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Introduction

Hemp is a broad term used to describe the many varieties of *Cannabis sativa* L. that produce less than 0.3% tetrahydrocannabinol (THC). The crop is globally significant, but only recently was allowed to be grown once again in the United States. Varieties have been selected and are currently grown with a wide cannabinoid profile. Cannabinoids are of high interest for their putative medical and therapeutic role in humans and companion pets. Cannabidiol (CBD) and THC are the two cannabinoids of primary interest. THC is of interest because it determines whether the final product is considered hemp (<0.3% THC) or marijuana (>0.3% THC). CBD is of interest because of its potential therapeutic properties and its legal status across many states. Currently, there is little published information regarding best management practices to grow CBD hemp in Kansas.

Controlled experiments are necessary to determine optimum production practices in Kansas. There are still many aspects of production that have not been addressed or answered in the scientific literature. Currently, growers must rely on only a limited volume of data in KS or information generated from other states with vastly different growing conditions. Variety selection, fertility management, and potting substrate characteristics are vital in CBD hemp production because environmental conditions strongly influence cannabinoid ratios and ultimately, total cannabinoid content.

The objectives of these studies were to evaluate the effectiveness of a simple controlled release fertilizer and to investigate the influence of potting substrate volume on yield and quality of CBD hemp plants. Fertility recommendations for containerized hemp plants can be complicated and require expensive equipment to deliver nutrients in the prescribed ratios at the right time. A simplified fertility program could be beneficial to hemp growers. However, growers would lose the ability to rapidly adjust the fertility program to meet changing conditions in the growing area. Additionally, these plants grow rapidly during the growing season and quickly become pot-bound before harvest. A larger volume for root growth may increase yield at the end of the season. However, larger substrate volumes require greater input costs, which may not be justified by an increase in yield.

Procedures

Controlled Release Fertilizer

On June 11, 2021, clones in 1-gallon pots (from rooted cuttings) of industrial hemp CBD varieties Cherry, Otto II Endurance, and The Wife were re-potted into 7-gallon plastic containers and placed in a 20 ft × 99 ft high tunnel covered with plastic, and 30% shade cloth on the top and insect netting on the sides and end-walls. Pots were filled with a soilless potting substrate composed of composted pine bark (HappiGro) and a commercial substrate (Sungro Metro-Mix 900) (1:1 by vol) amended with 1 lb/yd^3 dolomitic lime. Pots were placed on a 4 ft × 4 ft spacing and irrigated as needed with micro-irrigation. Each plant was surrounded by a 5 ft tall × 26-inch diameter tomato cage to support growth. The terminal growing point of each plant was pinched once at potting to encourage lateral branching. Fan leaves were removed throughout the growing season to improve airflow and reduce disease occurrence.

On June 12, 2021, controlled release fertilizer treatments were applied by evenly distributing the prills across the substrate surface. Treatments were selected based on the product's reported release rate and consisted of a 2- to 3-month release (Harrel's Polyon 16-6-13, 2.7 ounce), 3- to 4-month release (Osmocote Plus 15-9-12, 5.5 ounces), 5- to 6-month release (Osmocote Plus 15-9-12, 6.6 ounces), and 8- to 9-month release (Osmocote Plus 15-9-12, 8.2 ounces). Application rate matched the high rate on the product label.

On September 30, 2021, plant height was measured from the container's substrate surface to the tallest point of each plant. The plants were cut at the substrate surface and hung to dry in a ventilated storage building. After 1 week colas and leaves were removed from the stems and a biomass weight was obtained.

The experimental design was a randomized complete block design with a factorial arrangement of treatments. Treatments were three varieties and four fertilizer release rates replicated four times. Data were subjected to analysis of variance and means separated with Fisher's Protected LSD.

Container Size During Production

On June 7, 2022, clones in 1-gallon pots (from rooted cuttings) of industrial hemp CBD varieties Cherry and The Wife were re-potted into 7-gallon or 10-gallon plastic containers and placed in the high tunnel previously described. Pots were filled with a soilless potting substrate composed of composted pine bark (HappiGro) and a commercial substrate (Sungro Metro-Mix 900) (1:1 by vol) amended with 1 lb/yd^3 dolomitic lime. A conventional controlled release fertilizer (Osmocote Plus 15-9-12) was incorporated at 14.5 lb/yd^3. Pots were placed on a 5 ft × 5 ft spacing and irrigated as needed with micro-irrigation. As previously described, each plant was surrounded by a tomato cage, the terminal growing point of each plant was pinched, and fan leaves were removed throughout the growing season.

On October 6, 2022, plant height was measured from the container's substrate surface to the tallest point of each plant. The plants were cut at the substrate surface and hung

to dry in a ventilated storage building. After 2 weeks, colas and leaves were removed from the stems and a biomass weight was obtained.

The experimental design was a randomized complete block design with a factorial arrangement of treatments. Treatments were two varieties and two container sizes replicated 5 times. Data were subjected to analysis of variance and means were separated with Fisher's Protected LSD.

Results

Fertilizer release rates influenced biomass and plant height, however, there was no interaction of the main effects, suggesting that the three varieties responded similarly to the fertilizer release rates (Figure 1). Plants fertilized with the 2- to 3-month (40 inches) release fertilizer were shorter than plants fertilized with 3- to 4-month (44 inches), 5- to 6-month (43 inches), or the 8- to 9-month (45.0 inches) release rates. The difference in biomass averaged over variety was more pronounced. The greatest amount of biomass was produced with the 8- to 9-month (1.6 lb) release fertilizer. A 50% reduction in biomass was recorded with the 2- to 3-month (0.8 lb) release fertilizer. The 3- to 4-month (1.1 lb) and 5- to 6-month (1.2 lb) release fertilizers resulted in biomass yields in between the high and low release rates.

The influence of the fertilizers within the varieties produced minimal effects on height but dramatic effects on biomass yield (Table 1). Each variety increased its yield nearly 100% from the 2- to 3-month release fertilizer to the 8- to 9-month fertilizer. For each variety the 3- to 4-month and the 5- to 6-month release rates yielded biomass amounts that were similar to each other, and between the low (2- to 3-month) and high (8- to 9-month) yielding fertilizer release rates.

These results suggest that a controlled release fertilizer with an 8- to 9-month release rate can produce high yielding CBD hemp plants without supplemental nutrient packages. Fertilizers with a faster release rate will not, on their own, result in plants with similar yields. With fast release fertilizers, nutrients are likely used early in the growing season, leaving little remaining for the plants as they mature. However, growers may consider such products, giving them the option to customize and supplement plants with fertility programs specifically designed to their growing operation.

Plant height, plant weight, and biomass yield were all greatly influenced by container size (Table 2). However the main effect of variety did not affect growth or yield. Therefore, data presented are averaged over variety. Final plant height was greater in 10 gallon (47 inches) compared to 7 gallon (40 inches) containers (Figure 2). After curing for 2 weeks, total plant weight was 65% greater when grown in 10 gallon (1.9 lb) compared to 7 gallon (1.1 lb) containers. Similarly, there was a 53% increase in biomass yield from plants grown in 10 gallon (1.1 lb) compared to 7 gallon (0.7 lb) containers.

Clearly there is an increase in plant growth and yield when plants are grown in larger containers. CBD hemp plants grow rapidly during the growing season and it is likely their roots become confined by the smaller containers earlier in the season, thereby slowing growth. With the larger rooting volume, plants in the 10-gallon containers were likely to have more vegetative growth prior to the induction of reproductive

growth. These results suggest growers could produce larger plants with greater yield in larger containers. However, there is a cost-benefit to be considered as larger containers cost more to purchase, require more substrate to fill, need more fertilizer per plant, and would require more water during each irrigation event to thoroughly wet the substrate.

Acknowledgments

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Table 1. Biomass and plant height (Ht) of three CBD hemp varieties grown with one of four controlled release fertilizers with different release rates

	Cherry		Endurance		The Wife	
Release rate[z]	Biomass[y]	Ht	Biomass	Ht	Biomass	Ht
	lb	in.	lb	in.	lb	in.
2-3 month	0.9[c]	37	0.8[b]	44	0.7[c]	39
3-4 month	1.1[bc]	41	1.3[ab]	48	0.9[bc]	43
5-6 month	1.3[ab]	39	1.2[ab]	48	1.0[b]	41
8-9 month	1.6[a]	39	1.8[a]	53	1.3[a]	42

[z]Fertilizers were applied at the manufacturer's recommended high rate.
[y]Numbers within a column followed by the same letter are not significantly different at $P \leq 0.05$.

Table 2. Plant height (Ht), weight, and biomass of CBD hemp varieties grown in 7- or 10-gallon plastic nursery containers

Container size	Ht[z]	Weight	Biomass
	in.	lb	lb
7 gal	40[b]	1.1[b]	0.7[b]
10 gal	46[a]	1.9[a]	1.1[a]

[z]Numbers within a column followed by the same letter are not significantly different at $P \leq 0.05$.

Figure 1. Growth of Cherry (top), Otto II Endurance (middle), and The Wife (bottom) CBD plants fertilized with a controlled release fertilizer with a release rate of 2-3, 3-4, 5-6, or 8-9 months.

7 gal 10 gal

Fertilizer release rate, months

Figure 2. Growth of Cherry (top) and The Wife (bottom) CBD plants grown in traditional 7- or 10-gallon nursery containers.