NORTHWEST CROPS & SOILS PROGRAM

2020 Hemp Flower Combined Phosphorus-Potassium Fertility Trial

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2020 HEMP FLOWER COMBINED PHOSPHORUS-POTASSIUM 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 combinations of phosphorus (P) and potassium (K) 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 phosphorus (P) and potassium (K) application rates including a Control (0 lbs ac^{-1}). Application rates included the following combinations of P-K rates, 40-44, 60-66, 80-88, 100-110, and 0-0 lbs ac^{-1}.

Table 1. Agronomic information for the hemp variety trial, Alburgh, VT, 2020.

Location	**Borderview Research Farm Alburgh, VT**
Soil type	Benson rocky silt loam, 3-5% slope
Previous crop	Winter Canola
Plot size	5’ x 20’
Plant spacing (ft)	5’ x 5’
Plant material	Seedling
Planting date	9-Jun
Harvest date	1-Oct

The 4-week-old hemp seedlings (variety Lifter) were transplanted on 9-Jun into a seed bed prepared with conventional tillage. A cover crop mixture of crimson clover and annual ryegrass was planted between rows on 15-Jun.

Plots received the P-K fertility rates in split applications over a seven-day period during peak flower formation starting on 2-Sep in the form of P-K 13/14 (0-10-11) specialty fertilizer from Canna Solutions (Los Angeles, CA) applied directly to individual plants (Table 2).

Table 2. Daily hemp P-K rates applied during flower initiation (0-10-11).

Treatment	Daily application rate
lbs P-K ac^{-1}	oz gal^{-1}
Control	0
40-44	123
60-66	248
80-88	371
100-110	612

Image 1. Centurion Pro Gladiator Trimmer (Maple Ridge, BC, Canada).

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 were measured from all harvested plants in each plot. From each plot, flower samples were taken from the top 8” of colas and were analyzed in UVM’s testing lab (Burlington, VT) for cannabinoid profiles.

For each plant harvested, the whole plant weight was recorded. On 1-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 BuckmasterPro Bucker (Maple Ridge, BC, Canada) and remaining leaf material and buds were collected. Wet bud and leaf material was then run through the Centurion Pro Gladiator Trimmer (Maple Ridge, BC, Canada) (Image 1).

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 two harvested plants within each plot and a plot average was calculated.

After harvest (1-Oct) one plant per plot was harvested 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 $\leq$ 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	6.0b
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 the following 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 3).

The growing season was defined by hot and dry conditions throughout the summer months, punctuated by a handful of larger, infrequent rain events seen largely in August. June was especially dry during the transplant and establishment period for our hemp trials with below average precipitation in much of the growing season. Average temperatures during the growing period were 4.11 degrees higher than the 30-year average for the season with a 5.5% higher growing degree day accumulation for the year.

Table 3. Seasonal weather data collected in Alburgh, VT, 2020.

Alburgh, VT	June	July	August	September	October
Average temperature (°F)	66.9	74.8	68.8	59.2	48.3
Departure from normal	1.08	4.17	0.01	-1.33	0.19
Precipitation (inches)	1.86	3.94	6.77	2.75	3.56
Departure from normal	-1.77	-0.28	2.86	-0.91	0.00
Growing Degree Days (Base 50°F)	516	751	584	336	126
Departure from normal	35	121	2	-24	-6

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.

There was a significant difference in plant heights across treatments with highest values observed in the 100-110 lbs ac^{-1} at 164cm, yet was statistically similar to the Control, 40-44, and 80-88 lbs ac^{-1} treatments. Lowest observed values were seen in the 60-66 lbs ac^{-1} treatment at 152 cm. There were no significant differences seen in total plant weight.

Table 4. Hemp whole plant weight, height, and width, Alburgh, VT, 2020.

Treatment lbs P-K ac^{-1}	Plant height cm		Plant weight lbs
Control	156	ab†	14.8
40-44	153	ab	15.2
60-66	152	b	15.3
80-88	157	ab	14.8
100-110	164	a	15.4
LSD (0.10)‡	11.2		NS¥
Trial Mean	156		15.1

†Within a column treatments marked with the same letter were statistically similar (p=0.10).
‡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 P-K application rate (Table 5). In general, plants across treatments appeared to be fairly uniform in growth habit with little to no observable difference in appearance. Overall the P-K rates did not seem to consistently impact the percentage of stem, flower, and leaf when compared to the control.

Table 5. Hemp plant growth metrics, Alburgh, VT, 2020.

Treatment	Stem weight		Stem weight		Flower weight		Flower weight		Leaf weight	Leaf weight	Bud:stem		Leaf:stem	
lbs P-K ac^{-1}	lbs plant^{-1}		%		lbs plant^{-1}		%		lbs plant^{-1}	%				
Control	3.88	b†	26.2	b	5.75	ab	39.1	ab	5.13	34.7	1.33	ab	1.33	ab
40-44	5.75	a	37.2	a	5.50	b	36.1	b	3.99	26.7	0.880	bc	0.880	bc
60-66	4.10	ab	27.3	b	5.73	ab	37.4	b	5.48	35.4	1.34	a	1.34	a
80-88	4.73	ab	31.7	ab	6.30	a	42.5	a	3.78	25.8	0.857	c	0.857	c
100-110	4.48	ab	29.5	ab	5.98	ab	39.0	ab	4.90	31.5	1.09	abc	1.09	abc
LSD (0.10)‡	1.69		9.69		0.636		4.56		NS¥	NS	0.450		0.45	
Trial Mean	4.59		30.4		5.85		38.8		4.65	30.8	1.10		1.10	

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

At harvest, a composite subsample of flower materials was collected from each plot and dried down to determine flower dry matter and calculate dry matter flower yields (Table 6). Unmarketable flower material was also recorded for each plant which included any diseased or otherwise undesirable plant flower tissue. There were significant differences in unmarketable flower material with the highest amount of unmarketable flower observed in the control plot at 0.0062 lbs plant^{-1} alongside the lowest P-K treatment (40-44 lbs ac^{-1} P-K) at 0.0058 lbs plant^{-1}. Dry matter was also significantly different across treatments with highest dry matter observed in the control plot once again, and lowest observed in the 80-88 P-K treatment at 23.6%. Overall, yields did not appear to be impacted by P-K treatments and there were not significant differences across the control and supplemental inputs.

Table 6. Hemp flower bud yield, Alburgh, VT, 2020.

Treatment	Unmarketable flower		Dry matter€		Dry matter yields	Yield at 8% moisture
lbs P-K ac^{-1}	lbs plant^{-1}		%		lbs ac^{-1}	lbs ac^{-1}
Control	0.0062	a†	25.7	a	2562	2784
40-44	0.0058	a	25.4	ab	2416	2626
60-66	0.0000	b	24.8	ab	2456	2669
80-88	0.0017	b	23.6	b	2553	2775
100-110	0.0000	b	25.4	ab	2624	2852
LSD (0.10)‡	0.0051		1.99		NS¥	NS
Trial Mean	0.0027		25.0		2522	2741

†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.

Whole plant nutrient analysis was obtained by chipping one whole plant per plot and drying down plant material before subsampling and processing. Each plot was analyzed for primary and secondary plant nutrients (Table 7). Across the eleven analyzed nutrients, significant differences in plant nutrient analysis were observed in potassium, phosphorus, manganese, and zinc. Highest values for potassium and phosphorus were observed in the 100-110 lbs ac^{-1} treatment at 1.99% potassium and 0.676% phosphorus. Highest applications rates of phosphorus and potassium appeared to increase overall concentration in plants for those two primary nutrients. Similarly, highest values of manganese were seen in the 100-110 and 80-

88 lbs P-K ac^{-1} treatments with highest observed value seen in the 100-110 lbs P-K ac^{-1} treatment at 81.8 ppm.

Table 7. Whole hemp plant nutrient analysis. Alburgh, VT, 2020.

Treatment	Nitrogen	Potassium		Phosphorus		Calcium	Magnesium
lbs P-K ac^{-1}	%	%		%		%	%
Control	2.56	1.70	bc†	0.574	bc	2.19	0.259
40-44	2.62	1.82	abc	0.651	ab	2.10	0.281
60-66	2.46	1.65	c	0.539	c	2.16	0.253
80-88	2.77	1.85	ab	0.575	bc	2.29	0.273
100-110	2.77	1.99	a	0.676	a	2.39	0.281
LSD (0.10)‡	NS¥	0.18		0.080		NS	NS
Trial Mean	2.63	1.80		0.603		2.22	0.269

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

Table 7 cont. Whole hemp plant nutrient analysis. Alburgh, VT, 2020.

Treatment	Carbon	Manganese		Iron	Copper	Boron	Zinc	
lbs P-K ac^{-1}	%	ppm		ppm	Ppm	Ppm	ppm	
Control	19.9	66.0	bc†	317	11.5	26.8	35.1	Ab
40-44	19.7	76.3	ab	424	13.8	28.5	41.4	A
60-66	20.9	63.0	c	256	9.12	26.6	32.1	B
80-88	18.2	77.5	a	609	13.8	27.9	35.1	Ab
100-110	18.2	81.8	a	309	10.5	28.4	38.9	Ab
LSD (0.10)‡	NS¥	11.0		NS	NS	NS	7.65	
Trial Mean	19.4	72.9		383	11.7	27.6	36.5	

†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.

Each plot was also analyzed for cannabinoid profiles (Table 8). Given the application method, there appeared to be no impact of fertility treatments on the cannabinoid profiles for any of the analyzed compounds. There were no significant differences across treatments within the trial.

Table 8. Hemp P-K fertility cannabinoid profiles, Alburgh, VT, 2020.

Treatment	CBDA	CBD	D9-THC	THCA	Total THC	Total CBD	CBD : THC
lbs P-K acre-1	%	%	%	%	%	%	%
Control	15.8	0.851	0.081	0.507	0.525	14.7	28.1
40-44	19.1	0.982	0.092	0.609	0.626	17.7	28.3
60-66	17.3	0.953	0.088	0.558	0.578	16.2	28.0
80-88	15.2	0.866	0.078	0.476	0.495	14.2	28.8
100-110	14.9	0.807	0.064	0.475	0.480	13.9	29.6
Trial mean	16.5	0.892	0.080	0.525	0.541	15.3	28.5
LSD (0.10)	NS	NS	NS	NS	NS	NS	NS

NS – No significant difference between treatments.

DISCUSSION

While there were a number of statistically significant differences across the various analyzed growth metrics in the trial, there are no clear linear responses for many growth metrics as a result of increase in P-K rates. Research in other parts of the country have shown similar results with no observable impacts on plant growth from increasing phosphorus rates beyond crop requirements. Similar to other studies, increases in phosphorus or potassium fertility has little to no impact on cannabinoid profiles. Some similarities can be drawn from results from this trial and other grain hemp research with increased plant heights in response to increases in phosphorus and potassium fertility rates. No clear yield response was observed in flower yields within this trial, similar to hemp grain research which has also shown no clear yield response to fertility rates.

Timing of application rates as well as methods of application could have the potential to show more distinct differences in P-K treatments. With this particular fertilizer, application timing was determined by flower formation period with the aim of increasing flower biomass through application of supplemental phosphorus and potassium. While it appeared that highest individual plant floral biomass was seen in the 80-88 lbs P-K ac^{-1} treatment, it was also statistically similar to the control treatment which received no supplemental fertility making it difficult to determine contributing factors of these differences. With other measured plant metrics, similar results were seen throughout the trial often showing highest observable values within the highest rates, yet statistically similar results amongst those lowest fertility rates. It will crucial to test P-K fertility rates under a variety of soil types and environments.

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