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Hemp (*Cannabis sativa* L.) research priorities: Opinions from United States hemp stakeholders

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Abstract

After over a half century hiatus from hemp production research, the crop is once again legal to grow in the United States. A nationwide survey of hemp stakeholders was conducted to determine priority areas for research. Respondents were asked to rate and rank areas of research relating to agronomics, economics, and genetics. Additional information was collected in education and outreach needs, regulatory concerns, and stakeholder demographics. Stakeholders suggested that hemp markets and economics, regulatory compliance, human nutritional quality and health properties, flower quality, and seed characteristics and considerations were the top priorities. Additional areas of research were considered extremely important by the majority of stakeholders: postharvest considerations, disease management, and plant breeding. Survey responses suggest the strong need for investment in this crop to make it economically viable for stakeholders. The information gained from the survey results will aid hemp researchers in defining their research priorities. Furthermore, survey findings can be used by funding entities to develop targeted grant programs to help support this reemerging crop.

KEYWORDS
Cannabis sativa, CBD, hemp, hemp research, survey, hemp education, industrial hemp

1 | INTRODUCTION

Hemp was an economically important crop for the United States during the first half of the 20th century (Wright, 1942). However heavy taxation, competing products, negative associations with migrant populations, and its eventual Schedule 1 assignment in the 1970s Controlled Substance Act, led to its demise (The Federal Comprehensive Drug Abuse Prevention & Control Act, 1970). The 2014 Farm Bill made it possible for states to establish pilot programs to grow hemp for research purposes (H.R.2642, 2014). The success of pilot programs led to the 2018 Farm Bill which legalized hemp production in the US, however, there remain outstanding

logistical and production issues surrounding implementation and regulation (H.R.2, 2018).

Depressed prices for traditional commodity crops, exacerbated by recent tariffs and extreme weather events, have caused serious economic distress for farmers, forcing many to consider alternative crops (Nigatu et al., 2020). Hemp has potential use in numerous industries including textile, construction, furniture, plastics, health, personal care, food and beverage, feed, and energy (Small & Marcus, 2002). The promise of hemp, with thousands of possible uses, potential suitability to numerous environments, and emerging, fast-growing new product markets, could be a welcome alternative (Schluttenhofer & Yuan, 2017).

Interest in hemp was evident by the nearly fivefold increase in licensed growers between 2018 and 2019 (Vote Hemp, 2019) and the 27% increase in licensed growers between 2019 and 2020 (Drotleff, 2020). In 2019, approximately 87% of hemp was grown for cannabidiol (CBD) production (Brightfield Group, 2019). CBD is one of more than 100 cannabinoids, including tetrahydrocannabinol (THC), that are found in the hemp plant (Aizpurua-Olaizola et al., 2016). Shown effective in treating epilepsy syndromes, specifically Lennox-Gastaut and Dravet syndromes (White, 2019) and Tuberous Sclerosis Complex (van der Poest Clement et al., 2020) it is also used to treat anxiety and pain. It is believed that other cannabinoids and secondary metabolites will possess health benefits which could provide more market opportunities for farmers (Jin et al., 2020). Moreover, with improved cultivars and production methods, and increased processing capacity, it is likely hemp used for industrial purposes (e.g., fiber and construction material), and grain-derived products (e.g., dehulled hemp seed and hemp seed oil) will increase (Fike, 2016; Rupasinghe et al., 2020; Xu et al., 2020).

Despite significant developments in the US hemp industry over the past 6 years, there are substantial gaps in knowledge and supply chains. In 2019, a grant was awarded by the USDA NIFA Supplemental and Alternative Crops Competitive grants program to plan, conduct, and report on a national research and extension conference. The purpose of the conference was to assess the needs of stakeholders and gather information about the research and private-public partnerships needed to support the development of a sustainable national industrial hemp industry. Another component of the grant was to identify hemp research and education priorities for the next several years. To accomplish this a survey was completed by stakeholders involved in developing a sustainable hemp industry.

2 | MATERIALS AND METHODS

2.1 | Survey design and development

The survey instrument was programmed in Qualtrics by the University of Wisconsin, Madison Survey Center. In compliance with federal law, respondents under 18 years of age were excluded.

Survey questions were developed by the National Hemp Research & Education Conference planning committee, with input from industry stakeholders. Survey respondents were asked 31 questions of varying types including yes/no, percentages, fill-in entry, Likert scale ratings, and multiple choice. Questions were grouped into the following categories: (1) Hemp/agriculture experience, (2) current challenges in the hemp industry, (3) areas of research importance, (4)

areas of market research need, (5) economic issues, (6) areas of additional research to inform hemp improvement and markets, and (7) prioritizing hemp research. Question content focused on the 2019 growing season. Research areas included in the survey are listed in Table 1. Respondents were asked

TABLE 1 Areas of research and examples that were presented to survey respondents

Research area	Examples
Planting considerations	such as crop rotation, no-till vs conventional tillage systems, transplanting vs direct seeding, mechanization
Fertility considerations	such as nutrient sources and application rates
Organic production systems	such as nutrient sources, weed management, pest management
Seed characteristics	such as germination, dormancy, shelf life or stability
Seed considerations	such as certified seed or clones, cost, quality of seed
Plant breeding	such as stable and uniform cultivars, sources of germplasm, regional adaptability
Seedling and vegetative plant growth	such as growth rate, vigor, plant architecture
Disease management	such as downy mildew, bud rot or botrytis, septoria, disease management tools
Insect management	such as flea beetles, thrips, hemp russet mite, eurasian hemp borer, pest management tools
Abiotic stress tolerance	such as frost, drought, pH
Reproductive growth	such as photoperiod, bud density, bud count
Plant harvestability	such as seed shattering, maturation, uniformity
Harvest considerations	such as assessing maturity, harvest equipment
Postharvest considerations	such as drying, storage, cannabinoid degradation
Flower quality	such as cannabinoids, terpenes, color
Grain quality	such as oil or protein, quantity or quality, taste
Fiber quality	such as bast or hurd, quantity or quality
Regulatory	such as THC limit of 0.3%, field and lab testing for THC and other cannabinoids, risk of THC accumulation, pollen flow, pesticide drift
Hemp markets and economics	such as contracting with processors, building supply chain infrastructure, banking, insurance

to provide demographic information including age, gender, education, and primary residence. Survey questions are listed in Table S1.

2.2 | Participant selection

Licensed hemp growers and/or processors in six states (Minnesota, New York, North Carolina, Oregon, Pennsylvania, and Tennessee) with publically available contact lists, were directly invited to participate in the survey. Additional hemp stakeholders in other states were invited to participate in the survey by hemp farmer and advocacy groups, hemp pilot program authorities, and university research and extension personnel. Survey respondents received an invitation email with a survey link followed by two additional emails. The survey opened on December 4th, 2019 and closed on January 24th, 2020. Surveys with greater than 50% of questions answered were kept for final analysis. Data were analyzed in SPSS and R and are presented as frequencies and/or averages.

3 | RESULTS

## 3.1 | Demographic information

A total of 1552 survey responses, including partially completed responses, were received. After filtering, a subset of 1124 responses were used for analysis. Survey respondents were 74% male, 21% female and 5% preferred not to answer. The primary residence of survey respondents was 75% rural, 14% suburban and 11% urban. Only 1% of respondents reported an education level of high school or less, while 11%

had a high school diploma, 23% had some college or technical school, 12% had an associate degree, 30% had a bachelor's degree, and 22% had an advanced degree. The average age of survey respondents was 50 years old but age ranged from 21 to 83.

## 3.2 | Hemp and agriculture experience

The majority, 58%, of survey respondents, had over 10 years of agricultural experience but 67% had only 1 year or less experience in hemp (Figure 1a,b). The majority, 66%, of survey respondents anticipated or realized hemp-based income from field grown hemp. Other sources of income reported was greenhouse grown hemp (8%), processing (8%), research (4%), breeding (2%), extension (2%) and additional supporting industries (4%). Additional supporting industries included equipment sales, financing, real estate, advocacy, seed and clone sales, testing, retail, consultants, greenhouse supplies, regulatory, quality control, brokers, and advertising. When broken down by hemp type and area, the majority of anticipated or realized hemp-based income came from growing for essential oils (62%), followed by processing for essential oils (19%), growing for grain (3%) and fiber (3%) and processing grain (1%) and fiber (1%).

Survey respondents grew hemp in 23 states. The states with the highest number of respondents included Kentucky ($n = 167$), Wisconsin ($n = 132$), Colorado ($n = 106$), Virginia ($n = 79$), North Carolina ($n = 67$), Tennessee ($n = 67$), Oregon ($n = 55$), and Vermont ($n = 39$; Figure 1c). The most common hemp cultivars grown by survey respondents were Cherry Wine ($n = 150$), Sweetened $n = (95)$, BaOx ($n = 84$), T1 ($n = 84$), Lifter ($n = 52$) and Cherry ($n = 51$; Figure 2).
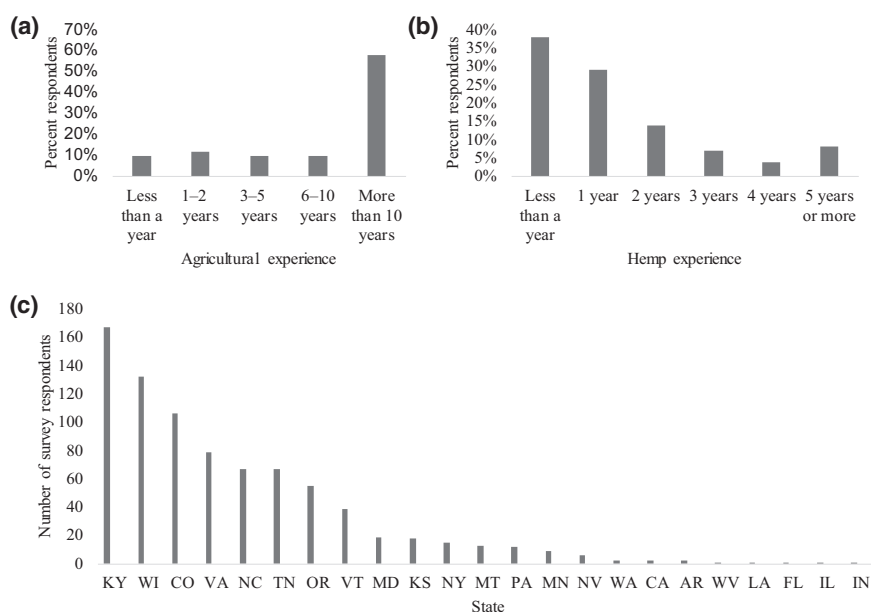

FIGURE 1 Hemp stakeholder growing experience shown in (a) number of years working in agriculture, (b) number of years working in hemp and (c) US state in which 2019 hemp crop was produced
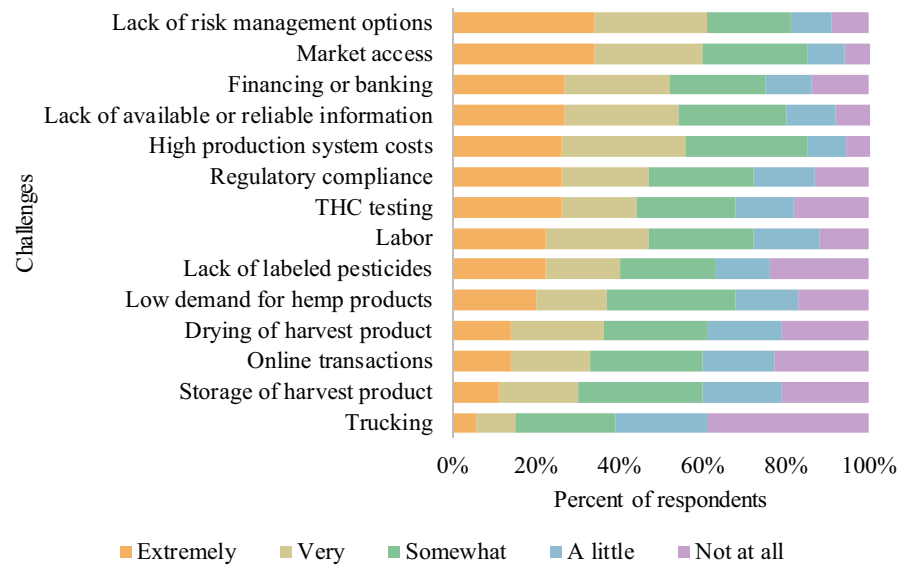
FIGURE 2 Most common hemp cultivars grown by survey respondents in 2019
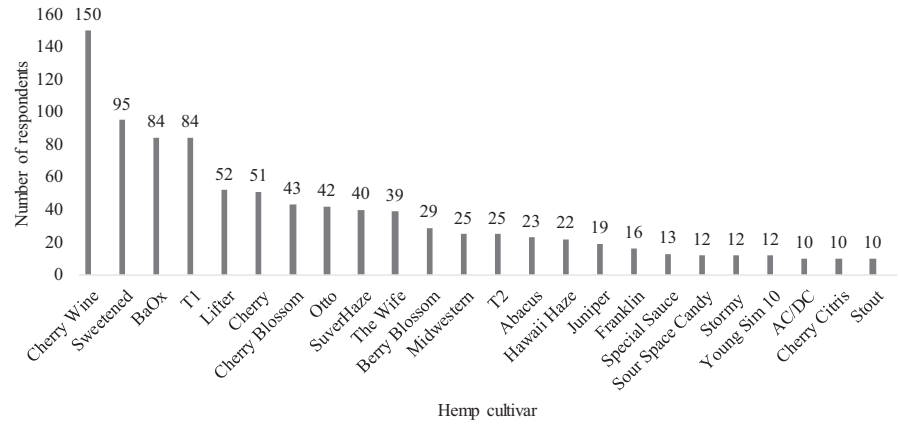
FIGURE 3 Survey responses to the question "Do you use the following sources to find educational information about hemp?"
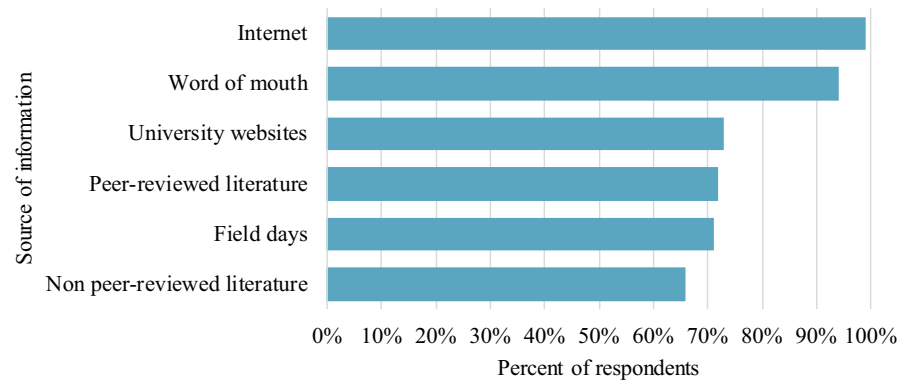
FIGURE 4 Survey responses to the question "Working in the hemp industry, how challenging are the following?"

The majority reported finding educational information about hemp from the internet (99%) and word of mouth (94%), followed by university websites (73%), peer-reviewed literature (72%), field days (71%) and non-previewed literature (66%; Figure 3). Additional reported sources of information came from personal experience, extension, hemp associations, the US government, consultants, books, radio, podcasts, TV, social media, advertising, newsletters, conferences, expos, and seminars.

3.3 | Current challenges in the hemp industry

Over half of the survey respondents found very or extremely challenging the lack of risk management options (61%), market access (60%), financing or banking (52%), lack of reliable and available information (54%), and high production costs (56%; Figure 4). Additional challenges noted included finding buyers, building trust, inconsistency in laws, weather,

lack of processors, unstable genetics, cross pollination, community education, theft, harvest, insurance availability, and organic certification.

3.4 | Areas of market research need and economic issues

Very or extremely important to respondents was market research on CBD (94%) and alternative cannabinoids (75%). Food products (65%), hempseed oil (57%), fiber products (54%), hemp biofuels (53%), hemp proteins (56%), and hemp animal feed (49%) were very or extremely important to approximately half of respondents (Figure 5). Additional suggestions for market research needs included textiles, THC, construction materials, bioremediation, bioplastics, health benefits, and public opinion.

The most important hemp production economic issues were seed or clone costs followed by labor, harvesting, and potency testing costs (Figure 6). Additional economic issues associated with production were financing and startup costs, insurance, legal fees, crop destruction, license and registration fees, specialized equipment, processing costs, transportation, and storage.

3.5 | Areas of research importance

Over half of all respondents designated postharvest considerations (50%), disease management (51%), plant breeding (52%), seed considerations (55%), flower quality (60%),

hemp markets and economics (69%), and regulatory issues (71%) to be extremely important areas of research (Figure 7).

3.6 | Areas of additional research to help inform hemp improvement and markets

More than 85% of hemp stakeholders believe additional research is needed to better understand the effects of hemp on human and animal nutritional quality and health properties (Figure 8). Specific human nutrition and health research requests include safety considerations, endocannabinoid system interactions and processing studies, dosing analysis, medical and health benefits, and long-term usage studies. Animal nutrition and health research requests also included feed nutritive quality assessment and a better understanding of cannabinoid transfer and impact on humans who consume hemp-fed or -treated animals.

More than 75% of respondents would like to see additional research in education and outreach (85%), consumer perceptions (83%), engineering, infrastructure, and equipment (84%), and genetic tools (79; Figure 8). Suggestions related to consumer perceptions and education and outreach efforts were similar and included clarity surrounding hemp versus drug-type cannabis misconceptions and confusion, medicinal and health benefits, and public and targeted (police, government, FDA) education and outreach. Also mentioned were regulation, safety, production and processing information for growers and manufacturers, environmental benefits and environmental sustainability concerns, and additional courses
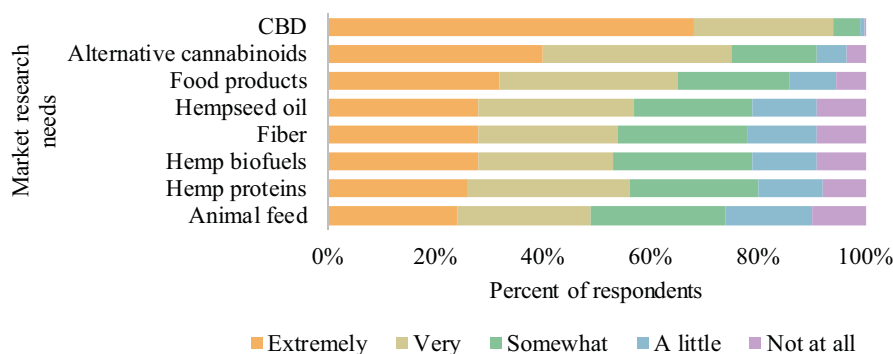
FIGURE 5 Survey responses to the question "How important are each of the following market research needs to the hemp industry?"
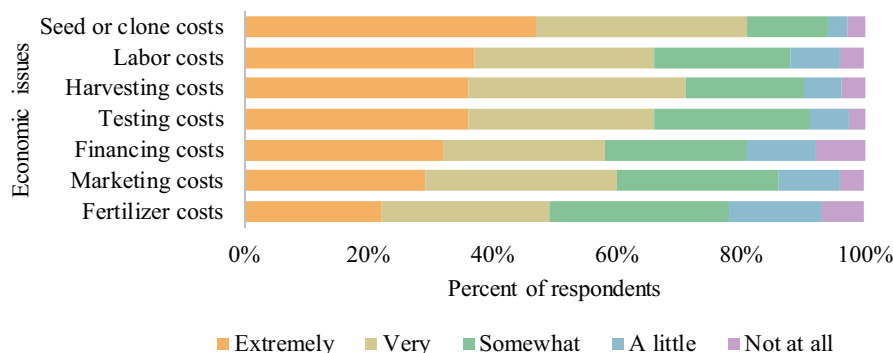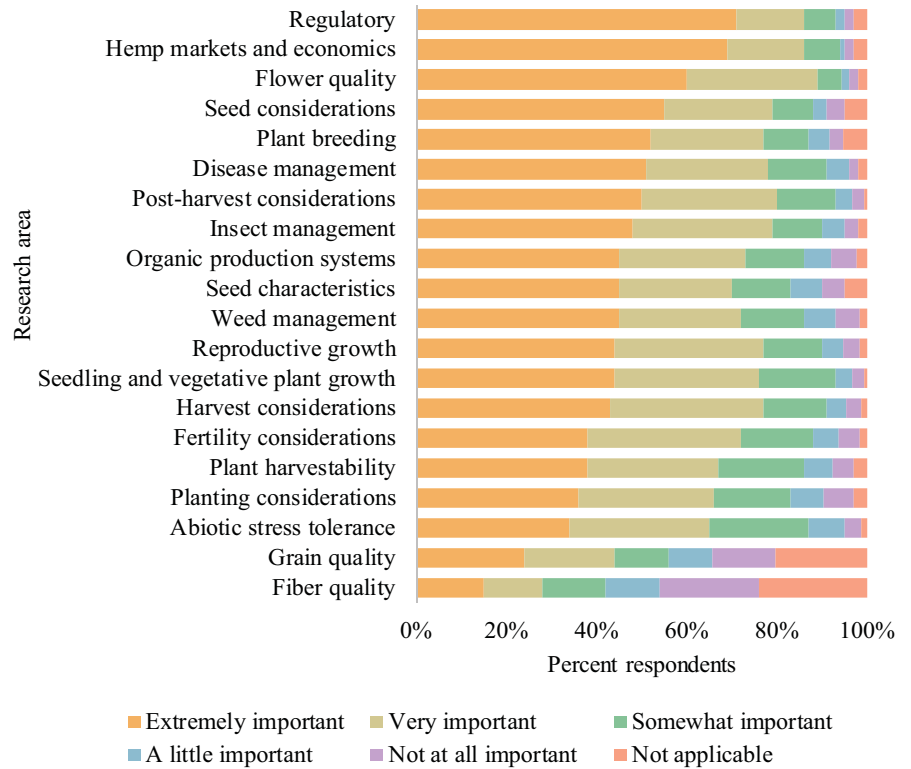
FIGURE 6 Survey responses to the question "How important are the following hemp production economic issues?"

FIGURE 7 Survey responses to the question "How important are each of the following areas of research to your work in the hemp industry?"

FIGURE 8 Survey responses to the question "Should additional research in this area be undertaken to inform future hemp improvements and markets?"
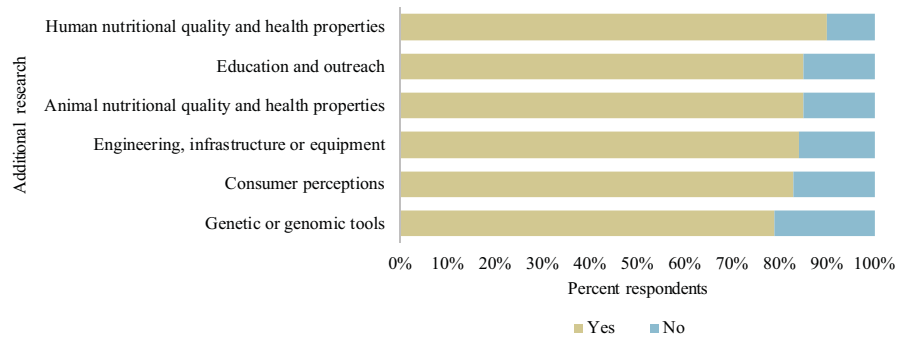
and training opportunities. Suggested research areas related to engineering, infrastructure, and equipment included increased productivity and efficiency especially related to harvest and postharvest. Also mentioned were standardization of techniques and procedures, better oversight, environmental impact studies, transparency and traceability, information and education accessibility, reduced labor and equipment cost, specialization and innovation, fiber processing, reduced harvest damage and loss, improved cannabinoid quantification, and options for small growers. Hemp stakeholders suggested additional research in genetic and genomic tools to improve CBD to THC ratios, maximize cannabinoid yields, increase stability and uniformity, understand genetic relatedness, genetically modification (both for and against), better seed production, improved pest resistance and regional adaptation, decreased costs and environmental impact, while also sharing concerns about large corporations controlling genetic resources.
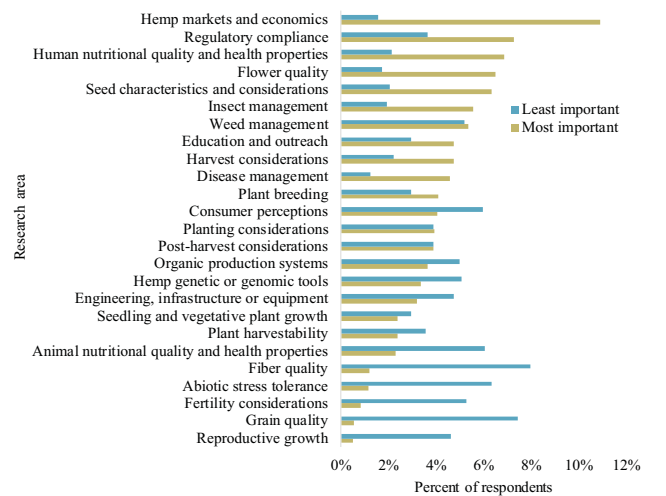
FIGURE 9 The frequency of each research area that was selected when respondents were asked "What are the five most and five least important areas of hemp research?"

Stakeholders were asked to select their five most important areas in need of research. The top five prioritized research categories were hemp markets and economics, regulatory compliance, human nutritional quality and health properties, flower quality, and seed characteristics and considerations (Figure 9).

4 | DISCUSSION

The goal of this survey was to assess the needs of stakeholders and gather their opinions of what research is necessary to advance the sustainable development of a national hemp industry. While almost every research category was deemed important amongst the majority of stakeholders, several areas appear to be of paramount significance. The highest priority research need is in economics and marketing of hemp. Similar results emphasizing economic concerns were observed in another recent hemp production survey (Owen & Behe, 2020). Stakeholders also found regulatory and policy issues a major concern with need for directed research. Despite the legal status of hemp, many of the important regulatory considerations are still uncertain. The 2018 Farm Bill directed USDA to establish a national regulatory framework for hemp production in the United States. USDA established the US Domestic Hemp Production Program through an Interim Final Rule (IFR). This rule outlines provisions for the USDA to approve plans submitted by States and Indian Tribes for the domestic production of hemp. The IFR was published on October 31st, 2019. Many in the hemp industry believe the guidelines in the IRF lack scientific support and are detrimental to the burgeoning hemp industry. Another regulatory concern to hemp stakeholders is the FDA's authority to regulate hemp derived products for food and drug use (Dabrowska & Johnson, 2019). Before food and beverages containing hemp essential oils are permitted, the FDA must consider issues, such as cumulative exposure risks and long-term effects, that require more research before issuing regulations. Similarly, studies regarding the safety and value of animals fed hemp products are needed.

Stakeholders want breeding and genetics research to produce stable and uniform cultivars and regional adaptability. This is directly related to seed characteristics and considerations such as germination rate, dormancy, shelf life, state certification, cost, and quality. Survey respondents also report need for research to better understand agronomic practices and production systems of hemp. Genetic improvement of cultivars and well vetted agronomic practices will have a direct effect on yield and production cost and therefore the return on investment for stakeholders. Finally, there is a substantial need for better and more accessible education and outreach across many groups including producers, processors, regulators, consumers, and law makers.

Hemp is once again a legal crop to grow and research in the United States, and there are many eager producers, processors, and stakeholders that would like to see it succeed. The results of this nationwide hemp research survey show there are many current bottlenecks in the US hemp industry. There are numerous research areas that will need collaboration across a multitude of hemp industry sectors to find the collective knowledge and experience needed to service this fledgling industry. Additionally, international collaborations, especially in countries that have been growing hemp legally for decades, will be needed to fill knowledge gaps and increase the potential for a global hemp economy.

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