2019 Hemp Flower Nitrogen Fertility Trial

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Hemp is a non-psychoactive variety of *Cannabis sativa* L. The crop is one of historical importance in the U.S. and re-emerging worldwide importance as medical providers and manufacturers seek hemp as a renewable and sustainable resource for a wide variety of consumer and industrial products. Hemp grown for all types of end-use (health supplement, fiber, and seed) contains less than 0.3% tetrahydrocannabinol (THC). Some hemp varieties intended to produce a health supplement contain relatively high concentrations of a compound called cannabidiol (CBD), potentially 10-15%. The compound CBD has purported benefits such as relief from inflammation, pain, anxiety, seizures, spasms, and other conditions. The CBD compound is the most concentrated in the female flower buds of the plant, however, it is also in the leaves and other plant parts as well.

To produce hemp for flower, the plant is generally grown intensively as a specialty crop and the flowers are cultivated for maximum growth. The various cannabinoids and terpenes concentrated in the flower buds are often extracted and incorporated into topical products (salves, lip balm, lotion) and food and is available in pill capsules, powder form, and more, which can be found in the market today. To help farmers succeed, agronomic research on hemp is needed in the United States. University of Vermont in partnership with CASE Institute (https://www.caseinstitute.org/), evaluated the impact of five different nitrogen (N) application rates on the growth habit, yield, flower quality, and whole plant nutrient concentration of hemp.

MATERIALS AND METHODS

The trial was initiated at Borderview Research Farm in Alburgh, Vermont (Table 1) and the experimental design was a randomized complete block design with four replications. Plots consisted of five plants spaced 5’ apart in the row and plot treatments consisted of five N application rates including a Control (0 lbs ac^{-1}), 75, 100, 125, and 150 lbs ac^{-1}.

Table 1. Agronomic information for the hemp variety trial 2019. Alburgh, VT.

Location	**Borderview Research Farm Alburgh, VT**
Soil type	Benson rocky silt loam, 3-5% slope
Previous crop	Organic corn
Plot size	5’ x 20’
Plant spacing (ft)	5’ x 5’
Variety	T2
Plant material	Seedling
Planting date	19-Jun
Harvest date	21-Oct

Plots received nitrogen fertility in split applications over an eight week period starting on 28-Jun in the form of ammonium nitrate plus sulfur (URAN 28-0-0) from NutriAg Ltd. (Toronto, ON) applied directly to individual plants (Table 3). Based on soil test results from the University of Vermont Agricultural and

Environmental Testing Laboratory (Burlington, VT), no further nutrients were required for production of hemp (Table 2). The 4 week old hemp seedlings (variety T2) were transplanted on 19-Jun into a seed bed prepared with conventional tillage. A cover crop mixture of tillage radish and annual ryegrass was planted between rows on 26-Jun. Drip irrigation was setup to supply moisture as needed by the hemp plants.

Table 2. Base soil nutrient analysis for Hemp Flower Nitrogen Fertility Trial, Alburgh, VT 2019.

Analysis	Value found	Optimum range
Soil pH	7.4	
Modified Morgan extractable, ppm		
Macronutrients		
Phosphorus	42.7	4-7
Potasisum	242	100-130
Calcium	5225	**
Magnesium	164	50-100
Sulfur	7	11*
Micronutrients		
Iron	3.1	7.0*
Manganese	7.6	8.0*
Boron	0.8	0.3*
Copper	0.2	0.3*
Zinc	1.4	2.0*
Sodium	12	20*
Aluminum	7	35*
Soil Organic Matter %	5.2	**
Effecetive CEC, meq/100g	28.1	**
Base Saturation, %		
Calcium Saturation	92.9	40-80
Potassium Saturation	2.2	2.0-7.0
Magnesium Saturation	4.9	10-30

* Micronutrient and S deficiencies are rare in Vermont and optimum ranges are not defined; thus average values in Vermont soils are shown instead.
** Ranges shown are for Field Crops; Vegetable ranges are higher. Ranges for Calcium, Organic Matter, and Effective CEC vary with soil type and crop.

Table 3. Weekly hemp nitrogen fertility rates (28-0-0).

Treatment	Application rate 28-0-0	Weekly application rate	Weekly application rate
lbs ac^{-1}	gal ac^{-1}	gal ac^{-1}	mL $plant^{-1}$
0	0	0	0
75	23.1	2.89	6.27
100	30.8	3.85	8.36
125	38.5	4.81	10.5
150	46.1	5.77	12.5

Irrigation was applied on a weekly basis at a rate of 8000 gallons of water per acre delivered via drip tape. Irrigation duration and amount was modified based on weekly rainfall. Prior to harvest, plant height and width was measured from all harvested plants in each plot. From each plot, flower samples were taken from the top 8” of colas and sent to ProVerde Laboratories (Milford, MA) to be analyzed for cannabinoid and terpene profiles.

Image 1. Munch Machine Mother Bucker (Toppenish, WA)

Image 2. Centurion Pro Gladiator Trimmer (Maple Ridge, BC, Canada)

For each plant harvested, the whole plant weight was recorded. On 21-Oct, all plants were harvested and were broken down into smaller branched sections and larger “fan” or “sun” leaves were removed by hand, while smaller leaves were left attached since they subtend from the flower bract. Remaining stems were then bucked using the Munch Machine Mother Bucker (Toppenish, WA)(Image 1) and remaining leaf material and buds were collected. Wet bud and leaf material was then processed through the CenturionPro Gladiator Trimmer (Maple Ridge, BC, Canada) (Image 2). Wet bud weight and unmarketable bud weight were recorded. The flower buds were then dried at 80º F or ambient temperature with airflow until dry enough for storage without molding. A subsample of flower bud from each plot was dried in a small dehydrator and wet weights and dry weights were recorded in order to calculate the percent moisture of the flower buds. The percent moisture at harvest was used to calculate dry matter yields. Metrics were collected for each of the three harvested plants within each plot and a plot average was calculated. After middle three plants were harvested and measurements collected, remaining two plants were harvested on 28-Oct and chipped to be analyzed for whole plant nutrient concentrations. A subsample of chipped plants was taken, dried, and sent to Dairy One in Ithaca, NY for nutrient analysis.

Yield data and stand characteristics were analyzed using mixed model analysis using the mixed procedure of SAS (SAS Institute, 1999). Replications within the trial were treated as random effects, and treatments were treated as fixed. Treatment mean comparisons were made using the Least Significant Difference (LSD) procedure when the F-test was considered significant ($p<0.10$).

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 treatments is real or whether it might have occurred due to other variations in the field. At the bottom of each table a p-value is presented for each variable that showed statistical significance (p-value ≤ 0.10). In this case, the difference between two treatments within a column is equal to or greater than the least significant difference (LSD) value and you can be sure that for 9 out of 10 times, there is a real difference between the two treatments. In this example, treatment C is significantly different from treatment A but not from treatment B. Treatment B and treatment C have share the same letter 'a' next to their yield value, to indicate that these results are statistically similar. The difference between treatment C and treatment B is equal to 1.5, which is less than the LSD value of 2.0. This means that these treatments did not differ in yield. The difference between treatment C and treatment A is equal to 3.0, which is greater than the LSD value of 2.0. This means that the yields of these treatments were significantly different from one another. The letter 'b' next to treatment A's yield value shows that this value is significantly different from treatment B and treatment C, which have the letter 'a' next to their value.

Treatment	**Yield**
A	6.0 b
B	7.5a
C	**9.0**a
LSD (p-value ≤ 0.10)	2.0

Participants of State Hemp Programs intending to grow should acknowledge state and federal regulations regarding hemp production and registration. Growers must register within their intended state for production and must adhere to most current or active rules and regulations for production within a grower's given state. Regulations are subject to change from year to year with the development and approval of proposed program rules and it is important to note that regulations may vary across state lines and may be impacted by pending federal regulations. Please refer to this link for a detailed outline of proposed rules in Vermont. Additional information regarding the Vermont Agency of Agriculture, Food and Markets (VAAFM) Hemp Program can be found on the VAAFM website here:

https://agriculture.vermont.gov/public-health-agricultural-resource-management-division/hemp-program.

RESULTS

Seasonal precipitation and temperature were recorded with a Davis Instrument Vantage Pro2 weather station, equipped with a WeatherLink data logger at Borderview Research Farm in Alburgh, VT (Table 4). The month of July was hot and dry when compared to the 30-year average, followed by a slightly cooler than normal August and September. The month of October had warmer above average temperature and precipitation. Overall, there were an accumulated 2211 Growing Degree Days (GDDs) this season, approximately 197 more than the historical average, with much of the heat coming mid-season. Hemp plants received supplemental irrigation to account for precipitation deficits throughout the growing season, as needed.

Table 4. Seasonal weather data collected in Alburgh, VT, 2019.

Alburgh, VT	June	July	August	September	October
Average temperature (°F)	69.2	73.5	68.3	60.0	50.8
Departure from normal	0.84	2.84	-0.53	-0.62	0.14
Precipitation (inches)	1.71	2.34	3.50	3.87	3.85
Departure from normal	0.33	-1.81	-0.41	0.23	1.88
Growing Degree Days (Base 50)	446	716	568	335	146
Departure from normal	-29	76	-13	17	146

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.

Plant height did not differ significantly between N application rates (Table 5). Whole plant weight was highest when grown at 75 lbs N ac^{-1}**,** 125, and 150 lbs N ac^{-1} rate.

Table 5. Hemp whole plant weight, height, and width, Alburgh, VT, 2019.

Treatment	Plant height	Whole plant weight
lbs N ac^{-1}	in	lbs
0	49.8	8.10 c†
75	51.3	**11.2 a**
100	51.5	8.15 bc
125	49.5	10.9 a
150	49.3	9.83 ab
LSD (0.10)‡	**NS ¥**	**1.69**
Trial Mean	**50.3**	**9.63**

†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.

Total bud weight, leaf weight, and stem weight were measured at harvest to further evaluate growth characteristics of each nitrogen application rate (Table 6). In general, the T2 cultivar appeared to have a very dense and compact growth habit when compared to other varieties within our trials (Image 3).

Image 3. T2 growth habit in fertility trial, Alburgh, VT

Plants grown at 150, 125, and 75 lbs N ac^{-1} had the highest overall wet flower bud weight. Plants grown with 150 lbs N ac^{-1} had the highest proportion of buds compared to other plant components (leaves and stems). The 150 N ac^{-1} treatment also had the highest ratio of bud:stem material per plant at 1.08:1. The 125 lb ac^{-1} rate had the highest leaf weight and percentage with 150 lb ac^{-1} and 75 lb ac^{-1} having comparable weights. The amount of total leaf or stem material can influence a number of factors such as harvest time to remove excess leaf material for trimmed flower or harvestable plant material in a biomass production system. Amount of time required to harvest plants could vary drastically depending on desired end-product and intricacy of trimming, influenced largely by overall plant size and proportions of bud, leaf, and stem material.

Table 6. Hemp plant growth metrics, Alburgh, VT, 2019.

Treatment lbs N ac^{-1}	Wet bud weight lbs plant-1	Wet bud weight % total	Leaf weight lbs plant^{-1}	Leaf weight % total	Stem weight lbs plant^{-1}	Stem weight % total	Bud:stem	Leaf:stem
0	2.41 b †	29.5 ab	3.13 b	38.9	2.55 b	31.6 bc	0.935 ab	1.24 ab
75	2.93 ab	26.1 b	4.26 a	38.1	**3.98 a**	**35.8 a**	0.731 c	1.07 b
100	2.35 b	29.8 ab	3.07 b	37.2	2.73 b	33.0 ab	0.922 abc	1.13 b
125	3.02 a	27.5 ab	**4.31 a**	39.6	3.58 a	32.9 ab	0.842 bc	1.20 ab
150	**3.07 a**	**31.4 a**	3.85 ab	39.2	2.90 b	29.4 c	**1.08 a**	**1.34 a**
LSD (0.10) ‡	**.599**	**4.67**	**.888**	**NS ¥**	**0.558**	**2.90**	**.193**	**.196**
Trial Mean	2.76	28.8	3.73	38.6	3.15	32.5	0.9	1.2

†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 a composite subsample of flower material was collected from each plot and dried down to determine flower dry matter and calculate dry matter flower yields (Table 7). While plants receiving the 150 lbs N ac^{-1} application rate had the highest overall wet bud weight, there was no significant difference amongst treatments for dry matter yields or yields at 8% moisture. The 150 lbs N ac^{-1} rate did result in the highest dry matter yields at 1056 lbs ac^{-1} overall, but also had the highest amount of unmarketable flower material at 78 lbs ac^{-1} compared to the next highest rate of 100 lbs N ac^{-1} with only 9.1 lbs ac^{-1} of unmarketable material. Unmarketable flower included any flower that had suffered from disease, rot, soil contamination, or otherwise damaged flower material. Dry matter yields for the T2 variety within the trial averaged 967 lbs ac^{-1} with unmarketable wet flower averaging 21.4 lbs ac^{-1}.

Table 7. Hemp flower bud yield, Alburgh, VT, 2019.

Treatment	Flower dry matter	Dry matter flower yield €	Yield at 8% moisture	Unmarketable flower yield
lbs N ac^{-1}	%	lbs ac^{-1}	lbs ac^{-1}	lbs ac^{-1}
0	20.6	861	936	7.05 †
75	20.1	1021	1110	7.29
100	20.8	846	919	9.12
125	20.1	1052	1144	4.99
150	19.9	1056	1148	78.4
LSD (0.10) ‡	**NS ¥**	**NS**	**NS**	**59.0**
Trial Mean	20.3	967	1051	21.4

†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.

€Dry matter yield is reported at 0% moisture.

There was a significant difference across treatments for percent carbon, nitrogen, calcium, magnesium, manganese (ppm), sulfur, and chloride (Table 8). Nitrogen, calcium, magnesium, manganese, and sulfur all showed increasing plant concentrations with N rates over 100 lbs ac^{-1}. Conversely, chloride concentrations were highest in the 0 and 75 lbs ac^{-1} rates and decreased with and increasing rate of nitrogen. 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 improve the availability and subsequent uptake of other essential nutrients.

Table 8. Hemp whole plant nutrient analysis, Alburgh, VT 2019.

Treatment	Carbon	Nitrogen	Calcium	Phosphorus	Magnesium	Potassium	Sodium
lbs N ac^{-1}	%	%	%	%	%	%	%
0	45.6 ab †	2.47 b	2.35 bc	0.625	0.238 c	2.21	0.002
75	45.8 ab	2.63 b	2.10 c	0.540	0.258 bc	1.96	0.003
100	**46.2 a**	2.66 b	2.38 bc	0.610	0.283 ab	1.93	0.002
125	45.2 b	**3.25 a**	**2.83 a**	0.620	0.303 a	2.09	0.002
150	45.4 ab	3.04 a	2.67 ab	0.548	**0.308 a**	2.10	0.004
LSD (<0.10) ‡	0.760	0.378	0.355	NS ¥	0.044	NS	NS
Trial mean	45.6	2.81	2.47	0.589	0.278	2.06	0.002

†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.

Table 8 cont. Hemp whole plant nutrient analysis, Alburgh, VT, 2019.

Treatment lbs N ac^{-1}	Iron ppm	Zinc ppm	Copper ppm	Manganese ppm	Molybdenum ppm	Sulfur %	Chloride %	Cobalt ppm
0	416	57.3	16.3	73.0 b †	0.700	0.240 bc	**0.243 a**	0.208
75	376	55.0	16.3	77.5 b	0.575	0.233 c	0.220 ab	0.250
100	343	56.8	14.8	101 ab	0.850	0.243 bc	0.195 bc	0.208
125	391	56.8	15.3	120 a	0.925	**0.285 a**	0.195 bc	0.215
150	405	56.5	15.5	**126 a**	0.750	0.268 ab	0.175c	0.190
LSD (<0.10) ‡	NS ¥	NS	NS	36.5	NS	0.032	0.034	NS
Trial mean	386	56.5	15.6	99.5	0.760	0.254	0.206	0.214

†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.

Results for cannabinoids are on a dry matter basis (0% moisture). Total potential CBD was highest at the 100 lbs N ac^{-1} rate at 8.54% and was statistically similar to 150, 125, and 0 lbs N ac^{-1} rates (Table 9). Total potential THC did not appear to be impacted by the N application rates. Under this year's growing conditions each of the tested nitrogen application rates was compliant with Vermont State regulations for THC limits in the 2019 growing season. Acceptable potency for hemp in the state of Vermont is defined as one that has a Δ-9 THC concentration of 0.3% or less **and** a total potential THC concentration of 1.0% or less reported on a dry weight basis. While there was some slight variation in the total potential THC across treatments, the differences were not significant amongst treatments. Each of the five nitrogen rates within this trial would also fall under the Type III definition for cultivars of *Cannabis sativa* L. where cultivars are CBD dominate and have a CBD:THC that is at least 20:1 under definitions proposed under Vermont Hemp Program Rules (5/17/19).

It is important to note that only one variety was tested and only one source of fertilizer was used to determine the impact of nitrogen rates on cannabinoids. Higher rates, nitrogen source, or other macronutrients or micronutrients may have some impact on cannabinoid profiles that was not expressed here.

Table 9. Total flower bud cannabinoids, cannabidiol, and tetrahydrocannabinol content, Alburgh, VT, 2019.

Treatment lbs N ac^{-1}	Total potential CBD ŧ % weight	Total potential THC ᵗ % weight	CBD:THC
0	7.34 ab †	0.26	28.6 a
75	7.12 b	0.25	28.1 ab
100	**8.54 a**	0.30	**28.7 a**
125	7.36 ab	0.26	28.4 a
150	7.24 ab	0.26	27.4 b
LSD (0.10) ‡	**1.38**	**NS ¥**	**0.967**
Trial mean	7.52	0.27	28.2

†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.

ŧ Total potential CBD = (0.877 x CBDA) + CBD.

ᵗ Total potential THC = (0.877 x THCA) + Δ-9 THC.

The Cannabis plant contains a wide array of non-cannabinoids that contribute to aromatic profiles and may potentially have similar health benefits to some cannabinoids. Terpenes are one of many types of compounds found in hemp. Terpene profiles were analyzed for each plot within the fertility trial (Table 10). Results are included for 18 analyzed, unique terpenes, which have distinct chemical compositions and associated aromas that contribute to individual plant characteristics. Some terpenes may have medicinal uses as anti-irritants, anti-inflammatories, anti-microbials, or pain relievers, however the medicinal effects of many known compounds remains to be unseen. As highly volatile compounds, many of these terpenes can be subject to high levels of loss as a result of various harvest, drying, processing, or storage methods. Each of these factors should be carefully considered when evaluating and determining your growing practices, as well as desired end-product.

Within this trial there appeared to be some effect on terpene profiles from varied N application rates.
As a whole, the 75 N ac^{-1} rate appeared to have the highest values for 6 of the prominent terpenes including alpha-pinene (202ppm), beta-myrcene (972 ppm), beta-pinene (70.3 ppm), camphene (3.82 ppm), cis-beta-ocimene (10.5 ppm) and terpinolene (3.38 ppm). Additionally the 75 N ac^{-1} rate was statistically similar to top performers for alpha-terpinene, p-cymene, and gamma-terpinene yet did not express highest levels for caryophyllene oxide, eucalyptol, or trans-nerolidol. Conversely, N rates appeared to have no impact on levels of alpha-bisabolol, alpha-humulene, beta-caryophyllene, d-limonene, linalool, or menthol.

Table 10. Total flower bud terpene profiles, Alburgh, VT, 2019†.

Treatment	Alpha-bisabolol	Alpha-humulene	Alpha-pinene	Alpha-terpinene	Beta-caryophyllene	Beta-myrcene	Beta-pinene	Camphene	Caryophyllene-oxide
	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
0	129	134	143 ab †	0.568 ab	492	593 b	48.5 b	2.82 ab	17.8 bc
75	94.0	150	**202 a**	0.593 ab	565	**972 a**	**70.3 a**	**3.82 a**	11.4 c
100	66.1	127	31.3 c	0.190 b	470	143 c	13.6 c	1.24 b	**48.0 a**
125	128	129	114 b	0.453 ab	483	480 b	40.0 b	2.45 ab	23.3 b
150	131	204	97.0 bc	**0.958 a**	757	464 b	40.3 b	3.75 a	15.1 bc
LSD (<0.10) ‡	NS ¥	NS	78.3	0.638	NS	308	21.1	1.58	11.8
Trial mean	110	149	118	0.552	554	530	42.5	2.82	23.1

†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.

Table 10 cont. Total flower bud terpene profiles, Alburgh, VT, 2019†.

Treatment	Cis-beta-ocimene	D-limonene	Eucalyptol	Gamma-terpinene	Linalool	Menthol	P-cymene	Terpinolene	Trans-nerolidol
lbs ac^{-1}	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
0	6.66 b †	53.45	1.28 ab	**1.03 a**	0	0.093	1.07 ab	2.67 ab	4.54 ab
75	**10.5 a**	77.88	0.538 b	0.948 a	0.868	0.037	1.20 ab	**3.38 a**	3.73 b
100	2.73 c	38.14	0.695 ab	0.198 b	0.44	0	0.660 b	1.23 b	2.34 b
125	5.73 b	50.04	**1.94 a**	0.500 ab	1.25	0.023	0.870 b	1.95 ab	4.30 ab
150	6.09 b	121.9	1.34 ab	0.973 a	1.57	0.088	**1.81 a**	3.26 a	**7.02 a**
LSD (<0.10) ‡	2.62	NS ¥	1.30	0.560	NS	NS	.838	1.55	3.05
Trial mean	6.34	68.29	1.16	0.729	0.825	0.048	1.12	2.5	4.39

†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

Overall, flower yields from the T2 cultivar within this trial were low compared to those grown within our variety trial. As a comparison, the highest yielding nitrogen rate within this trial (150 lbs N ac^{-1}) only resulted in a 1056 lbs ac^{-1} dry matter yield for the T2 cultivar whereas our top performing cultivar from the variety trial yielded 3453 lbs ac^{-1}. Lower yields may be a result of late planting, no plastic mulch, and small seedlings. Some plants at higher treatments also suffered from root burn, which stunted growth which may have impacted overall yields. Regardless, these rates appeared to have no impact on dry matter yields for this cultivar, yet highest rates did appear to impact total unmarketable wet flower material. Nitrogen treatments from this trial also appeared to influence the uptake and concentrations of a number of plant nutrients. Overall, the whole plant concentrations observed in the trial (3% N, 0.50% P, and 2% K). The 100 lbs N ac^{-1} rate showed over 1% higher values for CBD compared to the next highest values and results suggested that N rates may have an impact on CBD concentration but not THC concentrations for this cultivar. Despite minor yet not statistically significant differences in yields, flower quality differences in the form of cannabinoids and terpenes were noted with changes in N rates, which could have major impacts on crop value depending on the market.

Terpene profiles may also become increasingly important to consumers with greater levels of education and research. While many of these compounds contribute to the vast array of aromatics and can exhibit distinct aroma profiles across cultivars, many of these compounds may also be important for their purported health benefits and synergistic effects with other compounds when consumed in hemp and hemp related products. Within this trial, fertility rates appeared to have an impact on the concentrations of a number of analyzed terpenes with the lowest applied nitrogen rate (75 N ac^{-1}) expressing the highest levels of analyzed terpenes yet smallest percentage of cannabidiol for analyzed flower. With additional years of data and information there may be the potential to adjust fertility to accentuate specific terpenes and differentiate products in a specialty market.

Under current regulations, major concerns are present with the available plant material for producing compliant crops under what could potentially be a wide array of growing conditions throughout the region. With such wide scale variations in growth habits, yield, and quality of various cultivars, it will be increasingly important to continue research and evaluation not only of available cultivars but also fertility practices to provide region specific information to optimize farmer yields within the Northeast. It is also important to note that only one variety and one fertility source was tested within this trial and other macronutrients or micronutrients could potentially impact cannabinoid profiles or expression under different growing conditions.

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