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Industrial Hemp Knowledge and Interest among North Carolina Organic Farmers in the United States

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Abstract: Industrial hemp (*Cannabis sativa*), has been proposed as a new crop that might be of interest to organic farmers in the North Carolina and other states in the United States. However, little is known about how organic farmers view this crop. We conducted a survey among North Carolina certified organic growers to ascertain their knowledge of, and willingness to adopt, industrial hemp. Contact information was obtained from a database of certified organic farmers in North Carolina and the growers were contacted by email and directed to complete an online questionnaire. Growers were asked a wide range of questions about farm characteristics, technology adoption, interest toward industrial hemp, and policy issues regarding hemp adoption. A total of 245 farmers were contacted; 64 started the survey and 35 responded to all questions. Our results indicate that 85% of North Carolina organic growers are interested in growing hemp on their farms and the majority wanted to learn more about the crop production practices, adapted cultivars, and legality of growing it. Seventy-five percent expressed interest in being certified growers while 52% wanted to grow industrial hemp primarily for cannabidiol (CBD) oil. Most (65%) respondents indicate they aspired to be among the first farmers in their area to grow and sell hemp. Growers who have tried new crops or new farming technology in the last three years were more likely to adopt industrial hemp production. These findings will help decision-makers understand the critical concerns of growers who are willing to adopt industrial hemp as an alternative income-generating enterprise.

Keywords: *Cannabis sativa*; cannabidiol; CBD oil; hemp adoption; industrial hemp; North Carolina; organic farmers

1. Introduction

Industrial hemp (*Cannabis sativa* (L.)) is one of the oldest cultivated plants in the world and is native to central-northeast Asia where its cultivation dates as far back as 5000 years ago [1]. Hemp can be grown for use as a fiber, seed, or cannabidiol (CBD) oil. It has a vast number of possible applications and has been a source of fiber and oilseed used worldwide to produce a variety of industrial and consumer products including utilization in medical therapy [2]. Hemp has been produced throughout the history of global agriculture by more than 30 countries in Europe, Asia, and North and South America currently growing industrial hemp as an agricultural commodity [3]. Worldwide, industrial hemp cultivation has been limited because it can be easily confused with marijuana that usually contains higher amounts of delta-tetrahydrocannabinol (THC). Generally, all genotypes of hemp contain the psychotropic agent

THC, which causes a psychoactive effect when ingested by humans. *Cannabis* contains genetically different biotypes of both industrial (non-intoxicant) hemp and marijuana [4,5]. While industrial hemp and marijuana are the same plant (both varieties of *Cannabis sativa*), the legality is based on the amount of THC the plant produces. In the United States 2014 Farm Bill, the concentration of THC defines a *Cannabis* plant as either marijuana (>0.3% THC) or industrial hemp (<0.3% THC).

Although marijuana and hemp have completely distinct purpose and applications, the fact that they belong to the same plant species (*C. sativa*) has created a lot of ambiguity regarding its legalization in the United States. In 2014, Congress gave states permission through the farm bill to run test programs for growing and marketing industrial hemp. Since then, 41 states including North Carolina have passed legislation that allows hemp cultivation. In North Carolina, Senate Bill 313 legalized industrial hemp production but placed limitations on its production. Industrial hemp in North Carolina must be grown for research purposes and growers must apply for a license and pay an annual fee [6]. Since 2014, there has been increasing bipartisan support, which resulted in the United States Farm Bill Act of 2018 which legalized the production of industrial hemp and allows for it to be treated like any other agricultural commodity [7]. However, regulatory uncertainty still exists even though hemp has been removed from the Controlled Substances Act, (meaning it will no longer be an illegal substance under federal law). For instance, in all states where industrial hemp has been legalized, Congress explicitly preserved the Food and Drug Administration (FDA) current authority to regulate products containing *Cannabis* or *Cannabis*-derived compounds. In North Carolina, it is unlawful to introduce food containing added CBD into interstate commerce without first obtaining FDA approval. Many companies selling CBD products are marketing them as nutraceuticals to minimize FDA involvement since the FDA does not require the same safety evaluation for nutraceuticals as it does for drugs [8].

Canada is the only current commercial industrial hemp producer in North America [9] and the United States market has been largely dependent on imports (over 90%) from Canada [3,10]. The decreasing availability and rising prices of local wood fiber resources have greatly increased commercial interest in agricultural production of alternative fiber sources in the United States. Production of industrial hemp has been proposed as a viable source of substitute raw material for a wide range of industrial products including paper and composite wood products. There are numerous claims that this crop could transform the economy in a beneficial way given the growing recognition of the many uses for hemp beyond the traditional rope, cordage, and canvas. For example, in 2016, the Hemp Industries Association (HIA) reported a total retail sales of hemp products of nearly $700 million in the United States [11]. The legalization of hemp in the United States has the potential to increase production substantially; however, research on the crop has been very limited. Most researchers acknowledge the potential profitability of the crop and the potential challenges in hemp cultivation to organic growers.

The adoption of a new technology in agriculture is at the core of agricultural growth. Unfortunately, the adoption of new agricultural technology, including new crops, is seldom rapid. Researchers have been trying to understand and explain the behavioral patterns regarding adoption of a new technology. According to [12], there are five stages through which diffusion occurs (awareness, persuasion, decision, implementation, adoption) and five categories of adopters (innovators, early adopters, early majority, late majority, and laggards). Individuals do not just adopt new technology; instead, they make a conscious decision. This process is aided by five attributes of innovation (which helps decrease uncertainty about the innovation and increase the rate of adoption) and include: Relative advantage (the degree to which an innovation is perceived as better than previous ones); compatibility (the way an innovation is consistent with existing systems and values); complexity (the perceived difficulty of an innovation to understand or use); trialability (the potential to experiment with an innovation); and observability (visibility of results of an innovation) [12,13].

The number of certified organic farms in the United States increased by 11% in 2015–2016 and North Carolina was among the 10 top states for certified organic sales [14]. It is imperative to evaluate the perceptions and attitudes of North Carolina certified organic farmers to better understand the adoption of this new crop. Organic growers have been reported to have adoption behaviors that

distinguish them from conventional farmers. Previous studies have shown that organic farmers have a greater awareness and concern for environmental problems associated with agriculture, greater concern about long-term sustainability, and are prepared to incur present risk for future benefits or gain [15,16]. In addition, organic growers are willing to adopt new farming practices and take risk to try new technologies [15]. While organic producers may be willing to accept greater risk and adopt new technologies, they also are motivated by the potential for higher profit margins associated with organic products [17]. They are also more disposed to the risks associated with the adoption decisions they make, such as accepting reduced yields for future benefits [15]. These decisions have been reported to be positively correlated with environmental concerns [18–21]. Therefore, hemp could be an ideal crop for organic farmers not only because of associated value-added products and profit generation, but it is an incredible rotation crop that would improve soil health. Since its legalization in the United States, there is much to learn about growers' perspective to make industrial hemp a viable crop that can compete with other commodities and be adopted by growers. The objective of this study was to assess organic farmers' knowledge about hemp and the factors that might influence its adoption in North Carolina with particular focus on organic hemp production.

2. Materials and Methods

2.1. Sampling Population

The population for the study comprised of North Carolina certified organic farmers whose information was obtained from the USDA Organic Integrity Database in March of 2018. This database provides data on all certified organic farmers including the certifier, certification status, operation ID, crops certified, name, address, phone number, and email address. Through this database, a search was initiated for farmers in North Carolina. Data were downloaded, scrubbed for duplicate names, and 39 farmers in the database who did not provide an email address were contacted by phone to obtain a valid email address. Overall, a total of 245 organic farmers were emailed a link to an online questionnaire developed in Qualtrics; a quantitative online research tool and software that enables survey development, distribution, and analysis. The questionnaire was developed by the researchers based on the objectives of the study and consisted of five main sections: (1) Farm and farmer characteristics (type and size of farm, number of crops, number of years farming organically, age, and gender); (2) questions designed to determine if the respondent is an early adopter of agricultural technology; (3) motivation for farming organically; (4) interest in growing hemp; and (5) conditions that would influence farmer's willingness to adopt hemp such as pest issues, crop rotations, markets, the need for specialized equipment, and additional paperwork or legal requirements. The Institutional Review Board (IRB) of North Carolina Agricultural and Technical State University (NC A&T SU) approved this study. A weekly email reminder was sent to unfinished respondents during the course of the study (March to May 2018). Out of the 245 farmers contacted, 64 started the survey and 35 responded to all questions, giving a 55% completion rate (number of surveys fully completed divided by the number of surveys started). These were the responses used in the data analysis for this study.

2.2. Statistical Analyses

All statistical analyses were conducted using JMP® Version 14.0 Pro (SAS Institute, Cary, NC, United States). A combination of single and multiple regression analyses was used to determine how farmer and farm characteristics impacted innovativeness and willingness to adopt hemp. Optimal subsets of independent variables were obtained by using the SELECTION = STEPWISE (stepwise regression) option in PROC REG to explain how respondents' demographics and reasoning for farming organically impacted their openness to hemp adoption. These are algorithms that operate by successive addition or removal of significant or non-significant terms (forward selection and backward elimination, respectively). Selection of the best models was based on the reported Akaike information criterion (AIC). We also included a Bayesian information criterion (BIC) as additional model

testing tools [22]. Models with the smallest AICs and BICs were selected for further analysis [23–26]. Multicollinearity among variables was assessed using variation inflation factor (VIF) and if variation inflation factors were too high (>5), variables were not considered to have influence over the response variable. Farm type was not a discreet variable and therefore a correlation was used to evaluate any existing correlations among farm types. A principal component analysis (PCA) was used to identify common factors that account for most of the variations in the data and was performed by examining the pattern of correlations among independent variables (i.e., questionnaire statements). The PCA allows us to confirm our hypotheses and it also determines the eigenvectors which maximize the variance. Thereafter, it attains a second linear function PC2 that is uncorrelated with PC1. The attained variables are the principal components. A PCA with varimax rotation was carried out to reduce the number of variables which could potentially influence a respondent's answers [27]. PROC ANOVA in SAS was used to determine the importance of the five attributes of innovation to the sample population. Means were separated by least significant difference at the 0.05% level when ANOVA revealed significant ($P \leq 0.05$) differences among attributes. Descriptive statistics in MSO Excel 2016 (version 2016, Microsoft Corporation, Redmond, WA, United States) was used to calculate percentages.

3. Results

3.1. Farmer and Farm Characteristics

All survey respondents were certified organic farmers from North Carolina in the United States. The mean age of respondents was 53.4 years ± 2.2 SE (values ranged from 24 to 70 years) and the median age of 57 years. Nonetheless, the majority (40%) of survey respondents were between 60 to 69 years, 23% between 50 to 59 years, 17% between 40 to 49 years, and 13% between 30 to 39 years. Our findings are similar to the average age (53 years) of organic farm operators reported in the United States in 2012 [19]. A majority (68%) of respondents were male and 29% female and 3% provided no response. Our findings for women are similar to percentages reported [28] for organic farmers but more than the national average of 12.9% [29]. Most respondents (42%) had at least a two or four-year college degree, 39% had a high school diploma, and 16% had a graduate degree. A majority (65.7%) of the respondents operated farms >30 acres and reported gross incomes >$100,000. Fewer than 11.4% of the respondents operated farms <5 acres with $10,000 to $25,000 in income per year. Most (90%) of respondents own the land they farm on and a few (30%) rent a portion of the land. The majority of respondents (61%) indicated that their land has been certified for at least 1 to 5 years, 24% indicated for at least 6 to 10 years, and only 3% had land certified more than 15 years. On average, land was certified for six years. A majority (55%) of the farmers were involved in vegetable and grain production.

3.2. Factors Influencing Farmers' Willingness to Adopt Hemp

Survey participants were asked to indicate their level of agreement to the fact that they are open to trying hemp production on their farm. Without taking any other factors into consideration, 84.8% agreed or strongly agreed that they are open to trying hemp production on their farm. In addition, majority of survey respondents indicated their interest in learning more about industrial hemp production practices and adapter cultivars (87.9%); most agreed or strongly agreed they want to be one of the first farmers in their area to grow and sell hemp (65%). The majority of respondents (75%) indicated their interest in obtaining a certificate to grow hemp. Almost all (93%) respondents indicated that knowing there are markets for certified organic hemp seeds and hemp fiber would strongly influence their willingness to grow hemp and 91% indicated they are interested in learning more about hemp markets. More than half (52%) indicated they would grow industrial hemp primarily for CBD oil and 59.4% agreed that the ability to sell CBD oil positively influenced their willingness to grow the crop. Less than half (46.9%) agreed that the unclear legal regulations associated with industrial hemp production would negatively influence their willingness to grow the crop and 85% agreed or strongly agreed that they are interested in learning more about the legality of growing

hemp. Among the variables evaluated using stepwise multiple regression, 13 factors were extracted in the forward direction as those that influenced the innovativeness and willingness to adopt hemp. Of the 13 variables, inadequate knowledge and information about hemp emerged as the factors which negatively influenced the adoption of hemp to the large extent (Table 1). On the other hand, Bayesian information criterion (BIC) values showed the potential negative social attitude of the community towards hemp as the factor that would greatly impact adoption of hemp.

Table 1. Forward stepwise multiple regression of variable which influence willingness to hemp adoption. Akaike information criterion (AIC) and Bayesian information criterion (BIC) were used to select the best model.

Step	Parameter	*P*-Value	AIC	BIC
1	Interested in obtaining certificate to begin growing hemp on my farm	0.00	23.28	23.60
2	Interested in learning more about hemp production, practices and adapted cultivars	0.04	21.42	20.87
3	Age	0.11	22.15	20.01
4	I am usually not the first person in my area to try a new crop, tool or practice	0.03	20.27	15.57
5	Personal lack of knowledge and information about hemp	0.00	13.46	4.87
6	Not participate in the conventional agriculture system	0.04	14.31	−0.08
7	Previously grown in NC	0.07	18.54	−4.51
8	Knowing there are markets for certified organic hemp seed and hemp fiber	0.10	27.91	−8.36
9	Being one of the first farmers in my area to grow and sell hemp	0.04	39.69	−17.81
10	I am open to trying new or alternative crops, practices or technology on my farm	0.00	43.22	−51.51
11	Unclear legal regulations	0.00	86.13	−85.82
12	Cash crops typically farm	0.01	286.93	−122.25
13	Use less herbicide/pesticide	0.01		−180.96
14	Potential negative social attitudes of community towards crop	0.00		−374.24

Standard least square analysis of the output from Table 1 presented in Table 2, shows that overall, three factors significantly influenced openness to trying hemp cultivation. These are (i) interest in learning more about hemp production practices and adapted cultivars (likelihood ratio $X^2 = 12.99$; $P = 0.0003$), (ii) interest in obtaining a certificate to grow hemp (likelihood ratio $X^2 = 6.72$; $P = 0.0095$), and (iii) the unclear legal regulations associated with industrial hemp production (likelihood ratio $X^2 = 10.53$; $P = 0.0012$). Despite the unclear legal regulations, 84% of respondents agreed they are open to trying hemp on their farms. Table 2 also shows that personal lack of knowledge and information about hemp negatively affected respondent's willingness to grow the crop on their farms.

Table 2. Standard least square model for variables which influence willingness to hemp adoption.

Terms	Estimate	SE	*t*-Ratio	*P*	VIF
Intercept	0.36	0.90	0.39	0.6993	
Cash crops typically farm	0.00	0.00	−0.21	0.8334	2.44
Use less herbicide/pesticide	−0.01	0.12	−0.08	0.9374	3.58
Not participate in the conventional agriculture system	−0.10	0.12	−0.82	0.4247	4.46
I am open to trying new or alternative crops, practices or technology on my farm	−0.03	0.24	−0.14	0.8908	3.02
I am usually not the first person in my area to try a new crop, tool or practice	0.16	0.15	1.11	0.2892	1.72
Previously grown in NC	0.19	0.17	1.09	0.2945	1.88
Interested in learning more about hemp production, practices and adapted cultivars	0.54	0.20	2.77	0.0159	8.73
Interested in obtaining certificate to begin growing hemp on my farm	0.39	0.21	1.88	0.0829	13.32
Being one of the first farmers in my area to grow and sell hemp	−0.04	0.12	−0.31	0.7615	2.88
Knowing there are markets for certified organic hemp seed and hemp fiber	−0.21	0.18	−1.21	0.2474	3.09
Personal lack of knowledge and information about hemp	−0.29	0.20	−1.48	0.1616	5.05
Potential negative social attitudes of community towards crop	−0.11	0.17	−0.64	0.5348	2.08
Unclear legal regulations	0.35	0.14	2.44	0.0300	3.92
Age	0.001	0.01	0.13	0.8975	1.89

Table 3 shows a generalized linear model analysis on participants' willingness to try hemp cultivation on their farm. The same three factors reported in Table 2 significantly influenced openness to hemp cultivation. These are (i) interest in learning more about hemp production practices and adapted cultivars (likelihood ratio $X^2 = 12.99$; $P = 0.0003$), (ii) interest in obtaining a certificate to grow hemp (likelihood ratio $X^2 = 6.72$; $P = 0.0095$), and (iii) the unclear legal regulations (likelihood ratio $X^2 = 10.53$; $P = 0.0012$) (prior to the 2018 Farm Bill that legalized hemp production).

Table 3. Generalized linear model analysis for variables that influence openness to hemp production.

Terms	Estimate	L-R Chi Square	*t*-Ratio
Intercept	0.36	0.33	0.5634
Cash crops typically farm	0.00	0.10	0.7530
Use less herbicides/pesticides	−0.01	0.01	0.9065
Not participate in the conventional agriculture system	−0.10	1.43	0.2324
I am open to trying new or alternative crops, practices or technology on my farm	−0.03	0.04	0.8373
I am usually not the first person in my area to try a new crop, tool or practice	0.16	2.51	0.1129
Previously grown in NC	0.19	2.46	0.1169

Table 3. *Cont.*

Terms	Estimate	L-R Chi Square	*t*-Ratio
Interested in learning more about hemp production, practices and adapted cultivars	0.54	12.99	0.0003
Interested in obtaining certificate to begin growing hemp on my farm	0.39	6.72	0.0095
Being one of the first farmers in my area to grow and sell hemp	−0.04	0.21	0.6498
Knowing there are markets for certified organic hemp seed and hemp fiber	−0.21	2.99	0.0836
Personal lack of knowledge and information about hemp	−0.29	4.38	0.0363
Potential negative social attitudes of community towards crop	−0.11	0.86	0.3531
Unclear legal regulations	0.35	10.53	0.0012
Age	0.00	0.04	0.8472

3.3. Reasons for Farming Hemp Organically

Without considering the other factors, nearly all respondents (88.6%) agreed or strongly agreed that they farm organically to use less herbicides/pesticides; increase their income (88.6%); and not use genetically modified organisms (74.3%). Most respondents agreed or strongly agreed that other factors including receiving organic price premium (82.9%); improving soil health, water quality, and biodiversity (80%); and contribution to their community by using environmentally friendly practices (82.4%) contribute to the reason they farm organically. In addition, 79.4% agreed or strongly agreed that they farm organically to provide healthy food for their community (73.5%); for their family (73.4%) and to pass down values, land, and as a way of farming to future generations (78.9%). As described earlier, multiple regression analysis was used to examine relationships between respondents' reasoning for farming organically and their innovativeness and willingness to adopt hemp. The majority (68.1%) of survey respondents indicated that they farm organically because they want to improve soil health, water quality, and biodiversity, and 18.4% do so to use less herbicides/pesticides (Table 4). With regards to personal financial benefits, only 4.1% of survey respondents farm organically to increase their income and just 2.8% do so to receive organic price premiums. With regard to improving health, 0.7% of respondents farm organically to provide healthy food for their communities and 0.5% do so to contribute to the local food movement. The PCA shows that two factors (i) improve soil health, water quality, and biodiversity and (ii) use less herbicides/pesticides explained about 82% of the variation, suggesting they are the two most important factors considered by respondents to farm organically (Table 4).

Table 4. Eigenvalues, percentages of explained variance, and cumulative percentages of variance for farming organically.

Factors	Eigenvalues	Percent	Cumulative Percent
Improve soil health, water quality and biodiversity	7.1	64.1	64.1
Use less herbicides/pesticides	2.0	18.4	82.4
Not use GMOs	0.6	5.8	88.3
Increase my income	0.5	4.41	92.4
Receive organic price premium	0.3	2.8	95.1
Not participate in the conventional agriculture system	0.2	1.9	97.0

Table 4. *Cont.*

Factors	Eigenvalues	Percent	Cumulative Percent
Contribute to my community by using environmentally friendly practices	0.1	1.2	98.2
Provide healthy food for my community	0.1	0.7	98.9
Contribute to the local food movement	0.1	0.5	99.4
Provide healthy food for my family	0.0	0.4	99.8
Pass down values, land, and ways of farming to future generations	0.0	0.2	100

3.4. Likelihood to Adopt New Technology

Without taking any other factors into consideration, the majority (80%) of survey respondents indicated they have tried new crops or new farming technology in the last three years. In describing their farming practices, almost all respondents (76.5%) agreed or strongly agreed they rarely change their farming practices from year to year and all indicated they were looking for ways to improve their farms. Almost all respondents agreed or strongly agreed they were open to trying new or alternative crops, practices, or technology on their farms (97.1%); they were usually the first person in their area to try a new crop, cultivar, or farming practice (88.2%); that others farmers frequently asked them questions about their farming practices (88.2%). In addition, majority of respondents indicated they respond quickly to customer interested in new products (97.1%); and their farm size and income allows them to experiment with new crops and farming practices (79.4%); they are usually not reluctant to try new crops or farming practices (94.1%); and they would only try a new crop, farming practice, or technology if they see sufficient evidence that it worked (55%). Most (73.5%) agreed or strongly agreed that their production decisions were influenced by experts in the field such as extension educators and 87.8% did not wait to observe success from a new technology on other farms before adopting it on their own farm. Our results from the PCA (Table 5) identified three principal components that accounted for 57.1% of the variation implying these were the most important factors driving the likelihood of adopting a new technology. Figure 1 represents the factorial biplot defined by the two principal components 1 and 2 that explain 44.5% of the total variance. PC1 is the most important factor accounting for 28.8% of the variance distinguishing respondents according to those who have actually adopted or tried a new crop or new technology while PC2 accounted for 15.7%, which stipulates the enthusiasm toward adoption of new technology.

Table 5. Eigenvalues, percentages of explained variance, and cumulative percentages of variance for likelihood to adopt new technology.

Number	Eigen Values	Percent	Cumulative Percent
I have tried new crops or new farming practices in the last 3 years (New_crops)	3.7438	28.799	28.799
I am usually the first person in my area to try a new crop, cultivar or farming practice (First_person)	2.0412	15.702	44.500
Other farmers frequently ask me questions about my farming practices (Ask_question)	1.6361	12.586	57.086
I am usually reluctant to try new crops or farming practices (Reluctant)	1.2856	9.889	66.975

Table 5. *Cont.*

Number	Eigen Values	Percent	Cumulative Percent
I respond quickly to customer interest in new products (Respond_quickly)	0.9616	7.397	74.372
I am always looking for ways to improve my farm (Improve_farm)	0.7792	5.994	80.366
My farm size and income allows me to experiment with new crops and farming practices (Experiment)	0.7059	5.430	85.796
I rarely change my farming practices from year to year (Rarely_change)	0.5373	4.133	89.929
I like to wait and see if something works on other farms before adopting it on my farm (Wait)	0.3739	2.876	92.805
I am open to trying new or alternative crops, practices, or technologies on my farm (Open_newtechnology)	0.3627	2.790	95.595
If there is enough evidence of success for a new technology or crop, I will try it (Sufficient evidence)	0.2858	2.199	97.793
I am usually not the first person in my area to try a new crop, tool, or practice (Not_first)	0.1918	1.475	99.269
My production decisions are influenced by experts in the field such as extension educators (Influence_experts)	0.0951	0.731	100.000

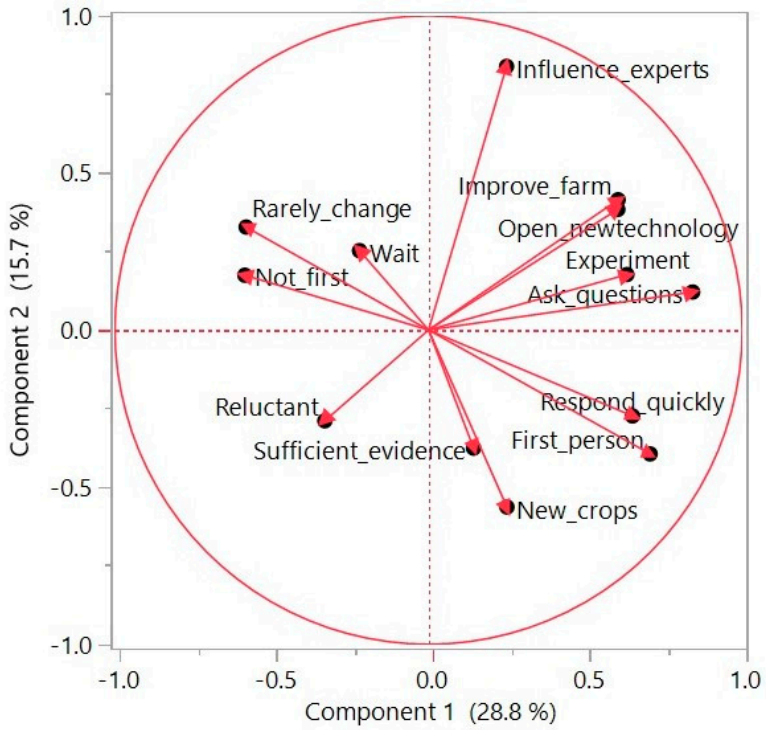

Figure 1. Principal component analysis (PCA) variables for innovative and willingness to adopt hemp parameters-projection of variables in the factor-plane, considering two factors.

3.5. Willingness to Adopt Hemp

Without taking any other factors into consideration majority of survey respondents indicated the following factors would positively or very positively affect their willingness to grow hemp. These include: knowing that their certifier would approve hemp as an organic crop (96.9%); has low insect pressure (93.8%); allows them to diversify their farm (93.8%); knowing there are markets for

certified organic hemp seed and hemp fiber (93.8%); fits into crop rotation (87.5%); competes well with weeds (84.4%); would allow them to reach new clients or markets (84.4%); ability to plant and or harvest hemp using existing equipment (71.9%); able to sell at restaurants, farmers markets, and wholesale (68.8%). About half of survey respondents indicated factors such as: lack of infrastructure in their area for processing fiber (58.1%); need to invest in new equipment for planting and harvesting (56.3%); had no effect to their willingness to grow hemp. A single regression equation was built to determine how the level of innovation for each farmer influenced their willingness to adopt hemp. Age and local food showed an inverse relationship as shown in Table 6. This implies that as age increases willingness to adopt hemp decreases. Also, when survey respondents farm organically because they want to contribute their produce to local food movement, their willingness to adopt hemp decreases. This might be because of the huge gaps in knowledge and infrastructure required for the crop and they are therefore not ready to venture into the unknown.

Table 6. Impact of demographics and openness to hemp adoption.

Factors	Estimate	SE	*t*-Ratio	*P*	VIF
Intercept	1.80	0.67	2.70	0.0127	
Education	0.34	0.10	3.32	0.0030	1.05
Age	−0.02	0.01	−2.48	0.0208	1.05
Increase my income	0.34	0.14	2.37	0.0264	1.14
Contribute to the local food movement	−0.47	0.17	−2.86	0.0089	2.56
Pass down values, land, and ways of farming to future generations	0.44	0.19	2.39	0.0255	2.50

3.6. Knowledge of Hemp

Six questions (answered as either true or false or unsure) were asked to determine each farmer's knowledge of hemp. The responses indicate that 93.8% of survey respondents indicated correctly that hemp can be grown for research purposes in some states however, when asked if hemp was a perennial crop, only 18.1% answered correctly, 15% of the population were unsure, and 66.7% answered incorrectly. When asked if hemp was previously grown in North Carolina, half the population (55%) answered correctly and 36.4% were unsure; however, 81% knew hemp is grown in Canada and Europe and only 18.8% were unsure. Ninety-four percent of respondents answered correctly that hemp can be grown for fiber and/or grain but no respondent answered correctly as to whether hemp contains large amounts of THC, the psychoactive chemical in marijuana, and 87.9% indicated it is false. Binary grading was conducted with the six questions where the correct answers were assigned a value of 1, while incorrect answers or those that answered unsure were given a 0. All answers were summed, calculating a single score for each farmer representing their knowledge of hemp (higher scores representing more knowledge). A single regression analysis was then used to determine how hemp knowledge impacted respondents' openness to hemp. Table 7 shows that most respondents did not know hemp is a perennial crop. Several factors that could positively or negatively impact openness to hemp are shown in Table 7. Openness to hemp decreases among respondents who know that hemp contains large amounts of THC, the psychoactive chemical that are present in high concentrations in marijuana (maybe because of the social stigma associated with the cannabis crop). There was a decrease in openness to hemp among survey respondents who were aware that hemp can be grown for fiber and seed. This is most likely because the majority of survey respondents were interested in growing hemp mainly for CBD oil. On an economic scale, the CBD oil brings the highest value of the crop's components. Openness to hemp decreases among respondents who know that it is also grown in Canada and Europe (may be due to market competition issues).

Table 7. Multiple regression in the forward direction of previous knowledge on openness to hemp adoption.

Terms	Estimate	SE	*t*-Ratio	*P*	VIF
Intercept	2.58	1.15	2.25	0.0339	
Hemp previously grown in several states in NC	0.17	0.31	0.57	0.5772	1.35
Hemp is grown in Canada and Europe	−0.75	0.45	−1.70	0.1030	1.57
Is a perennial crop	1.68	0.61	2.75	0.0111	2.96
Contain large amounts of THC	−1.88	0.92	−2.05	0.0518	4.32
Can be grown for research	1.00	0.62	1.62	0.1193	1.35
Can be grown for fiber and grain	−1.38	0.98	−1.40	0.1738	3.41

3.7. Five Attributes of Innovation as Perceived to Apply to Hemp

For each respondent, a score for the five attributes of innovation was calculated. The survey contained a set of 20 questions regarding aspects of hemp production that correlated with these attributes and included: (i) Relative advantage (diversify farm, knowing there are markets for certified organic hemp seed and hemp fiber, competes well with weeds, has low insect pressure, can reach new clients or markets, and ability to sell CBD) oil; (ii) compatibility (fits into current rotation, knowing certifier would approve hemp as an organic crop, is able to sell at restaurants, farmers markets, and wholesale, and ability to plant and or harvest hemp using existing equipment); (iii) observability (being one of the first farmers in my area to grow and sell hemp, potential negative social attitudes of community toward crop, could negatively impact ones reputation); (iv) trialability (small number of markets to sell products, personal lack of knowledge and information about hemp, extension educators are knowledgeable about growing hemp); and (vi) complexity (having to send tissue samples to the state chemist each year to be tested for THC, seed only available from international seed companies, lack of infrastructure for processing fiber, need to invest in new equipment for planting and harvesting, and unclear legal regulations). Answers for all questions that corresponded with each attribute were averaged thus assigning each respondent a score for each attribute. A cumulative score was averaged for each attribute to determine how the surveyed population valued each attribute of innovation.

There was significant difference among the five attributes with complexity and trialability being the most important attributes of innovation of hemp production (Table 8). This includes factors of concern to respondents such as personal lack of knowledge and information about hemp, the fact that tissue samples have to be tested for THC, seeds can only be obtained from international seed companies, the lack of infrastructure for processing fiber, the need to invest in new equipment for planting and harvesting, and unclear legal regulations. Relative advantage and compatibility were the least valued attributes of innovation to hemp production. This included factors that would provide additional benefit to the respondents such as the fact that hemp allows grower to diversify their farm production, it fits into current crop rotation, and knowing that the crop is able to sell at restaurants, farmers markets, and wholesale; furthermore, the ability to plant and/or harvest hemp using existing equipment and knowing that the certifier would approve hemp as an organic crop; as well as knowing that there are markets for certified organic hemp seed and hemp fiber, its ability to compete well with weeds coupled with low insect pressure, and ability to sell CBD oil.

Table 8. Mean (±SE) of five attributes of innovation as perceived to apply to hemp.

Attributes	Means ± SE
Compatibility	1.84 ± 0.10c
Observability	2.77 ± 0.09b
Complexity	3.38 ± 0.13a
Relative advantage	1.66 ± 0.08c
Trialability	3.03 ± 0.12ab
F	52.3
P	<0.000
df	4, 155

Means within a column followed by the same letter are not significantly different at $P \leq 0.05$.

4. Discussion

In the United States, industrial hemp production is controlled under drug enforcement laws. To grow industrial hemp in the United States, the farmer must obtain a permit from the Drug Enforcement Agency (DEA). Despite this regulation at the time the survey was administered (pre-legalization to grow industrial hemp in the United States, Farm Bill Act, 2018), there was a high likelihood that industrial hemp would be adopted by North Carolina organic farmers. To the best of our knowledge, this is the first study in North Carolina to ascertain knowledge and willingness of organic growers regarding industrial hemp. The majority of organic farmers in this study indicated several factors that influenced their decision to grow organically; these reasons are in alignment with several other studies which have also concluded that growers adopt organic farming because they want to increase their income [15,17,19,30–33]; reduce herbicide/pesticide use [34]; improve soil health, water quality, and biodiversity and as a lifestyle [17,35,36]; provide healthy food for their community and for their family [37,38]; and contribute to their community by using environmentally friendly practices [19].

Our survey shows that organic farmers who have tried new crops or new farming technology in the last three years are more likely to adopt hemp. These highly innovative individual (innovators) are likely to be imitated by a larger group of people (early adopters) who would adopt only when they are certain of the innovation's potential benefits. Early adopters tend to have greater knowledge about the benefits of a technology and are usually committed to sharing crop know-how with others [39]. On the other hand, late adopters wait to obtain information from early adopters [40]. However, while most growers are willing to share information and learn from other growers a valuable crop such as hemp may cause farmers to keep innovation information closely guarded to maintain a competitive advantage. Our results show that over 50% of respondents would try a new crop, farming practice, or technology if they see sufficient evidence that it worked somewhere. If we assume that farmers who are willing to adopt technologies early will be lead farmers, then our findings will suggest that organic growers in North Carolina will be willing to adopt hemps if they find out that there are some farmers already growing it.

The decision to adopt, or not to adopt, is influenced by the knowledge and perception of the potential adopter towards the innovation. Farmers can have knowledge about the existence of a new technology, how to apply it, and what the outcomes are in terms of products, yield, potential environmental benefits, risks, and costs. This information then forms the basis of the perceptions and attitudes these individuals develop towards the technology. Therefore, a positive attitude towards an agricultural innovation will increase the likelihood of adoption and a negative attitude will reduce the probability of adoption. We have demonstrated in this study that organic growers in North Carolina were concerned about personal lack of knowledge and information about hemp (lack knowledge that hemp is a perennial crop, hemp contains large amount of THC, etc.) and indicated this would negatively affect their willingness to grow the crop on their farms. Similarly, smallholder farmers in western Tanzania indicated that the main obstacle influencing adoption of improved fallow practices

was lack of awareness or poor knowledge [41]. Innovations that can be tried on a small scale prior to full implementation are more likely to be adopted. Our results show the existence of a gap in knowledge on hemp and the need for extension services to disseminate the necessary information to farmers and set up demonstration plots in North Carolina and elsewhere. There is enthusiasm to acquire knowledge regarding industrial hemp as 87.9% of survey respondents indicated their interest in learning more about hemp production practices and adapted cultivars. In addition, 75% of respondents are interested in obtaining a certificate to begin hemp cultivation. The lack of knowledge for this crop is very concerning. For example, growers need to know simple information such as the fact that while seed and fiber hemp plants can be grown close together and harvested with most traditional equipment, CBD-producing plants, much like their THC-producing cousins, have to be planted at wider intervals and have to be harvested by hand. The role of extension in training is crucial in the development of knowledge, perceptions, and attitudes about agricultural innovations.

Generally, innovations that offer more relative advantage, compatibility, simplicity, trialability, and observability will be adopted faster than other innovations [12] The relative advantage and observability of an innovation represents the immediate and long-term economic benefits from using it, whereas compatibility, complexity, and trialability are indicators of the ease with which a potential adopter can learn about and use an innovation [42]. Complexity and trialability were the most important attributes of innovation of hemp production from this study. Several other factors, including the fact that tissue samples have to be tested for THC, (the principal intoxicant cannabinoid), seeds can only be obtained from international seed companies, the lack of infrastructure for processing fiber, the need to invest in new equipment for planting and harvesting, and unclear legal regulations were some of the issues growers wanted addressed before adoption. Relative advantage, compatibility, observability, and trialability were factors that significantly affected adoption of integrated pest management (IPM) practices [43]. One study found that additional beneficial IPM practices such as economic profitability, decreasing production cost, and effort saving would greatly influence farmers' decision to adopt technology [44]. Relative advantage was the most significant factor affecting adoption of alfalfa (lucerne) into a pastoral management system [45]; as with the adoption of new legumes [46,47]; and the adoption of conservation practices [48,49]. Support programs that are based on yield tended to increase the relative advantage of the intensification of farming and thus increase adoption and use of herbicides [50,51]. In the United States, farmers have rapidly adopted genetically modified crops since their introduction in the mid-1990s as a result of the numerous benefits (including higher yields, lower costs as a result of reduced pesticide use, and ease of management) it provides to growers [52].

Industrial hemp production in North Carolina is not straightforward and involves a series of steps that include applying and obtaining a North Carolina grower license to start. Industrial hemp growers are required to work with university researchers and are compelled to report their data, information, and results to the institution. The law requires the research program consist primarily of demonstration plots planted and cultivated by select growers. However, farmers are encouraged to make comparisons between varieties, practices, planting dates, harvest dates, or other variables. The potential negative social attitude of the community towards hemp is likely to have a slowing of industrial hemp adoption. This stems mainly from the stigma of producing cannabis, which is different from industrial hemp. Organic growers are justified in being reluctant to adopt hemp because hemp has historically been given negative publicity and therefore production was banned in Western world in the early 20th century because most biotypes had high THC [53]. Although hemp is the main source of THC, there are many other important attributes of hemp. In Central Asia, where this herbaceous plant originated, hemp has been used in folk medicine and as a source of textile fiber since the dawn of times and as a fast-growing plant it has recently seen a resurgence of interest because of its multi-purpose applications including high levels of phytochemicals and a rich source of both cellulosic and woody fibers. Hemp is used extensively in pharmaceuticals and in the construction sector, since its metabolites show potent bioactivities in human health. Its outer and inner stem tissues can be used to make bioplastics and concrete-like material [53].

From our study, younger farmers may be more willing to adopt hemp. This supports several other studies which have concluded that older farmers are less likely to be early innovation adopters than younger farmers [21,54,55]. Adoption of the crop by the younger farmers may be attributed to the fact that young farmers may be interested in capitalizing on the booming consumer demand for local and sustainable food and are more likely to grow organically. It could also be that young farmers are more educated and willing to learn compared to older farmers. Education is a factor that has a bearing on adoption of agricultural technologies. Some technologies are more knowledge-intensive than others. Farmers with higher education have better access to information that is beneficial to farming operation. They also tend to possess higher analytic comprehension of the information necessary to successfully implement new technology. In this study, the number of years of formal education appears to have no influence on the willingness regarding adoption of hemp production. Almost all respondents had at least a high school diploma. In other studies, involving the adoption of legume cover crop [56] and fertilizer and hybrid seeds by maize growers [57], a positive association was reported between education and age. Another study by [58] found education to have a negative influence on adoption of tree-based fodder technologies. Education was reported to be negatively correlated with adoption of conservation tillage for farmers in Wisconsin in the United States [59].

Hemp is traditionally grown for either seed or fiber. The seeds contain approximately 30% protein, 25% starch, and 30% oil [60,61]. Opportunities for hemp production have increased with the recognition that the crop can be grown for different uses not only for fibers, but also for the seed and oils. From our study of organic growers in North Carolina, 52% of the growers indicated they would grow industrial hemp primarily for CBD oil and 59.4% agreed that the ability to sell CBD oil positively influenced their willingness to grow the crop. The presence of well-established markets for crops and produce grown by farmer would contribute to decreasing the uncertainty and risk [62]. The global industrial hemp market size is estimated to be 10.6 billion in 2025. Total sales for the United States hemp industry in 2017 were $820 million and this was boosted by explosive growth in the hemp-derived CBD oil. Given the presence of a market for the crop, it is not surprising that from our study, respondents indicated that the willingness to grow industrial hemp was influenced by the presence of ready markets for certified organic hemp seeds and fiber. The industry is experiencing this growth as a result of increasing consumer awareness pertaining to benefits associated with hemp products. Growth of industrial hemp is expected to escalate even more in the light of the recent legalization nationwide of the 2018 Farm Bill. Growing hemp primarily for CBD oil could be a reflection of the fact that as a new crop, growers are less interested in the diversity the crop has to offer but would rather focus on an aspect, for example CBD oil, which they perceived would be more profitable. The observed responses could also be attributed to the fact that hemp produces over 100 known cannabinoids, most notably CBD [63], and in the United States, clinical trials are ongoing to investigate CBD for treatment of several medical conditions [64]. Moreover, CBD has been granted orphan drug status for some conditions [64]. With the use for CBD oil on the rise in the United States and the hemp industry projected to reach $1 billion dollar in 2018 as a result of hemp-derived CBD oil, most growers may want to create a niche for this crop.

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