MURRAY STATE UNIVERSITY

Journal of Agricultural Hemp Research

Volume 1 | Issue 2 Article 4

May 2020

A National Survey to Characterize Industrial Hemp (Cannabis sativa L.) Production Challenges Under Protected Cultivation

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Recommended Citation

Owen, William G. and Behe, Bridget (2020) "A National Survey to Characterize Industrial Hemp (Cannabis sativa L.) Production Challenges Under Protected Cultivation," *Journal of Agricultural Hemp Research*: Vol. 1 : Iss. 2 , Article 4.
Available at: https://digitalcommons.murraystate.edu/jahr/vol1/iss2/4

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Introduction

Since the recent legalization of industrial hemp (IH; *Cannabis sativa* L.) in the United States, cultivation and research of IH-fiber, grain, biomass, and to a greater extent, the non-intoxicating cannabidiol (CBD) compound has gained much attention. Traditionally, IH harvested for fiber, grain, and biomass is cultivated under outdoor field conditions where separation of dioecious plants and wind pollination is not a concern. Although plants for CBD extraction can be cultivated outdoors, to date, rouging of staminate plants is required; cross pollination is problematic; chemical control for weeds, pests, and diseases is limited; environmental conditions [light intensity, quality, and duration (photoperiod), temperature, air flow, and humidity] cannot be managed or controlled; and cultivation is limited to the growing season. Therefore, to mitigate these outdoor production challenges and to cultivate CBD-type hemp year-round, controlled environments such as greenhouses, shipping containers, buildings or warehouses can be used and are increasing in number.

Controlled environments are commonly used for floriculture and/or edible food crop production where crop-specific environmental and cultural parameters have been previously established (Nau 2011). To date, research efforts to identified stock plant, propagation, or growth management and production requirements for cultivation of CBD-type hemp under controlled environmental conditions is limited. Thus, the objectives of this survey were to identify current and future domestic grower challenges of CBD-type IH under controlled environmental conditions and to characterize current production practices as a benchmark for future research.

Materials and Methods

Survey development. An online IH survey was developed in Qualtrics (Provo, UT). The evaluation protocol and survey were approved by Michigan State University's institutional review board involving human subjects research (IRB STUDY00003413). In compliance with federal law, participants under 18 years of age were excluded. The survey was active from 8 Oct. to 8 Nov. 2019.

Survey. A series of 32 questions which had response formats including multiple choice, yes or no, free-form text entry, and Likert scale ratings. Survey questions with multiple choice answers in regards to units of measurement (i.e., area and concentration rate) were asked based on U.S. and S.I. units. In other instances, questions with multiple choice answers asked participants to check all that applied. Free-form text entry questions asked for specific information such as cultivar(s) and provided examples. Survey questions were grouped into seven categories to identify different production practices, challenges, and feedback. Question categories included: 1) current business attributes; 2) propagation supplies and procedures; 3) cultural practices (substrates, plant nutrition, water quality); 4) environmental management and manipulation (lighting and temperature); 5) challenges; 6) marketing practices; and 7) additional feedback.

The first block of questions defined IH and asked participants to indicate if they currently cultivate, were considering cultivating, or do not plan to cultivate IH. Participants were then asked to identify their current business model by selecting all that applied from a list of pre-determined cultivation systems or were allowed to specify. Additionally, participants were asked to indicate the months in which the business cultivated propagules, mother or stock plants, and crop for harvest, production area dedicated for IH, and cultivars grown. The second block of questions queried propagation methods, propagation plant material; and cultural and environmental practices to germinating seedling or rooting shoot-tip cuttings of IH. The third block of questions queried cultural practices such as fertility application, timing, and source; water source, irrigation systems, water quality monitoring; and substrate nutritional monitoring. The fourth block of questions asked participants to indicate lighting strategies, management, manipulation, and quantification; and temperature setpoints for cultivation. The fifth and sixth block of questions queried major production topics for cultivation challenges and marketing, respectively. The participant was asked to rate pre-determined topics and challenges by importance of addressing or removing them for successful IH cultivation. Respondents were asked to rate their answer on a Likert scale from 0 (not all important) to 100 (extremely important). The final block of questions included two free-form text entry fields that asked participants to provide the postal code(s) of their business and an opportunity to provide feedback.

We recruited potential subjects through a convenience sample, since no national listing of IH growers was available. We strived to publicize the survey broadly through a wide variety of trade publications, list servs, and email lists such as e-GRO.org, Hortidaily.com, and Floraldaily.com. Distribution efforts were state-wide through Michigan State University Extension, Michigan Department of Agriculture and Rural Development, and regional greenhouse and floriculture bulletins. Researchers strived to reach a broad potential number of respondents. Data were analyzed using SAS (version 9.4; SAS Institute, Cary, NC). Survey data presented represent means and/or frequencies.

Results and Discussion

Business. Of 310 surveys initiated and consented, only 43.2% of the respondents finished the survey, therefore analyses were conducted using the 134 complete responses. We queried participants on their current status of IH cultivation and determined that 65.7% (n = 88) grew IH, 29.1% (n = 39) were considering growing IH, and 5.2% (n = 7) were not considering growing IH (table 1). Further analyses presented here were conducted using only the responses of the 88 respondents that currently grew IH. Participants were asked to select all options that best described their business and 17% indicated their business to be *new, no previous experience in plant propagation or production*, 27.3% were *propagators*, 15.9% grow IH *indoors in shipping containers, buildings or warehouses*, 29.5% grow in *greenhouses*, 15.9% in *hoop houses or high tunnels*, and 62.5% grow *outdoor in-ground*. Furthermore, 12.5% were *floriculture* growers, 1.1% were *hydroponic food crop growers*, 27.3% were *processors*, 15.9% *breeders*, and 40.9% of the respondents described themselves as g*overnment, university, private consultant or other*.

Postal code(s) determined the geographic range of participants in the U.S.; 6.7% were located in the Northeast (CT, RI, VT, MD, and NY), 67% in the Midwest (IN and MI), 17.1% in the Southeast (AL, KY, NC, SC, TN, VA, and WV), 4.6% in the Southwest (CO), 1% in the West (CA), and 3.6% in the Northwest (OR and WA). More than half of the respondents were located in the Midwestern U.S. and was likely because in 2019, Michigan legalized the cultivation of IH under the 2018 Farm Bill along with 45 other U.S. states (Nepveux 2019). The result is also likely due to more prominent exposure to Michigan firms. However, the survey was disseminated nationally through e-GRO and internationally through secondary *e*-newsletters, thus potentially capturing a broader pool of participants. Without a reliable list of current producers, it is difficult to assess the reach of the sample.

Of those currently producing IH, 17% reported they were *new with no previous experience in plant propagation or production* (table 1). This presents a tremendous opportunity to Cooperative Extension personnel to provide production information to this never-before-producer population.

The magnitude of area dedicated to IH production under controlled environmental conditions, e.g. (greenhouse, hoop house, high tunnel, indoor production) varied; 16% dedicate < 999 ft^2 (< 92 m^2), 28.4% dedicate 1,000 – 9,999 ft^2 (93 – 928 m^2), 19.2% dedicate 10,000 – 99,999 ft^2 (929 – 9,289 m^2), 5.7% dedicate 100,000 ft^2 + (9,290 m^2 +), and 30.7% did not grow under controlled environmental conditions (table 1). For outdoor in-ground field production, 69.3% dedicated < 24 acres (< 9 hectares) to IH, and as acreage of dedicated production increased from 25 to 1,000+ acres (10 to 405+ hectares), responses generally decreased from a range of 4.6% to 2.3%, respectively. Much like commercial production of floriculture (USDA 2019) and vegetable crops (USDA 2020), the operation size varies widely. This size variation will dramatically influence economies of scale, affordable technologies, as well as labor requirements. Additionally, it may help formulate education and research programs and target outreach communications for both types of information.

Cultivators were asked to specify the cultivars of IH grown. Regardless of production system, 23 cultivars were specified of 124 entries while an additional 33 responses were either classified as new cultivars, proprietary, or other. The top five cultivars specified were: Cherry Wine (36.4%), BaOx (10.2%), Trump/T1 (10.2%), Wife/Wife II/The Wife/Trophy Wife (10.2%), and Sweetened/Sweeten/Sweet (8.0%; data not shown). There were 44 other cultivars that were classified as other (31.8%) and include cultivars that were either specified once or varietal crosses. This wide range of cultivars produced will present challenges for future research. As with many floral crops, the cultural responses (Latimer 2020; Owen 2019a; Owen 2019b; Whipker 2019) may vary widely. Researchers may need to include multiple varieties in any production experiments.

Controlled environment IH culture. We queried participants who indicated cultivation of IH under controlled environmental conditions (n = 39) to identify their production schedule or the month(s) in which the business grows IH (figure 1). Participants indicated propagation of seedlings, rooted cuttings, and/or tissue culture propagules occur from Jan. to May and ranged between 46.2% to 79.5%, respectively, and decreased onward to a range of 56.4% to 35.9%, respectively, from June to Dec. Production of mother or stock plants, e.g. shoot-tips are excised to produce unrooted vegetative cuttings, declined from a range of 66.7% to 46.2% from Jan. to Aug., respectively, and increased from 51.3% in Sept. to 66.7% in Dec. The production schedule of bulking stock plants for shoot-tip excision in spring months (Jan.–May) was consistent with ornamental stock plant production (Gibson 2006). Inverse to propagation, production and harvest occurred from Jan. to Sept. and ranged between 66.7% to 87.2%, respectively, but 84.6% of participants indicated that harvest continues into Oct. and declines onward. Understanding the timing of certain procedures will help researchers identify times of year when experiments should be conducted to obtain results readily applicable to producers.

Propagation and culture of young plant material. Of the respondents that identified as propagator (n = 24 of 88), 9.1% indicated that propagation material produced on-site was for the business only, 15.9% started plant material for the business and wholesale sales, and 1.1% (n = 1) were wholesale propagators and 1.1% (n = 1)did not produce plant material for the business or wholesale sales (table 2). Propagation of IH was most commonly started from feminized seed (58%) and vegetative unrooted shoot-tip cuttings (47.7%), but also from unfeminized seed

(28.4%) and tissue cultured propagules (5.7%). Breaking down the data further, for cultivators who propagated for their business, 27.3% and 20.5% used either feminized seed or vegetative unrooted shoot-tip cuttings, respectively (data not shown). Similarly, propagators who started plant material for the business and wholesale sales indicated 27.3% and 23.9% used either feminized seed or vegetative unrooted shoot-tip cuttings, respectively (data not shown). Nearly half of the respondents indicated that plant material was propagated in 72-cell trays (48.9%), 15.9% using 50-cell trays, and 35.2% used either 128-, 105-, 32-, or 18-cell trays or other sizes not mentioned (table 2) and 18.2% do not propagate (data not shown). Propagation substrate constituents and mixes varied and in general, peat moss (50%), perlite (30.7%), coconut coir (23.9%), field soil (13.6%), and vermiculite (10.2) were most used. To a lesser extent, other materials used included bark (3.4%), wood fiber (5.7%), and rockwool (8%) while 9.1% indicated hydroponic production. Nearly a quarter of the respondents indicated they used a commercially available blended propagation mix (23.9%) while 22.7% of the respondents specified other materials were used for propagation. This information helps researchers and extension personnel develop and report information that is readily applicable to current growers as well as conduct experiments to find better performing and potentially less expensive or more sustainable substrates.

IH culture. Participants were queried on culture and production practices of IH (table 3). Substrate constituents and mixes varied and in general, peat moss (40.9%), field soil (38.6%), perlite (28.4%), coconut coir (26.1%), and commercially available blended mixes (21.6%) were utilized. Consistent with propagation substrates, bark, wood fiber, and rockwool were less frequently utilized. Most (81.3%) of the respondents indicated they fertilized IH during young (57%) and mature (55.8%) growth stages, and at flowering (43%). Only 59.1% of respondents specified fertilizer type; 50% of the cultivators indicated using a synthetic commercial N–P–K fertilizer while 20.4% use natural fertilizers (e.g. manures, fish emulsion, or compost tea). Only 1.1% used homeowner fertilizers, 2.3% used a proprietary fertilizer, and 12.5% did not specify or selected other. Water source(s) varied but over half (n = 56) indicated irrigating with well water while 20.5%, 14.8%, 10.2%, and 4.5% used either municipal, pond, reverse osmosis/deionized, or reclaimed water sources. Interesting, 15.9% of the respondents selected other water sources and provided specifics such as rain or river water. In the National Nursery Survey (Hodges et al., 2015), 52.7% of nursery and greenhouse production irrigation water came from wells, 20.6% from city sources, 14.2% from natural surfaces, and 11.2% was recaptured. Over half (n = 50) of IH cultivators used intermittent drip irrigation (56.8%), but hand irrigation (47.7%), boom or overhead irrigation (14.8%), ebb and flood (6.8%) and other (17%) irrigation systems were utilized. Hodges et al (2015) reported nearly 70% of nursery growers used overhead irrigation while 50% reported using drip irrigation (multiple responses were permitted). So, while there was consistency between producers in this survey and a national nursery and greenhouse production survey, the application methods reflect the varying cultural practices used by the industry.

In-house nutritional monitoring of substrate pH and electrical conductivity (EC) and irrigation water pH, EC, and alkalinity allows cultivators to assess plant health and make management and corrective decisions (Owen, Henry, and Whipker 2018). Monitoring substrate pH and EC prior to seed sow or sticking of cuttings and throughout production of IH was indicated by 59.1% and 50% of cultivators, respectively. Of the respondents, 73.9%, 56.8%, and 63.6% monitored irrigation water pH, EC, and alkalinity, respectively. Owen (2019b) has shown that monitoring substrate metrics dramatically improves crop quality. For extension personnel, instruction on crop monitoring, especially for new growers, should be a part of the most basic programming.

Cultivators were asked to indicate types of light management (n = 88) utilized by the business to grow IH. Natural daylight (72.7%) was utilized the most and other lighting strategies were provided by high-pressure sodium lamps, high-intensity light-emitting diode arrays, metal halides among others. For electrical lighting, 38.6% and 37.5% of respondents indicated they deployed supplemental or photoperiodic lighting, respectively. Interestingly, almost a quarter (n = 23) did not know the method of lighting utilized, therefore, results suggest an opportunity to educate cultivators on electrical lighting strategies and management techniques during IH cultivation. Lighting research in floral crop production has improved crop quality by improving the type of desired growth [e.g. vegetative (Owen and Lopez 2017) versus flowering (Owen, Meng, and Lopez 2018)]. Growth manipulation using lighting could be tested on IH cultivars to discover the effects and whether there is sufficient return on investment to merit installation of incandescent, LED, or other forms of artificial light.

Production and economic challenges. We asked respondents to rate production (table 4) and economic (table 5) topics and challenges by importance using a 100-point Likert scale of 25 variables. Only 32% of the topics or challenges ranked an average ≥ 75 points and included: processing, drying, cultivar evaluations, harvesting and handling, environmental factors to increase yield, CBD oil enhancement via environmental management, insect pest management strategies., and disease management strategies. Almost half (42.8%) of the economic topics ranked an average ≥ 75 points and include: return on investment, access to information, and consumer perception. Only, return on investment was ≥ 80 points.

Post-production issues also ranked highly included drying, harvesting/handling, and processing. The production challenges provide insights for future research. Cultivar evaluation were the highest-ranking production need, followed by insect pest management strategies, disease management strategies, and fertilization. Part of the cultivar evaluation would include CBD oil production measures. Given the wide range of cultivars, multiple studies may be needed to provide adequate information to meet producer needs.

Conclusions

In this study, we established and determined the current cultivation practices of IH, identified knowledge gaps, and research priorities for the successful production and marketing of IH. In the future, a larger sample size of controlled environment IH cultivators to assess cultural and environmental production practices, economic management strategies, and research priorities is warranted. Clearly, there is a need to investigate a multitude of factors in order to provide producers with information to grow better crops. Since many respondents to the survey reported they had no prior experience producing IH, there are great opportunities not only for research but for extension or other instructional programming.

Acknowledgments

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References

Gibson, J.L. 2006. In Stock plant management, p. 31−38. In: Dole, J.M. and J.L. Gibson (eds.). Cutting propagation- A guide to propagating and producing floriculture crops. Ball Publishing, Batavia, IL.

Hodges, A.W., H. Khachatryan, C.R. Hall, and M.A. Palma. 2015. Production and marketing practices and trade flows of the United States Green Industry 2013. Southern Cooperative Series Bulletin #420, ISBN: 1-58161-420-9.

Latimer, J.G. 2020. Plant growth regulators for containerized herbaceous perennials. 10 Mar. 2020. https://www.fine-americas.com/wp-content/uploads/2019/01/Perennial_PGR_GUIDE_2020.pdf

Nepveux, M. 2019. Farm Bureau: USDA releases long-awaited industrial hemp regulations. 10 Mar. 2020. https://www.fb.org/market-intel/usda-releases-long-awaited-industrial-hemp-regulations

Nau, J. 2011. Ball redbook, 18th ed. Ball Publishing, W. Chicago, IL.

Owen, W.G. and R.G. Lopez. 2017. Geranium and purple fountain grass leaf pigmentation is influenced by end-of-production supplemental lighting with red and blue light-emitting diodes (LEDs). HortScience 52:236–244.

Owen, W.G., Q. Meng, and R.G. Lopez. 2018. Promotion of flowering from far red radiation depends on the photosynthetic daily light. HortScience 53:1–7

Owen, W.G., J. Henry, and B.E. Whipker. 2018. Fert, Dirt, and Squirt: Monitoring pH and EC of Greenhouse Crops. e-GRO Diagnostic Series, Raleigh, NC. p.106.

Owen, W.G. 2019a. Leaf tissue nutrient sufficiency ranges of four *Heuchera* cultivars by chronological age. HortScience 54:1751–1756.

Owen, W.G. 2019b. Response of *Calceolaria ×herbeohybrida* cultivars to substrate pH and susceptibility to iron deficiency. HortScience 54:2163–2168.

United States Department of Agriculture. 2019. Floriculture Crops 2018 Summary. 10 Mar. 2020. https://downloads.usda.library.cornell.edu/usda-esmis/files/0p0966899/rr1728124/76537c134/floran19.pdf

United States Department of Agriculture. 2020. Vegetables 2019 Summary. 10 Mar. 2020. https://downloads.usda.library.cornell.edu/usda-esmis/files/02870v86p/0r967m63g/sn00bf58x/vegean20.pdf

Whipker, B.E. 2019. Plant growth regulators for annuals. 10 Mar. 2020. https://www.fine-americas.com/wp-content/uploads/2019/01/Annuals_PGR_Guide_2019.pdf

Appendix

Table 1. Business Characteristics of Participants of An Internet Survey That Assessed the Current Status of Industrial Hemp Production in the United States

Descriptor	No. of respondents	Frequency (%)
Respondents (*n* = 134)		
Yes, we grow industrial hemp.	88	65.7
No, but we are considering growing industrial hemp.	39	29.1
No, and we are not considering growing industrial hemp.	7	5.2
Business category (*n* = 88, multiple responses possible)		
New, no previous experience in plant propagation or production.	15	17.0
Propagator (e.g., tissue culture, vegetative cuttings, or seedlings)	24	27.3
Indoor hemp grower (e.g., shipping container, building, and/or warehouse)	14	15.9
Greenhouse hemp grower	26	29.5
Hoop house/High tunnel hemp grower	14	15.9
Outdoor in-ground field hemp grower	55	62.5
Floriculture grower	11	12.5
Hydroponic food crops	1	1.1
Processor	24	27.3
Breeder	14	15.9
Government	1	1.1
University (e.g., research, teaching, and/or Extension)	6	6.8
Company	13	14.8
Private Consultant	7	8.0
Other	9	10.2
U.S. Geographic region (*n* = 88)		
Northeast	6	6.7
Midwest	59	67.0
Southeast	15	17.1

Southwest	4	4.6
West	1	1.0
Northwest	3	3.6
CE[z] production area (n = 88)		
Less than 500 ft^2 (46 m^2)	7	8.0
500–999 ft^2 (46–92 m^2)	7	8.0
1,000–4,999 ft^2 (93–464 m^2)	18	20.4
5,000–9,999 ft^2 (465–928 m^2)	7	8.0
10,000–19,999 ft^2 (929–1857 m^2)	5	5.7
20,000–29,999 ft^2 (1858–2786 m^2)	3	3.4
30,000–49,999 ft^2 (2787–4644 m^2)	2	2.3
50,000–99,999 ft^2 (4645–9289 m^2)	7	8.0
100,000 ft^2 or more (9,290 m^2 +)	5	5.7
Do no grow under CE	27	30.7
Field production area (n = 88)		
Less than 24 acres (< 9 hectares)	61	69.3
25–49 acres (10–19 hectares)	4	4.6
50–99 acres (20–39 hectares)	3	3.4
100–249 acres (40–100 hectares)	2	2.3
250–499 acres (101–201 hectares)	1	1.1
500–999 acres (202–404 hectares)	2	2.3
1,000 acres or more (405 hectares +)	2	2.3
Do not grow outdoor in-ground	13	14.8

[z] Controlled environment (CE)

Table 2. Current Status of Propagation and Culture of Young Industrial Hemp Plant Material in the United States Reported by Participants

Descriptors	No. of respondents	Frequency (%)
Propagation (*n* = 24 of 88)		
Business only	8	9.1
Business and wholesale sales	14	15.9
Wholesale only	1	1.1
Neither	1	1.1
Propagation plant material (*n* = 88, multiple responses possible)		
Unfeminized seed	25	28.4
Feminized seed	51	58.0
Vegetative unrooted shoot-tip cuttings	42	47.7
Tissue cultured propagules	5	5.7
Propagation tray cell-size (*n* = 88)		
18	8	9.1
32	4	4.5
50	14	15.9
72	43	48.9
105	1	1.1
128	8	9.1
Other	10	11.4
Propagation substrate and components (*n* = 88)		
Peat moss	44	50.0
Coconut coir	21	23.9
Bark	3	3.4
Wood fiber	5	5.7
Field mineral soil	12	13.6
Perlite	27	30.7
Vermiculite	9	10.2
Rockwool	7	8.0
Hydroponic	8	9.1

Commercial Mix	21	23.9
Other	20	22.7

Table 3. Current Status of Industrial Hemp Culture Under Controlled Environmental Conditions in the United States

Reported by Participants

Descriptors	No. of respondents	Frequency (%)
Propagation substrate and components (*n* = 88)		
Peat moss	36	40.9
Coconut coir	23	26.1
Bark	7	8.0
Wood fiber	11	12.5
Field mineral soil	34	38.6
Perlite	25	28.4
Vermiculite	11	12.5
Rockwool	3	3.4
Hydroponic	3	3.4
Commercial Mix	19	21.6
Other	15	17.0
Provide mineral nutrition (*n* = 70)		
Young plant stage	49	57.0
Mature plant stage	48	55.8
Flowering	37	43.0
Fertilizer type (*n* = 88)		
Synthetic commercial blend	44	50.0
Chicken manure	5	5.7
Cow manure	1	1.1
Fish emulsion	3	3.4
Compost tea	3	3.4
Organic	9	10.2
Calcium	4	4.5
Homeowner fertilizer	1	1.1
Proprietary	2	2.3
Other	11	12.5
Water source		

Well	56	63.6
Municipal	18	20.5
RO/DI[z]	10	10.2
Reclaimed water	4	4.5
Pond water	13	14.8
Other	13	15.9
Unknown	1	1.1
Prefer not to respond	1	1.1
Irrigation delivery system (*n* = 88)		
Hand irrigation	42	47.7
Ebb and Flood	6	6.8
Intermittent drip	50	56.8
Boom or overhead	13	14.8
Other	15	17.0
Monitor substrate pH/EC[y] (*n* = 88)		
Check prior to seed sow or cutting stick	52	59.0
Check throughout production	44	50.0
Monitor irrigation water (*n* = 88)		
pH	65	73.9
EC	50	56.8
Alkalinity	56	63.6
Light management strategy (*n* = 88)		
High-pressure sodium[x]	29	33.0
MH[w]	17	19.3
High-intensity LEDs[v]	24	27.3
Low-intensity LEDs	7	8.0
INC[u]	3	3.4
CFL[t]	9	10.2
Natural daylight	64	72.7
Blackout curtains	15	17.0
Other	7	8.0
Don't know	2	2.3
Method of electrical lighting (*n* = 88)		

Supplemental	34	38.6
Photoperiodic	33	37.5
Sole-source	16	18.2
Don't know	23	26.1
Prefer not to respond	11	12.5

[z] Reserved osmosis/deionized (RO/DI)

[y] Electrical conductivity (EC)

[x] High-pressure sodium lamp (HPS)

[w] Metal halide (MH)

[v] Light-emitting diode

[u] Incandescent lamp (INC)

[t] Compact fluorescent lamp (CFL)

Table 4. Relative Importance of 25 Production Topics and Challenges for Current Industrial Hemp Cultivators

Label	Grow Hemp? Yes	Order of Importance
Drying	88	1
Harvesting/Handling	86	2
Cultivar evaluations	85	3
Processing	85	4
CBD oil enhancement via environmental management	84	5
Insect pest management strategies	83	6
Best growing environment to increase yield	82	7
Disease management strategies	79	8
Fertilization	74	9
Labor	73	10
Weed management strategies	72	11
Irrigation management	71	12
Germination uniformity	70	13
Mother or stock plant management	70	14
Nutritional monitoring	68	15
Production schedules or recipes	67	16
Propagating unrooted cuttings	65	17
Nutrient disorders	65	18
Temperature management	61	19
Energy use & resource-use management	59	20
Substrates	56	21
Photoperiodic lighting	55	22
Supplemental lighting	51	23
Sole-source lighting	48	24
Carbon dioxide management	43	25

Table 5. Relative Importance of Economic Topics and Challenges for Current Industrial Hemp Cultivators

	Grow Hemp?
Label	**Yes**
Return on investment	90
Access to information	78
Cost of production	77
Finding buyers	77
Consumer perception	75
Consumer preference	73
Cost of new technology	71

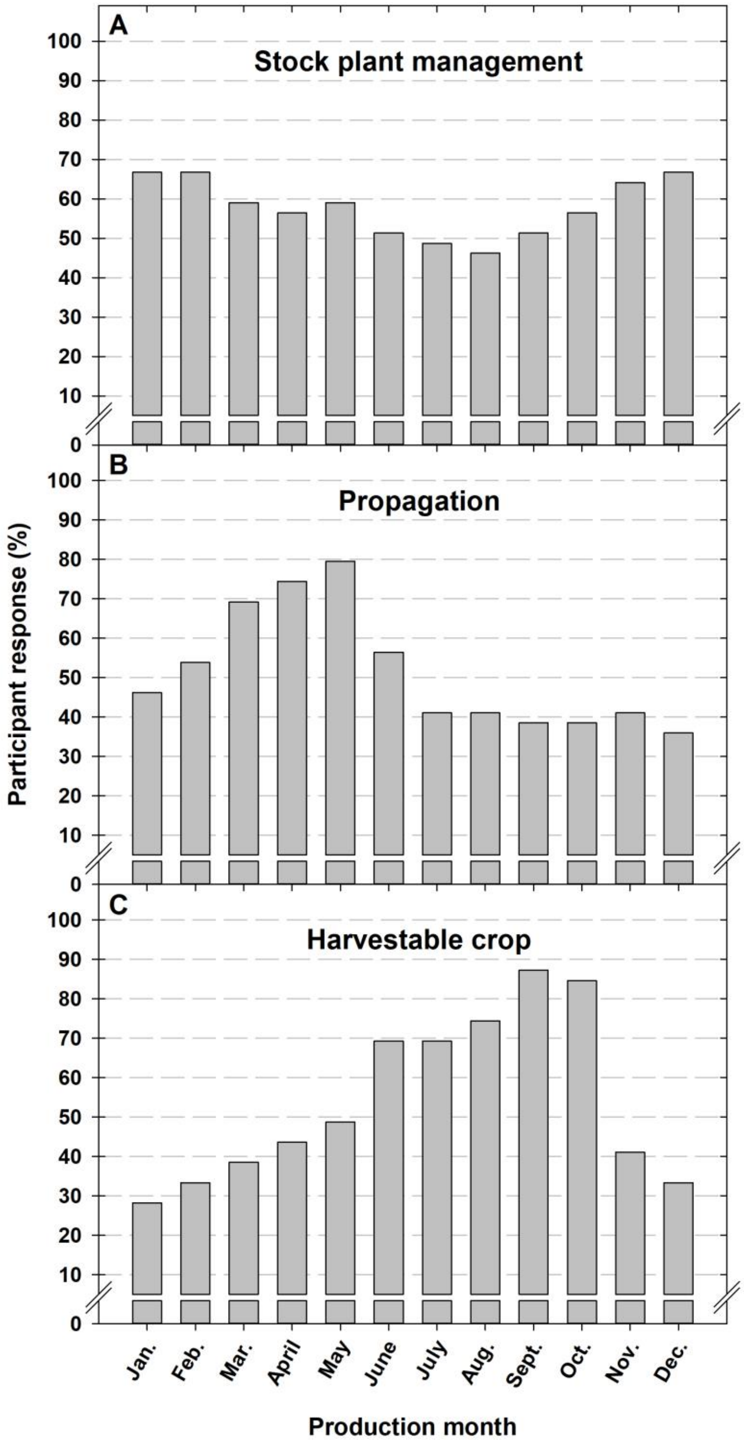

Figure 1. Controlled environment (CE) industrial hemp stock plant management (A), propagation (B), and harvestable crop (C) cultivation schedule indicated by participants (*n* = 39)