Industrial hemp vegetative growth affected by substrate composition

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Abstract

Little scientific literature exists on cultivation techniques for cannabis (*Cannabis sativa* L.) in container production environments, and there is almost none concerning horticultural substrate requirements. Substrates are one of the most important factors in maximizing crop production in controlled environments and the efficient use of inputs such as water and fertilizer. Due to the growing economic importance of hemp in the United States, and the need for a more thorough understanding of its cultivation in container culture, two studies were conducted to evaluate vegetative growth in a variety of horticultural substrates. Four cultivars, 'Cherrywine', 'Baox', 'T1', and 'Sweetened' were grown in peat-based and coir-based mixes containing either 0, 15, 30, or 45% perlite by volume. Six weeks after transplant, height, diameter, growth index and dry weight were measured. Additionally, to evaluate a range of commercially available mixes, 'Cherrywine', and 'Baox' were grown in 20 mixes marketed to the cannabis industry. These plants were harvested and dry weights measured at four weeks after transplant. Aside from coir-based mixes with higher levels of perlite, growth measurements were similar in all substrates tested. Physical properties of all 28 mixes were determined using the NCSU Porometer method, and all were found to be within or close to recommended ranges for most horticultural crops. These experiments suggest cannabis can be grown successfully in a range of horticultural substrates.

Keywords: *Cannabis sativa* L., growing media, physical properties, vegetative growth, perlite

INTRODUCTION

Cannabis sativa L. is one of the earliest examples of cultivated plants, with domestication possibly occurring 8,500 years ago (Small and Cronquist, 1976; Small and Marcus, 2002). The economic importance and domestication efforts by man have focused on the seed, fiber, and flowers. Fiber has been utilized for cordage and cloth, seeds have served as a source of oil, as well as food, and flowers have been selected for resin with intoxicant or medicinal properties (Schultes, 1970; Clarke and Merlin, 2017). According to Small and Cronquist (1976) cannabis cultivated for medicinal resin falls under two taxon, *C. sativa* subs. *sativa* and *C. sativa* subsp. *indica* (Lam.) (Hillig, 2005; McPartland and Guy, 2017; McPartland, 2018). These taxa are known commonly as hemp and marijuana, respectively. Subspecies *sativa* is differentiated by containing <0.3% tetrahydrocannabinol (THC) by dry weight, and includes cultivars cultivated for cannabidiol (CBD), fiber and seed. Subspecies indica contains >0.3% THC and is cultivated for its intoxicant properties.

Substrates are one of the most important factors in maximizing crop production in controlled environments. To determine the most effective substrate for a specific growing environment, it is necessary to understand the substrate's physical properties. Substrates possessing the ideal total porosity (TP), container capacity (CC), air space (AS), and bulk density (BD) for a given crop can provide an even distribution of air, water and nutrients to the root environment. Irrigation events and nutrient inputs can be minimized, avoiding excessive runoff, and allowing for more profitable container production (Fields et al., 2014a, b; Fonteno et al., 2013).

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Little scientific literature exists on cultivation techniques for cannabis in container production environments; and there is almost none concerning substrate requirements. Most research regarding cultivation of cannabis provides only vague description of substrates used, peat/perlite mixture (Potter and Duncombe, 2012), 4:1 mix of composted bark and coarse washed river sand (Lisson et al., 2000), 3 soil-leaf: 1 mold-Kureha: 1 compost (Yoshimatsu et al., 2004), or no description of substrates used, soil-filled pots (Coffman and Gentner, 1979), grown in pots (Potter, 2014).

Due to the importance of substrates in container production and the lack of scientific literature describing substrate effect on cannabis growth, the objective of this research was to evaluate substrates with varying physical properties and their effect on cannabis vegetative growth. Two of the most common substrate components in mixes marketed to the cannabis industry are peat and coir (Caplan et al., 2017). For this reason, we chose to focus on peat and coir, alone and with increasing ratios of perlite. An additional objective was to quantify the physical properties of a range of commercially available substrates marketed to the cannabis industry and evaluate vegetative growth of cannabis in these mixes.

MATERIALS AND METHODS

Hemp cuttings from cultivars 'Baox' and 'T-1' were collected from Triangle Hemp (Durham, NC) and stuck on 12 June. Cuttings of 'Cherrywine', and 'Sweetened' were collected from Broadway Hemp (Sanford, NC) on 13 June. All cuttings were three nodes in length and had at least three fully expanded, uncut leaves. Cuttings were stuck in 72 cell plug flats [3.6×6 cm (diameter × height)] containing Sunshine® mix #1 (Sun Gro Horticulture, Agawam, MA), with one node below the substrate surface, and placed under mist. The mist bench was covered with opaque white plastic. Four hours of night interruption, between 22:00 and 2:00 was initiated on 22 June (four 40 W incandescent bulbs per 1.52×6.1 m bench) following the summer solstice on 21 June to prevent flowering as day length decreased. Cuttings were propagated and grown in a glass greenhouse at 35°N latitude in Raleigh, NC, USA.

Experiment 1

On 10 July, four peat-based (Lambert Peat Moss, Rivière-Ouelle, Québec) and four coir-based (RainSoil, Las Vegas, NV) substrate blends were mixed using a soil mixer (Model 12101; Bouldin & Lawson, McMinnville, TN). Peat was fluffed and wetted by hand to a moisture content of 50% before being added to the soil mixer. Coir bricks were submerged in water until they could be fluffed by hand, and then added to the soil mixer. Both peat and coir-based substrates had perlite (Carolina Perlite Co., Gold Hill, NC) added at ratios of 0, 15, 30, and 45% by volume. All mixes were amended with wetting agent (Aquatrols, Paulsboro, NJ) at a rate of 0.607 kg m^{-3}. Peat mixes containing 0, 15, 30, and 45% perlite had rates of 7.06, 6.18, 6.18, and 5.357 kg m^{-3} of dolomitic limestone (Rockydale Quarries Corp., Roanoke, VA) added, respectively. Liming rates were similar to rates used in other published research concerning substrates (Henry et al., 2018) and decreased as peat level decreased. The physical properties (TP, CC, AS, and BD) of all substrate blends were determined using the NC State University (NCSU) Porometer method established by Fonteno et al. (1995).

Rooted cuttings were transplanted on 12 July into a 5.68 L plastic blow molded nursery pots (C600; Nursery Supplies Inc., Kissimmee, FL). Plants were hand watered with clear water and drip irrigation was installed. Drip irrigation was applied as needed and plants were fertilized at each watering with 150 mg L^{-1} nitrogen (N) from 13 N - 0.86 phosphorous (P) - 10.8 potassium (K) water soluble fertilizer (Excel® 13-2-13, The Scotts Co., Marysville, OH). Night interruption continued at the same rate as was used for cuttings, 4 h (between 22:00 and 02:00) of incandescent 40 W bulbs, spaced four per 1.52×6.1 m bench. Plants were grown in a poly greenhouse at 35°N latitude in Raleigh, NC, USA, and arranged in a randomized block design grouped by perlite percentages to allow treatments with similar irrigation requirements to be grouped accordingly. The experiment consisted of 6 replications × 4 cultivars × 8 substrate treatments. PourThrus were conducted on 30 July and 17 Aug. on three replications of each substrate treatment to monitor pH and electrical conductivity. Plants were measured on 22 August six weeks after transplant. Measurements included height (from substrate surface to the tallest point on the plant along with two canopy width measurements (width at widest point, then the container was rotated 90° and the second width measurement was taken). The average of these three measurements were used to determine the growth index (GI) of plants. Plants were then harvested at the substrate level and dried in an oven at 75°C for seven days before dry weights were recorded.

Experiment 2

Except where indicated, procedures used in Expt. 2 were the same as Expt. 1. Rooted cuttings of *Cannabis sativa* L. 'Cherrywine' and 'Baox' were transplanted on 12 July into 7.57 L plastic containers filled with 20 commercially available substrate blends from five horticultural substrate companies. On 9 Aug., 4 weeks after transplant, 3 replicates were harvested at substrate level and oven-dried before recording dry weights. An additional 3 replicates were harvested on 22 Aug. but data were compromised due to a lab oven malfunction.

RESULTS AND DISCUSSION

Experiment 1

Total porosity, CC, AS, and BD values (Table 1) were similar for all treatments. There was however a slight decline in TP as perlite percentage increased. The peat and coir used for these experiments were already highly porous with TP values of 88.78 and 95.55%, respectively. Peat can have highly variable physical properties and has been reported to have TP values ranging from 72 to 84% by Hanan (2017) and 94.2% by Abad et al. (2005). Abad et al. (2005) reported on physical properties of coir samples from six different countries and found a TP range of 94.1 to 98.3%. Adding small particles, in this case perlite, to a course medium with high porosity will reduce the total volume of the material. Fine particles fill large pore spaces reducing TP (Hanan, 2017). To further increase the TP of the substrate blends, the perlite used would require a higher TP than the peat or coir alone.

Table 1. Physical properties of peat based and coir-based substrate blends containing 0, 15, 30, or 45% perlite by vol[a].

Substrate blends	Total porosity[b] (% vol)	Container capacity[c] (% vol)	Air space[d] (% vol)	Bulk density[e] ($g\ cm^{-1}$)
100:0 peat:perlite[f]	88.78c	64.23c	24.56a	0.11a
85:15 peat: perlite	85.40d	62.57cd	22.83ab	0.11a
70:30 peat: perlite	81.88e	60.30d	21.58abc	0.11a
55:45 peat: perlite	81.73e	60.43d	21.29bc	0.12a
100:0 coir: perlite	95.55a	74.45a	21.10bc	0.07c
85:15 coir: perlite	92.54b	73.74ab	18.80cd	0.08c
70:30 coir: perlite	87.30c	70.32b	16.98d	0.09b
55:45 coir: perlite	83.81d	63.47cd	20.34bc	0.11a

[a]Physical property data represent the mean (*n*=3). Analysis performed using the NC State University Porometer method (Fonteno et al., 1995).

[b]Total porosity is equal to container capacity + air space.

[c]Container capacity is (wet weight – oven dry weight)÷volume of the sample.

[d]Air space is the volume of water drained from the sample ÷ volume of the sample.

[e]Bulk density after forced-air drying at 105°C for 48 h; 1 g cm^{-1} = 0.5780 oz $inch^{-3}$.

[f]Substrates were formulated with peat or coir amended with 0, 15, 30, or 45% perlite by vol.

Although there are no recommended ranges for substrate physical properties to maximize Cannabis growth, or universally accepted standards in general, the physical properties observed were similar to the suggested ranges for many container-grown horticultural crops in commercial environments (Bilderback et al., 2005; Yeager et al., 1997).

Container capacity was higher (70 to 74%) than the recommended range of 45 to 65% in some treatments but did not coincide with the smaller growth parameters observed.

Two interactions were found to affect GI of the cannabis cultivars grown. Type of substrate (peat or coir) by percentage of perlite (Table 2), and type of substrate by cultivar (Table 3). Three out of the four cultivars ('Cherry Wine', 'Baox', 'T1') had larger GI when grown in peat compared to coir. Peat with 0 or 30% perlite had plants with the largest GI, while coir with 45% perlite were the smallest. There was little difference in GI overall between substrate treatments, except for coir with 45% perlite.

Table 2. Growth index (GI) and dry weight measurements of *Cannabis sativa* L. cultivars 'Cherry Wine', 'Baox', 'Sweetened' and 'T1' in peat and coir based substrates containing 0, 15, 30, and 45% perlite by vol.[a].

Substrate blends	GI (cm)[b]	Dry weight (g)[c]
100:0 peat: perlite[d]	75.71ab	31.33ab
85:15 peat: perlite	71.91bc	28.58 ab
70:30 peat: perlite	78.28a	32.74 a
55:45 peat: perlite	71.77bc	26.82 ab
100:0 coir: perlite	71.66bc	27.03ab
85:15 coir: perlite	68.11c	23.84bc
70:30 coir: perlite	68.86c	19.81cd
55:45 coir: perlite	60.86d	14.00d

[a]Tukey-Kramer grouping for least square means of growth index (GI) and dry weight for substrate by perlite (% vol).

[b]GI = (Height from substrate to tallest point + diameter at widest point + second diameter 90° turn from first) / 3.

[c]Dry weight of all above ground plant parts after forced-air drying at 75°C.

[d]Substrates were formulated with peat or coir amended with 0, 15, 30, or 45% perlite by vol.

Table 3. Growth index (GI) measurements of *Cannabis sativa* L. cultivars 'Cherry Wine', 'Baox', 'Sweetened' and 'T1' in peat and coir based substrates[a].

Substrate*cultivar	GI[b] (cm)
Peat: Cherry Wine	81.84a
Peat: Baox	79.27ab
Peat: Sweetened	75.93bc
Peat: T1	60.63e
Coir: Cherry Wine	71.86cd
Coir: Baox	70.53d
Coir: Sweetened	72.49cd
Coir: T1	54.61f

[a]Tukey-Kramer grouping for least square means of growth index (GI) and dry weight for substrate by cultivar.

[b]GI = (Height from substrate to tallest point + diameter at widest point + second diameter 90° turn from first) / 3. Substrate*Cultivar p-value = 0.0268

For dry weights, the interaction of substrate type and percentage of perlite had an effect (Table 2). Cultivar also had an effect, with 'Sweetened' and 'Baox' having larger dry weights and 'Cherry Wine' and 'T1' having smaller dry weights (data not shown). All peat blends and coir with 0% perlite had plants with similar, greater dry weights, coir with 30 and 45% perlite had plants with the smallest dry weight.

Other than slight negative trends in GI and dry weight for plants grown in coir with higher levels of perlite, substrate blend treatments appeared to have little effect on plant growth. These data suggest peat and coir-based substrates possessing TP, CC, AS, and BD values within suggested ranges of most other horticultural crops (Bilderback et al., 2005) will have minimal effect on GI and dry weight of vegetative cannabis.

Table 4. Dry weight at four weeks after transplant for plants grown in 20 commercially available substrate mixes[a].

Substrate blends	Dry weight (g)[b]
Mix 1	10.13bcd
Mix 2	10.66abcd
Mix 3	12.63abcd
Mix 4	14.85ab
Mix 5	16.50a
Mix 6	16.28a
Mix 7	13.53abc
Mix 8	12.80abcd
Mix 9	8.56cd
Mix 10	11.38abcd
Mix 11	7.08d
Mix 12	12.63abcd
Mix 13	13.25abc
Mix 14	13.88abc
Mix15	10.10bcd
Mix 16	12.50abcd
Mix 17	12.33abcd
Mix 18	11.73abcd
Mix 19	11.76abcd
Mix 20	12.61abcd

[a]Tukey-Kramer grouping for least square means of dry weight for each substrate.

[b]Dry weight of all above ground plant parts after forced-air drying at 75°C for 72 h.

Table 5. Physical properties of 20 commercially available substrate mixes marketed to the cannabis industry[a].

Substrate blends	Total porosity[b] (% vol)	Container capacity[c] (% vol)	Air space[d] (% vol)	Bulk density[e] (g cm^{-1})
Mix 1	89.32 abc	60.07 hi	29.26 a	0.09 de
Mix 2	84.76 gh	64.14 e-g	20.62 cde	0.10 c
Mix 3	88.20 cd	67.48 b-e	20.72 cde	0.09 d
Mix 4	91.14 ab	68.12 bcd	23.02 bc	0.09 d
Mix 5	88.76 bc	68.80 bc	19.95 cdef	0.08 e
Mix 6	91.69 a	68.38 bc	23.31 bc	0.09 d
Mix 7	89.16 bc	71.13 ab	18.04 defgh	0.08 e
Mix 8	88.72 bc	70.97 ab	17.75 efgh	0.08 e
Mix 9	87.36 cdef	73.55 a	13.81 h	0.09 cd
Mix 10	85.89 defg	66.32 cdef	19.57 cdef	0.09 d
Mix 11	84.99 fgh	63.59 fgh	21.39 cde	0.09 d
Mix 12	87.68 cde	72.90 a	14.77 gh	0.09 cd
Mix 13	87.69 cde	65.34 cdefg	22.35 bcd	0.09 d
Mix 14	84.42 gh	68.59 bc	15.83 fgh	0.10 c
Mix 15	85.19 fgh	58.71 i	26.48 ab	0.10 c
Mix 16	85.75 defg	71.17 ab	14.58 gh	0.09 d
Mix 17	87.96 cde	60.05 hi	27.91 a	0.10 c
Mix 18	85.08 fgh	62.25 ghi	22.83 bc	0.13 b
Mix 19	82.83 h	64.41 defg	18.42 defg	0.15 a
Mix 20	85.69 efg	70.63 ab	15.06 gh	0.09 d

[a]Physical property data represent the mean (n=3). Analysis performed using the North Carolina State University Porometer method (Fonteno et al., 1995).

[b]Total porosity is equal to container capacity + air space.

[c]Container capacity is (wet weight – oven dry weight) ÷ volume of the sample.

[d]Air space is the volume of water drained from the sample ÷ volume of the sample.

[e]Bulk density after forced-air drying at 105°C for 48 h; 1 g cm^{-1} = 0.5780 oz inch^{-3}.

Experiment 2

Dry weight values at 4 weeks after transplant were similar, with minimal visual differences (Table 4). Mixes that produced the plants with the largest dry weights were 5 and 6 (16.5 and 16.3 g, respectively) and mixes that produced the plants with the lowest dry weights were 9 and 11 (8.6 and 7.1 g, respectively). Air space was within the range of 10 to 30% for all commercial mixes (Table 5). Total porosity with an average of 87%, was at the higher end of the recommended range of 50 to 85%. Container capacity was also slightly higher with an average of 66% with the recommended range being 45 to 65% (Bilderback et al., 2005). Although there was some variation (around 10 to 20% maximum) of physical properties tested in the substrates studied, dry weights were relatively unaffected. These data suggest cannabis can be grown successfully in a variety of commercial substrate mixes.

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