Coir-based growing substrates for indoor cannabis production

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Abstract

Cannabis production for both medical and recreational purposes is an expanding industry in North America. Due to the historically illegal nature of this crop, scientific literature on cultivation is lacking, specifically with regards to growing substrate use and management. To evaluate coir-based growing substrates for the vegetative and flowering growth stages of cannabis production, two trials were conducted in walk-in growth chambers. In the first trial, plants were grown in three substrates: two coir-based organic substrates, i) ABcann UNIMIX 1 (U1); ii) ABcann UNIMIX 1 – HP (U1-HP) and a commercially available peat-based organic substrate; iii) PRO-MIX MP ORGANIK MYCORRHIZAE (PM-V). The coir-based substrates differed primarily in container capacity, U1 having higher container capacity (CC) than U1-HP. In the second trial, two other coir-based substrates were evaluated: i) ABcann UNIMIX 2 (U2); and ii) ABcann UNIMIX 2 – HP (U2-HP), with U2 having higher CC than U2-HP. Plants in both trials were container-grown and fertigated using liquid organic fertilizer at ≈30% substrate moisture content. In trial 1, after the 22-day vegetative growth period, all plants were transplanted into the same substrate and maintained under a 12-h photoperiod to initiate flowering and allow the measurement of dry floral weight (yield). Treatments in both trials were evaluated on their effects on plant health, growth rates and dry floral weight. It was concluded that either coir-based substrate (U1-HP or U1) is effective for cannabis production during the vegetative stage, and in the flowering stage, the drier coir-based substrates (U2-HP) may be preferred as it delivered 29% higher yield.

Keywords: *Cannabis sativa,* cannabis growth, floral dry weight, marijuana, media

INTRODUCTION

The production of cannabis (*Cannabis sativa* L.) in North America is becoming increasingly profitable as cannabis-related regulations continue toward liberalization. In 2016, combined spending on medical and recreational cannabis in legal markets was reported at 6.7 billion USD and is projected to reach 22.6 billion USD by 2021 in North America (ArcView Market Research, 2017).

Cannabis is an annual herbaceous species, often cultivated for its unique and high concentration of secondary metabolites called cannabinoids. Cannabinoids are concentrated mostly in the essential oils of unfertilized female flowers (Potter, 2014). The cannabinoids Δ9-tetrahydrocannabinol (THC) and cannabidiol (CBD) have been most widely studied for their psychoactive and medicinal properties and varying ratios of these two compounds are often used to differentiate between cannabis varieties. Cannabis with relatively low THC and high CBD concentrations are generally termed hemp or fiber-type cannabis whereas cultivars with high THC and low CBD are termed marijuana or drug-type cannabis (van Bakel et al., 2011). The latter is the focus of the present study and will hereafter be referred to as cannabis.

Due to its historically illegal nature, there is little information on cannabis cultivation in the scientific literature. Cannabis is grown mostly indoors, under controlled environment, usually in two growth stages: vegetative and flowering, controlled by photoperiod (Farag and Kayser, 2015; Potter, 2014). Our communications with Canadian medical cannabis producers suggest that most growers use either solution culture systems or soilless growing substrates.

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Appropriate choice of growing substrate is crucial for soilless crop production, since it directly affects root zone water, air and nutrient availability (Zheng, 2016). Peatmoss is one of the most common component of soilless growing substrates used in commercial horticulture; however, it is harvested from bogs and swamps and the practice is deemed unsustainable in certain regions (Caron and Rochefort, 2013). Coconut coir, a waste product of coconut husk processing, can be used as an effective alternative to peat for growing a variety of container crops (Evans and Stamps, 1996; Meerow, 1995), but coir-based substrates have yet to be developed and evaluated for cannabis production. The objective of this study was to evaluate two coir-based growing substrates for the vegetative growth stage of cannabis and two for the flowering stage of cannabis production. Two trials were conducted; one to evaluate vegetative-stage substrates and the other to evaluate flowering-stage substrates.

MATERIALS AND METHODS

Vegetative-stage trial

Seventeen-day-old rooted cuttings (≈10 cm high with ≈6 leaves) of *Cannabis sativa* L. 'OG Kush × Grizzly' were transplanted into round peat-based pots (95 mm diameter × 102 mm high) with one plant per pot. Pots were filled with one of three growing substrates, ABcann UNIMIX 1 – HP (U1-HP; ABcann Medicinals Inc., Napanee, ON, Canada), ABcann UNIMIX 1 (U1; ABcann Medicinals Inc.) or a control, PRO-MIX MP ORGANIK MYCORRHIZAE (PM-V; Premier Tech, Rivière-du-Loup, QC, Canada). The physical and chemical properties of these substrates are presented in Tables 1 and 2, respectively. The substrates U1-HP and U1 were coir-based with two distinct container capacities (CC): U1-HP with lower CC and better drainage than U1. The control, PMV, was a commercially available peat-based growing substrate.

Table 1. Physical properties of growing substrates ABcann UNIMIX 1 HP (U1-HP), ABcann UNIMIX 1 (U1), PRO-MIX MP ORGANIK MYCORRHIZAE (PM-V), ABcann UNIMIX 2 HP (U2-HP) and ABcann UNIMIX 2 (U2).

Growing substrate	Total porosity[a] (%)	CC[a] (%)	Air space[a] (%)	Bulk density[a] (g cm^{-3})
U1-HP	93±0.4	61±1.2	31±1.3	0.088±0.001
U1	91±0.3	72±0.2	19±0.3	0.101±0.001
U2-HP	83±0.5	49±0.4	34±0.4	0.096±0.001
U2	91±0.9	55±2.2	35±1.3	0.091±0.0005
PMV[b]	-	-	8-12	z

[a]Data are means±SEM (*n*=3). CC=container capacity.

[b]Values derived from manufacturer's specifications.

Table 2. Chemical properties of growing substrates ABcann UNIMIX 1 HP (U1-HP), ABcann UNIMIX 1 (U1), PRO-MIX MP ORGANIK MYCORRHIZAE (PM-V), ABcann UNIMIX 2 HP (U2-HP) and ABcann UNIMIX 2 (U2).

Substrate	EC[a] (mS cm^{-1})	pH[a]	NO_3^--N	P	K	Ca	Mg	SO_4^{2-}	Na	Cl^-
			mg L^{-1}							
U1-HP	1.8±0.07	6.3±0.01	5	9.2	338.1	<1	2.7	31.2	104.5	413
U1	2.3±0.12	6.3±0.01	8	10.4	431.2	2.3	5.3	41.3	136.3	724
U2-HP	2.2±0.02	6.2±0.03	5	11.8	423.2	<1	4.0	34.0	118.9	534
U2	1.9±0.04	6.4±0.02	5	9.8	352.9	<1	3.2	37.0	109.4	488
PMV[b]	1-2	5.2-6.2	20-50	-	100-150	65-110	20-45	120-200	-	-

[a]Data are means ± SEM (*n*=3). EC = electrical conductivity.

[b]Values derived from manufacturer's specifications.

Pots were randomly arranged in a walk-in growth chamber (15 m^2) at a density of 97 plants m^{-2}. The growth chamber was set at 22°C, 85% RH, 500 ppm CO_2 (day and night) with canopy-level photosynthetically active radiation (PAR) maintained at 250±50 µmol m^{-2} s^{-1} with an 18-h photoperiod under fluorescent lighting. Beginning three days after transplant (DAT), plants were fertigated using a liquid organic fertilizer (4.0N-1.3P-1.7K; Nutri Plus Grow; EZ-GRO Inc., Kingston, ON, Canada), at the manufacturer's recommended rate of 234 mg N L^{-1} diluted with RO water. Fertigation was administered with a 20% leaching fraction to reach container capacity when mean substrate moisture reached ≈30%, measured using a WET-2 soil moisture sensor (Delta-T Devices Ltd., Cambridge, UK). Plants were re-randomized after each irrigation to reduce location effects. The experiment was a completely randomized design with substrate type as the single factor and 10 replicates per substrate. Each potted plant was an experimental unit.

At the end of the vegetative growth period (21 DAT), six plants with average height and canopy size from each treatment were selected and transferred into a walk-in growth chamber (130 m^2) for the flowering stage. Plants were potted into 6-L blow-molded black pots (220 mm diameter × 220 mm height) containing a custom blended organic growing substrate (60% Sphagnum peatmoss and 40% bulk coconut coir; Premier Tech). Agricultural dolomitic lime (Premier Tech) was incorporated at a rate of 3.0 kg m^{-3} substrate. Plants were spaced on tables to a density of 6.5 plants m^{-2}. Canopy-level PAR was maintained at 500±50 µmol m^{-2} s^{-1} with a 12-h photoperiod. Drip irrigation was administered with one emitter per plant. During the first 11 days in the flowering stage, plants were irrigated whenever the substrate moisture content reached 30% with Nutri Plus Grow at the manufacturer's recommended rate of 140 mg N L^{-1} and from then on with a flowering specific fertilizer, Nutri Plus Organic Bloom (2.00N-0.87P-3.32K; Nutri Plus Bloom; EZ-GRO Inc.). Nutri Plus Bloom was diluted with RO water and administered at the following manufacturer-recommended rates: 77 mg N L^{-1} from day 12 to 19 in the flowering stage, 103 mg N L^{-1} from day 20 to 27 and 129 mg N L^{-1} from day 28 to 39. Both vegetative and flowering fertilizers were amended with 2 mL L^{-1} of an organic calcium-magnesium supplement (3.0N-0.0P-0.0K-3.0Ca-1.6Mg; EZ-GRO Inc.). Between days 39 and 47 in the flowering stage, no fertilizer was applied and the substrates were flushed, as per current industry practice, with RO water: 10 L pot^{-1} at 7 days before harvest and 6 L at 5 days before harvest.

Substrate pH and EC were determined during the vegetative stage at 8, 16 and 22 DAT using the pour-through method (Wright, 1986). Pour-through solutions were measured using a HI991300 portable pH/EC/TDS/Temperature Meter (Hanna Instruments, Woonsocket, R.I., USA). At the end of the vegetative growth period (21 DAT), leaf number, canopy area and plant height were measured on 5 randomly selected plants from each treatment. Growth index for each plant was calculated as height (cm) × length (cm) × width (cm) × 300^{-1} (Ruter, 1992). Plants were harvested after 47 days in the flowering stage when floral resin on most plants had ≈50% amber coloration. Before harvest, branch number, canopy area and plant height were measured on all plants. Stems were cut at soil-level, floral material was cut from stems and leaves were trimmed thereafter. Floral material was placed in paper bags for drying at 21°C and 40% RH for 5 days until moisture content reached 11±1%. Dry material was then cured at 18°C and 60% RH for 14 days before floral dry weight (yield) measurement.

Flowering stage trial

Fifteen-day-old rooted cannabis cuttings (≈10 cm high with ≈6 leaves) 'WP:Med (Wappa)' were transplanted into round peat-based pots (95 mm diameter × 102 mm high; Jiffy Products N.B. Ltd., NB, Canada) filled with U1-HP and one plant per pot. Pots were placed in a walk-in growth chamber (15 m^2) at a density of 97 plants m^{-2}. The growth chamber was set at 24°C, 76% RH, 553 ppm CO_2 (day and night) and a canopy-level PAR of 250±50 µmol m^{-2} s^{-1} with an 18-h photoperiod under fluorescent lighting. Beginning three days after transplant, plants were fertigated, as per Caplan et al. (2017) using Nutri Plus Grow at a rate of 389 mg N L^{-1} amended with 1 mL L^{-1} of the previously mentioned calcium-magnesium supplement, and with a 20% leaching fraction. Irrigation was administered when mean substrate moisture was ≈30%, measured using a WET-2 soil moisture sensor (Delta-T Devices

Ltd.).

After 19 days in the vegetative stage, 60 plants with average height and canopy size were transferred into a larger walk-in growth chamber (130 m^2) for the flowering stage. This was considered the first DAT. Plants were up-potted into 6 L blow-molded black pots (220 mm diameter × 220 mm height) filled with one of two growing substrates: ABcann UNIMIX 2 – HP (U2-HP) or ABcann UNIMIX 2 (U2) (Physical and chemical properties presented in Table 1; ABcann Medicinals Inc.). The substrates were coir-based with distinct CC: U2-HP with lower CC and better drainage than U2. Coir weed control disks were used on top of the growing substrate to prevent algae growth. The experiment was a completely randomized design with substrate type as the single factor and 6 replicates per treatment. Each potted plant was an experimental unit.

Plants were spaced on growing tables at a density of 5.3 plants m^{-2}. Chamber temperature was set at 22°C from 1 to 6 DAT, 20°C from 7 to 9 DAT and 18°C from 10 to 53 DAT. RH was set at 70% from 1 to 6 DAT, 64% from 7 to 43% DAT and 56% from 44 to 53% DAT. Chamber CO_2 was set at 594 ppm from 7 to 9 DAT, 673 ppm from 7 to 9 DAT and 781 ppm from 44 to 53 DAT. Canopy level PAR was maintained at 580±93 μmol m^{-2} s^{-1} throughout the flowering stage under high pressure sodium lamps with a 12-h photoperiod.

During the first 11 DAT, plants were fertigated with 389 mg N L^{-1} of Nutri Plus Organic Grow. From then on, fertigation was administered at the manufacturer's recommended rate of Nutri Plus Bloom (113 mg N L^{-1}), diluted with RO water, amended with 1 mL L^{-1} of the previously mentioned Calcium-Magnesium supplement and 22.9 mg N L^{-1} of Organa ADD micronutrient supplement (2.0N-0.0P-0.0K; EZ-GRO Inc.). Fertigation was administered with a 20% leaching fraction when mean substrate moisture was ≈30%, measured using a WET-2 soil moisture sensor (Delta-T Devices Ltd.). Between 45 and 53 DAT, no fertilizer was applied, and the substrates were flushed, as per current industry practice, with RO water when mean substrate moisture content reached ≈30%. Fertigation solution pH was adjusted to maintain substrate pH between 5.5 and 6.3, measured using the pour-through method during both vegetative and flowering stages. Substrate pH and EC during the flowering stage were determined at 12, 23 and 43 DAT using pour-through method. Pour-through solutions were measured using a HI991300 portable pH/EC/TDS/Temperature Meter (Hanna Instruments).

Plants were harvested at 53 DAT when floral resin on most plants had ≈50% amber coloration. Branch number, canopy area and plant height were measured on 5 randomly selected plants from each treatment. Stems were cut at soil level; large leaves were removed from stems and plants were hung to dry at 18°C and 49% RH for 6 days then cured at 18°C and 58% RH for 11 days. Floral material was then cut from stems and leaves were trimmed using a Twister T4 mechanical trimming machine (Keirton Inc., Surrey, BC, Canada) before yield measurement.

Statistical analysis (trial one and two)

Data were analyzed using JMP Statistical Discovery Version 13.0 (SAS Institute Inc., Cary, NC) at a Type 1 error rate of ≤0.05. One-way ANOVA was used to determine the effects of vegetative-stage substrate type on growth attributes and yield as well as substrate EC and pH. The effects of flowering-stage substrate type on these same attributes were tested using Student's T-tests. The residuals of the analyses were tested for normality and equality of variance using The Shapiro-Wilk test and Bartlett's test, respectively.

RESULTS AND DISCUSSION

Vegetative stage growing substrates

In the first trial, all three growing substrates demonstrated acceptable qualities for the growth of cannabis in the vegetative stage. There was no difference in growth or yield between the three substrates; though plants grown in PMV had higher mean branch number than those grown in the coir-based substrates (Table 3). Equal growth and yield in the lower CC (drier) substrate (U1-HP) and the higher CC (wetter) substrate (U1) suggests that during the vegetative stage, cannabis can tolerate a range of substrate moisture content without

noticeable effects on growth. Substrates with higher CC, or wetter substrates, normally retain moisture longer. This moisture displaces air in the substrate resulting in lower availability of root zone oxygen and can create favorable conditions for root rot-causing pathogens (Zheng et al., 2007). To reduce root pathogens, such as *Pythium*, growers may favor U1-HP as a growing substrate while U1 may be favored as it can reduce fertigation frequency.

Table 3. Response of vegetative- and flowering-stage growth attributes and yield (dry floral weight) to vegetative-stage growing substrates ABcann UNIMIX 1 HP (U1-HP), ABcann UNIMIX 1 (U1) and PRO-MIX MP ORGANIK MYCORRHIZAE (PM-V).

Substrate	Vegetative stage[a]		Flowering stage[b]		
	Growth index	Leaf number	Growth index	Branch number	Yield (g plant^{-1})
U1-HP	37±6.5 a[c]	34±4.3 a	565±58 a	15±0.7 a	40±4.7 a
U1	35±3.2 a	40±2.5 a	441±73 a	14±1.5 a	35±3.2 a
PMV	38±5.4 a	36±1.8 a	534±64 a	19±0.9 b	34±1.5 a

[a]Data are means ± SEM; *n*=5.

[b]Data are means ± SEM; *n*=6.

[c]Data followed by the same letter within the same column do not differ at *P*<0.05.

In all treatments, substrate EC remained relatively consistent over time during the vegetative stage (Figure 1); however, EC was lower in PMV than in U1 at 22 DAT. The coir-based substrates maintained similar substrate pH levels to each other (means of 6.3-6.9), these were higher than in PMV (means of 5.5-6.1). During the vegetative stage, plants under all treatments grew normally and without any symptoms of nutrient disorder. It is estimated that a substrate pH range of 5.5 to 6.9 may be satisfactory for container production of cannabis during the vegetative stage. Further research is required to determine the optimal pH range.

Flowering stage growing substrates

In the second trial, plants grew well in both U2-HP and U2 and there was no difference in growth between them; however, U2-HP delivered 29% higher yield (Table 4). As previously discussed, drier substrates, such as U2-HP can provide higher root zone oxygen and reduce the risk of root rot (Zheng et al., 2007). Since U2-HP delivered substantially higher yield than U2 and provides the benefits of a drier growing substrates, it is considered preferential for cannabis production during the flowering stage.

Table 4. Response of growth attributes and yield (dry floral weight) at harvest to flowering-stage growing substrates ABcann UNIMIX 2 HP (U2-HP) and ABcann UNIMIX 2 (U2).

Substrate	Flowering stage[a]		
	Growth index[b]	Branch number[b]	Yield[b] (g plant^{-1})
U2-HP	463±46.4	10±0.5	35±1.4
U2	389±53.5	10±0.2	27±1.7
Significance[c]	NS	NS	**

[a]Measurements were made directly before harvest, after 53 days in the flowering stage.

[b]Data are means±SEM; *n*=6 for U2-HP and *n*=5 for U2.

[c]NS,*, **, *** Nonsignificant, or significant at P<0.05, 0.01, and 0.0001, respectively.

During the flowering stage, plants under all treatments grew normally and without any symptoms of nutrient disorder. Substrate pH (Figure 1) was similar between U2-HP and U2 until 43 DAT when mean pH in U2-HP was 5.5 (SEM±0.21) compared to 6.4 (SEM±0.24) for U2. It is estimated that the substrate pH range measured in this trial of 5.5-7.3 may be satisfactory for container production of cannabis during the flowering stage; though, further research is required to determine the optimal pH range.

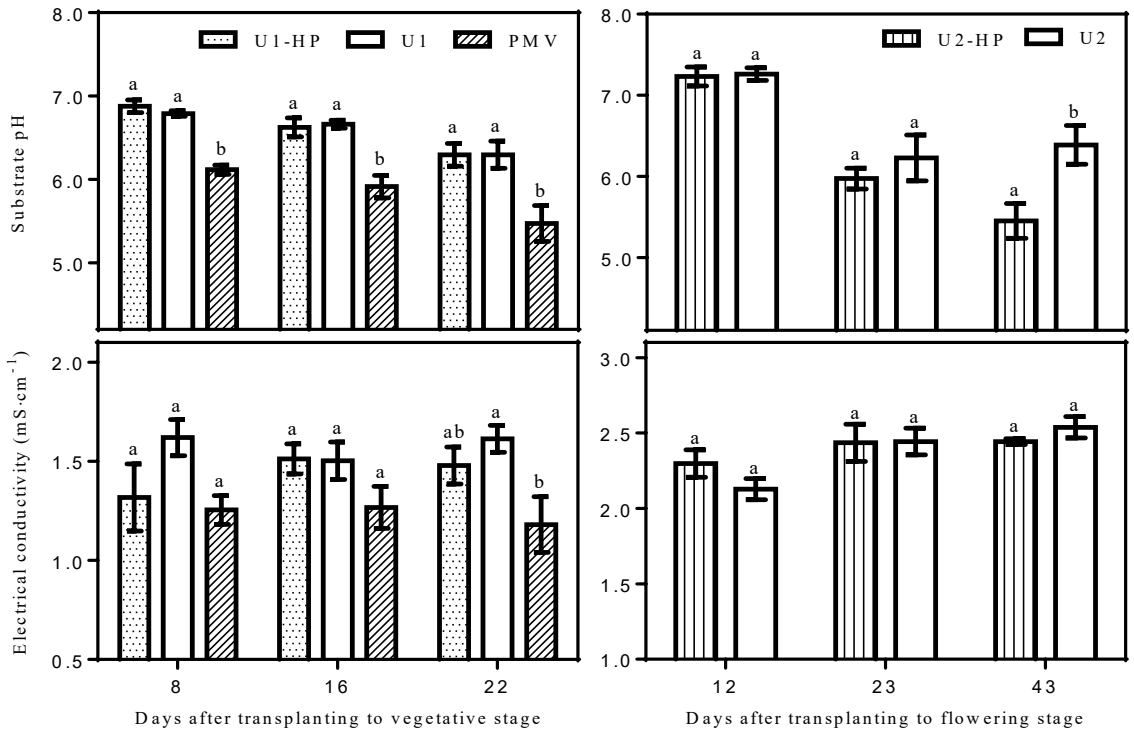

Figure 1. Growing substrate pH and electrical conductivity (EC) of different substrates during the vegetative stage (left) and during the flowering stage (right) of cannabis production. Data are means ± SEM (*n*=5 for vegetative-stage substrates; U1-HP, U1 and PMV and *n*=4 for flowering-stage substrates; U2-HP and U2). Bars followed by the same letter for each day do not differ at P<0.05. U1-HP = ABcann UNIMIX 1–HP, U1 = ABcann UNIMIX 1, PM-V = PRO-MIX MP ORGANIK MYCORRHIZAE, U2-HP = ABcann UNIMIX 2–HP and U2 = ABcann UNIMIX 2.

CONCLUSIONS

It was concluded that coir-based substrates (either U1-HP or U1) are effective for cannabis during the vegetative stage of production and that the two coir-based substrates are an effective alternative to organic peat-based substrates. Growers may favor U1-HP to reduce low oxygen-induced root pathogens, such as *Pythium* or U2 to reduce fertigation frequency. In the flowering stage, drier coir-based substrates such as U2-HP may be preferred for increased dry floral weight and for higher root zone oxygen availability.

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