_150	**200**	50.8	62.8 ab	3.75 b	**25.0 a**	1000
100_150	**250**	50.5	67.8 b	3.00 ab	23.6 bc	888
LSD (0.10) ‡		NS	9.75	1.06	1.26	NS ¥
Trial mean		48.8	64.4	3.19	24.4	901

†Within a column treatments marked with the same letter were statistically similar (p=0.10). Top performers are in **bold.**

‡LSD –Least significant difference at p=0.10.

¥NS –No significant difference between treatments

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

Higher rates of nitrogen also appeared to have some impact on hop resins (Table 7). Highest values for both alpha and beta acids were seen at the lowest nitrogen rate with 8.90% alpha acid and 3.62% beta acid.

The lowest values were observed that the highest nitrogen rate at 7.37% alpha acid and 2.98% beta acid. It should be noted that alpha and beta acids did not differ statistically between 100 and 150 lbs N ac^{-1} application rate. Essentially indicating that rates over 200 lbs N ac^{-1} might actually depress quality of the hops. The various nitrogen application rates appeared to have no impact on hop storage index (HSI).

Table 7. Fertility trial brew quality, Alburgh, VT, 2019.

Treatment Spring_Summer lbs N ac-1	Total applied N	Alpha acids %	Beta acids %	HSI
100	**100**	**8.90 a** †	**3.62 a**	0.257
100_50	**150**	8.31 ab	3.43 ab	0.256
50_100	**150**	8.09 abc	3.12 ab	0.224
100_100	**200**	8.21 abc	3.23 ab	0.235
50_150	**200**	7.66 bc	3.08 bc	0.229
100_150	**250**	7.37 c	2.98 c	0.231
LSD (0.10) ‡		0.921	0.398	NS ¥
Trial mean		8.09	3.24	0.239

†Within a column treatments marked with the same letter were statistically similar (p=0.10). Top performers are in **bold.**
‡LSD –Least significant difference at p=0.10.
¥NS –No significant difference between treatments.

DISCUSSION

In 2019, cones became noticeably browner in the week prior to harvest for the Cascade variety and major cone affecting diseases such as downy mildew and alternaria were found throughout the hops. The Centennial hops harvested at an earlier date appeared to be relatively unaffected by cone disease. The influx of hop aphids throughout the season may have also had an impact on cone quality towards harvest with large populations observed in pockets within the hop yard this season. While highest populations were observed in 100_100 lbs N ac^{-1} treatment, low populations were observed at the 50_150 lbs N ac^{-1} treatment (each receiving a similar 200 lbs N ac^{-1} total), which could point towards the importance of nitrogen application timing, or be a result of other confounding effects in this case.

The use of an in-field nitrate meter could have the potential to become a useful tool with quick results. This would require some additional work to determine nitrogen fertility requirements corresponding to petiole nitrate readings for this crop. Based on some of the preliminary data collected, it appeared that the tested nitrogen rates provided adequate nitrogen fertility leading into the last week of sampling which may be sufficient for required vegetative growth prior to flower maturation. It was also apparent that nitrogen can have an impact on other macro and micronutrients. The uptake of other nutrients is closely linked to nitrogen fertility and should be taken into consideration alongside soil test results to adequately feed a hop crop. This first year of the study also showed that the timing of application may also impact some aspects of nutrient uptake as well as pest susceptibility, especially at higher nitrogen rates. Furthermore, hops receiving lesser amount of total nitrogen throughout the season appeared to have higher resin concentrations, whereas excessive nitrogen may actually decrease resins in hop cones, especially with rates above 200 lbs N ac^{-1}.

It's important to note that these plants were in their first harvest year and second year of growth, and increased yields or response to nutrients could potentially be expected in subsequent years. Dry conditions in summer months, in addition to limited well capacity, may have resulted in low and variable yields across fertility treatments as the crop received approximately 4 inches of water less than is generally required for hop production. Yields may have further been impacted by late season cone disease in addition to insect pest pressure within the trial. Based on this first year of study, it appeared that 150 lbs N ac^{-1} rates would likely provide adequate nitrogen, however this may change as plants reach full maturity. We intend to continue this study in the 2020 growing season to determine the impact of both rates and application timing on pests, nutrient uptake, and hop growth and quality. 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 Northeast.

ACKNOWLEDGEMENTS

This project was supported by USDA SARE Grant LNE16-348. UVM Extension would like to thank Roger Rainville and his staff at Borderview Research Farm in Alburgh, VT for their generous help with the trials. We would like to acknowledge Catherine Davidson, Hillary Emick, Haley Jean, Rory Malone, Shannon Meyler, Lindsey Ruhl, and Sara Ziegler for their assistance with data collection and entry. The information is presented with the understanding that no product discrimination is intended and no endorsement of any product mentioned or criticism of unnamed products is implied.

UVM Extension helps individuals and communities put research-based knowledge to work.

THE UNIVERSITY OF VERMONT EXTENSION