Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
energies-14-02066		

4. Title and Subtitle
Farmer Interest in andWillingness to Grow Pennycress as an Energy Feedstock

5. Report Date
April 2021

6. Performing Organization Code

7. Author(s)
Xia Vivian Zhou, Kimberly L. Jensen, James A. Larson and Burton C. English

8. Performing Organization Report No.

9. Performing Organization Name and Address
Center of Excellence for: Alternative Jet Fuels and Environment

University of Tennessee, Agricultural & Resource Economics Department, Knoxville, TN 37996, USA

10. Work Unit No. (TRAIS)

11. Contract or Grant No.
13-C-AJFE-UTENN-005

12. Sponsoring Agency Name and Address
Federal Aviation Administration
Office of Environment and Energy

13. Type of Report and Period Covered
Journal Article

14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract
Pennycress can be used as a renewable biomass because its harvested seeds can be converted into biofuel, supplying, for example the aviation industry. Pennycress can be adopted as a winter cover crop to make extra profit in addition to summer cash crops. This study ascertains influences on row crop farmers' interest in growing pennycress to supply a biofuels industry. The study uses data from a survey of row-crop farmers in seven US states. Effects of farm and farmer attributes on acceptance of a farmgate pennycress price are measured. Nearly 58% were interested in growing pennycress if profitable. Among those interested, 54.4% would accept the farmgate pennycress price offered. Positive influences on interest included farm size, education, and familiarity with pennycress, while concern about knowledge on growing pennycress, and use of no-till practices had negative influences. Farmers aged 40 to 65 were more likely to accept the price, while share of rented hectares and no debt had positive influences. More risk-averse farmers and those using no-till were less likely to accept. Results suggest that the majority of row crop farmers would be interested in growing pennycress if profitable, while the overall willingness to accept the farmgate price was when it was at $0.28/kg.

17. Key Words
interest; willingness to grow; pennycress; oilseed cover crops, ASCENT

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified		

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

energies

Article

Farmer Interest in and Willingness to Grow Pennycress as an Energy Feedstock

Xia Vivian Zhou *, Kimberly L. Jensen, James A. Larson and Burton C. English

Department of Agricultural & Resource Economics, University of Tennessee, Knoxville, TN 37996, USA; kjensen@utk.edu (K.L.J.); jlarson2@utk.edu (J.A.L.); benglish@utk.edu (B.C.E.)
* Correspondence: xzhou11@utk.edu; Tel.: +1-865-974-3716

Abstract: Pennycress can be used as a renewable biomass because its harvested seeds can be converted into biofuel, supplying, for example the aviation industry. Pennycress can be adopted as a winter cover crop to make extra profit in addition to summer cash crops. This study ascertains influences on row crop farmers' interest in growing pennycress to supply a biofuels industry. The study uses data from a survey of row-crop farmers in seven US states. Effects of farm and farmer attributes on acceptance of a farmgate pennycress price are measured. Nearly 58% were interested in growing pennycress if profitable. Among those interested, 54.4% would accept the farmgate pennycress price offered. Positive influences on interest included farm size, education, and familiarity with pennycress, while concern about knowledge on growing pennycress, and use of no-till practices had negative influences. Farmers aged 40 to 65 were more likely to accept the price, while share of rented hectares and no debt had positive influences. More risk-averse farmers and those using no-till were less likely to accept. Results suggest that the majority of row crop farmers would be interested in growing pennycress if profitable, while the overall willingness to accept the farmgate price was when it was at $0.28/kg.

Keywords: interest; willingness to grow; pennycress; oilseed cover crops

Citation: Zhou, X.V.; Jensen, K.L.; Larson, J.A.; English, B.C. Farmer Interest in and Willingness to Grow Pennycress as an Energy Feedstock. *Energies* **2021**, *14*, 2066. https://doi.org/10.3390/en14082066

Academic Editors: Mariusz J. Stolarski and Byong-Hun Jeon

Received: 25 February 2021
Accepted: 7 April 2021
Published: 8 April 2021

1. Introduction

The Energy Independence and Security Act of 2007 (EISA) requires that the consumption of renewable transportation fuel increase to 136 million cubic meters by 2022 [1,2]. The goal of EISA is to relieve reliance on resources that will be depleted and dependence on imported oil, reduce greenhouse gas (GHG) emissions, and decrease trade deficits [1,3–5].

Pennycress (*Thalaspi arvense* L.) can be used as a renewable biomass feedstock for jet fuel because its harvested seeds can be converted into biofuel supplied for the aviation industry. Pennycress has been found throughout the United States [6,7]. It is native to Eurasia and belongs to the Brassicaceae family. Some farmers consider it a "weed", but it can be grown as an annual winter cover crop [1,6]. It germinates in the fall and flowers, and sets seeds in the spring the next year. It is typically planted from September through November and harvested from May to June next year before planting of summer cash crops.

Pennycress can be adopted as a winter cover crop to make extra profit in addition to summer cash crops. For example, pennycress can be incorporated into a two-year corn–soybean rotation that is widely used by farmers in the United States [6,8]. In addition to the economic benefit, adoption of pennycress as a winter cover crop can bring soil and environmental benefits such as increased crop residues on the soil surface, enhanced soil organic matter and moisture holding capacity, immobilization of excess nutrients in soils, and reduction of soil erosion, weeds, pests, and GHG emissions [6,8,9].

Research has found that pennycress is prolific in seed yield. Studies in North Dakota found that pennycress produced seed yields of 1500 kg/hectare [10]. Researchers from Illinois found wild pennycress produced seed yields of 900 to over 2351 kg/hectare [11], and genetically improved pennycress produced seed yields over 2463 kg/hectare [1,12]. Markel et al. [6] estimated that pennycress yield ranged from 897 to 1793 kg/hectare.

Harvested pennycress seeds contain up to 36% oil content, almost twice as much as soybean [1]. Oilseeds from pennycress contain high proportion of unsaturated fatty acid [1]. The favorable oil characteristics and prolific yields of oilseeds make pennycress a feedstock that can be processed into biofuel efficiently and sustainably. Due to those properties, pennycress meets the feedstock requirements for biodiesel production under the United States American Society for Testing and Materials D6751 regulation [6,8,13–15]. Harvested oilseeds from pennycress can be crushed and processed into an oil to be converted into a hydroprocessed esters and fatty acids fuel for the aviation industry [6].

Prior studies have suggested that pennycress could contribute to biofuels production due to its relatively high oil content [1,15]. However, no research has examined factors, including pennycress price, that may influence farmer's willingness to adopt pennycress as a biofuels feedstock crop. While pennycress can be produced in many crop-growing regions of the US, information about farmer willingness to adopt pennycress as an oilseed or winter cover crop is lacking. Little is known about farmers' response to levels of pennycress prices and what price may be required to incentivize pennycress production. Other non-price factors may likely influence the viability of pennycress as a biofuels feedstock. For example, development of pennycress as a viable feedstock crop for biofuels production will likely entail contract production to ensure sufficient feedstock for conversion facilities producing biofuels. However, no studies have measured farmer willingness to adopt pennycress as a biofuel feedstock nor the effects of price or other non-price factors, such as farmer demographics and attitudes or farm characteristics, on willingness to adopt pennycress. This represents an important research gap in assessing future feasibility of growing pennycress to supply biofuels production.

While studies assessing farmer willingness to grow pennycress as a feedstock are lacking, prior research has evaluated an interest and willingness to adopt other dedicated energy crops, including switchgrass and other oilseeds, such as canola or camelina [16–18]. Prior research can provide insights into farmer interest in adopting dedicated energy feedstock crops and the factors that may influence this adoption. Among western U.S. farmers, Embaye et al. [16] found that about 58% were interested in growing oilseeds for bioenergy feedstock. Lynes et al. [19] found that 61% of the Kansas farmers surveyed would be willing to grow annual bioenergy feedstock crops such as sweet sorghum, while 44% would grow perennial bioenergy crops such as switchgrass. Jensen et al. [17] found that about 30% of Tennessee farmers surveyed were interested in growing the perennial switchgrass.

As noted by Embaye et al. [16], larger farm size could influence interest in growing because farmers may perceive that bio-refineries may have preference for dealing with fewer, larger farmers. The effects of farm income on willingness to grow dedicated energy crops have been found to be negative in several studies, reflecting the opportunity cost of switching from other crops to the feedstock crop [16,17,20], however, Embaye et al. [16] found farm income to have a positive effect on area that western U.S. farmers would commit to oilseeds such as canola or camelina in rotation with wheat. Greater share of rented land may signal less autonomy of the farmer in making farm management decisions on that rented land, and prior studies have found negative effects of share of land that is rented on farmer willingness to grow bioenergy feedstock crops [16–18]. Use of no-till practices was found to have a positive effect on interest in growing switchgrass and other oilseeds, including canola and camelina [16,17], however it is important to note that pennycress serves as a winter cover crop, and many farmers using no-till use them together. Hence, the effects of using no-till could differ for interest in growing pennycress for oilseed and as a winter cover crop compared with the interest in growing other dedicated energy crops.

Findings from several studies have suggested that farmer demographics such as age and education level may influence interest in growing dedicated energy crops [16–19]. Most studies have found positive effects of higher education, however, findings regarding the effects of age on willingness to grow bioenergy feedstock crops have been mixed. Qualls et al. [18] found negative effects of age on willingness to grow switchgrass, however, Embaye et al. [16] found no significant effect on western U.S. farmers willingness to grow oilseed crops for feedstock. In addition, farmers' perceived knowledge about the energy feedstock crops [16,17] and their risk aversion have been shown to influence willingness to grow energy feedstock crops [16,18].

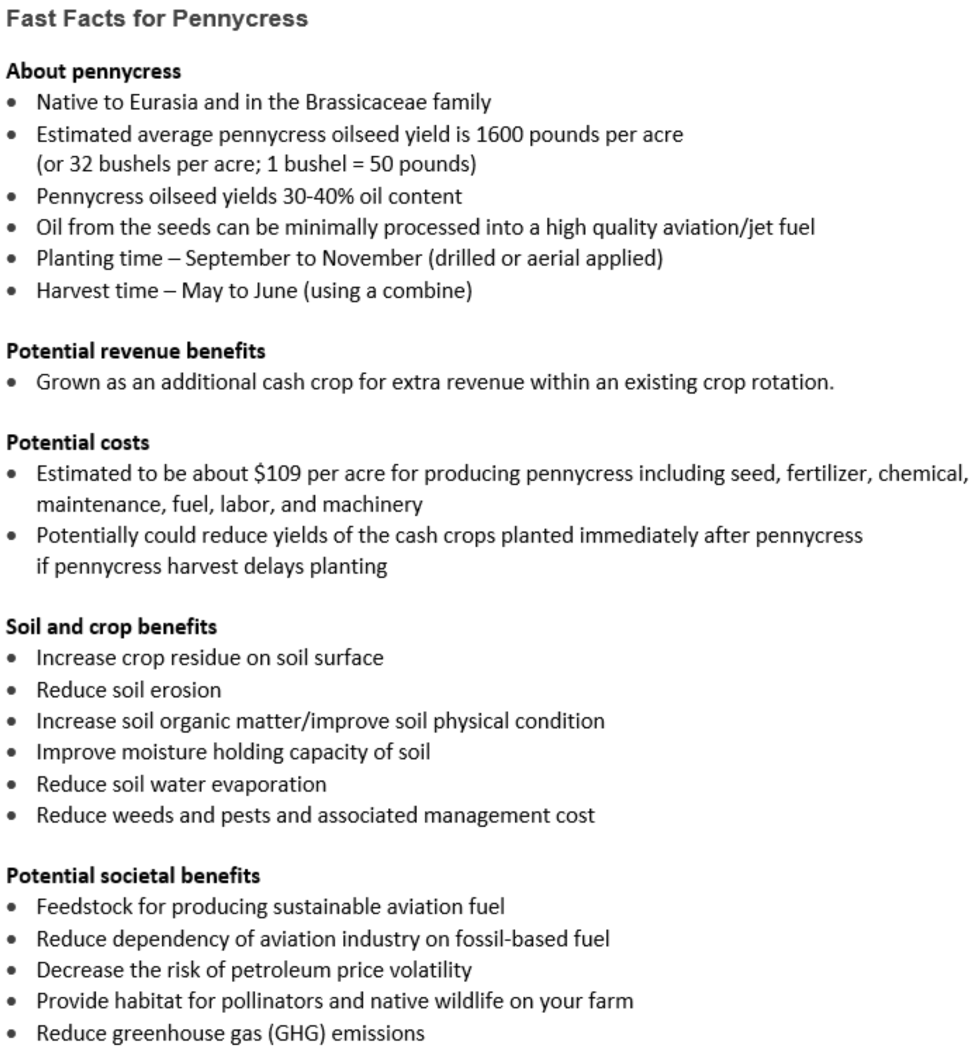
While the aforementioned studies provide insights into farmer interest in growing dedicated energy crops for biofuels production, studies evaluating interest in growing and price responsiveness of farmers to price for pennycress are lacking. This study fills this research gap and provides a better understanding of price and other factors influencing pennycress adoption by crop farmers. The objective of this study is to ascertain farmers' willingness to grow pennycress as a winter oilseed crop to supply feedstock for biofuel production. A survey of row crop farmers in seven states (Alabama, Arkansas, Illinois, Kentucky, Missouri, Mississippi, and Tennessee) was conducted in 2020 to achieve the study objective. Factors influencing farmer interest in growing pennycress, including farm attributes, farmer demographics, and farmer attitudes, are assessed using survey responses. In addition, farmer willingness to supply pennycress for given pennycress oilseed prices as influenced by farm operation attributes, farmer demographics, and farmer attitudes are also evaluated using survey responses. This study provides an initial analysis of farmer willingness to supply pennycress as a biofuel feedstock.

2. Data and Methods

2.1. Survey and Data Collection

A survey instrument was developed to be hosted on the online platform Qualtrics. Prior to distribution of the full survey, the survey was pretested on 25 respondents whose response were not included in the final survey results. Using the comments from the pretest takers, the questionnaire was revised and finalized. Then, on behalf of the research team, Farm Journal sent the survey web link by email to 14,000 farmers who were corn, cotton, or soybean producers in the seven states including Alabama, Arkansas, Illinois, Kentucky, Missouri, Mississippi, and Tennessee. Farm Journal sent the survey web link by email on 22 February 2020, with two follow-up email contacts by 28 March 2020. At the end of April 2020, survey responses were closed. From the email contacts, a total of 224 farmers consented to participate in the survey. All appropriate human subjects protocols and internal review board procedures were followed (UTK IRB-19-05487-XM).

The survey instrument contained several sections. First an information screen about pennycress was provided (see Figure 1). This information screen contained background information as well as potential costs and benefits of growing pennycress, and example photos of pennycress [21,22]. Farmers were asked about familiarity with pennycress. They were then asked about interest in growing pennycress (see Figure 2A). The interest question offered three possible outcomes. The farmer could respond, "Yes, I am interested in planting pennycress", or alternatively they could answer "No", but expressing support for planting pennycress as a feedstock for aviation fuel, or that they don't support for planting pennycress as a feedstock for aviation fuel. The second option was offered as a means to enable farmers to support the idea without saying they would grow pennycress themselves. The purpose of this is to help reduce tendency of a respondent to agree with a statement when in doubt but feels responsible to provide an affirmative answer [23]. Farmers who were interested in growing pennycress if profitable were then asked about their response to specific price points (see Figure 2B). Note that yield and estimated cost information were provided as information to help the farmer with decision making. The sample was divided into five price levels with 20% of the farmers being offered one of these price points ($0.11, $0.22, $0.33, $0.44, or $0.55/kg). The offered price or bid levels were based on estimated breakeven price ranges for pennycress [8].



Fast Facts for Pennycress

About pennycress

- Native to Eurasia and in the Brassicaceae family
- Estimated average pennycress oilseed yield is 1600 pounds per acre (or 32 bushels per acre; 1 bushel = 50 pounds)
- Pennycress oilseed yields 30-40% oil content
- Oil from the seeds can be minimally processed into a high quality aviation/jet fuel
- Planting time – September to November (drilled or aerial applied)
- Harvest time – May to June (using a combine)

Potential revenue benefits

- Grown as an additional cash crop for extra revenue within an existing crop rotation.

Potential costs

- Estimated to be about $109 per acre for producing pennycress including seed, fertilizer, chemical, maintenance, fuel, labor, and machinery
- Potentially could reduce yields of the cash crops planted immediately after pennycress if pennycress harvest delays planting

Soil and crop benefits

- Increase crop residue on soil surface
- Reduce soil erosion
- Increase soil organic matter/improve soil physical condition
- Improve moisture holding capacity of soil
- Reduce soil water evaporation
- Reduce weeds and pests and associated management cost

Potential societal benefits

- Feedstock for producing sustainable aviation fuel
- Reduce dependency of aviation industry on fossil-based fuel
- Decrease the risk of petroleum price volatility
- Provide habitat for pollinators and native wildlife on your farm
- Reduce greenhouse gas (GHG) emissions

Figure 1. Survey information screen for pennycress.

The farmers were also asked how many hectares they would produce if they agreed to the price offered and their interest in signing a contract for pennycress production. They were also asked about factors that might influence their decision to grow pennycress and the importance of potential pennycress production benefits. In addition, they were asked farm attributes and farmer demographics. Copies of the full survey instrument are available from the authors upon request.

Selected farm and farmer attributes among the respondents are compared with values for farms in the surveyed states from the 2017 Census of Agriculture [24] in Table 1. The farmer age of the respondents was 58 years old which is very similar to the 2017 Census of Agriculture average age of farmer of just over 59 years. In addition, the percentages of farmers responding by state appears to closely match percent of farms with corn for grain hectares according to the US Department of Agriculture (USDA) Census of Agriculture (Table 1). Farms with corn for grain were used as a comparison rather than all farms with cropland since that measure by USDA includes many different types of crop farm. Also, percentages of corn farmer respondents by state were close to those from the Census of Agriculture (Table 1). Thus, the sample of row-crop farmer respondents in this study may be representative for corn producers in the seven states. However, it should be noted from Table 1 that the respondents tended to have higher farm incomes and to have larger hectares of farms than average according the Census of Agriculture. Therefore, the respondents appear to be larger farms with higher farm incomes than all farmers on average.

(A)

If producing pennycress and other winter oilseed crops is sufficiently profitable, would you be interested in planting it?

○ Yes, I am interested in planting pennycress
○ No. I am not interested, but I support planting pennycress as a feedstock for sustainable aviation fuel.
○ No. I am not interested, and I don't support planting pennycress as a feedstock for sustainable aviation fuel.

(B)

Assume you are responsible for pennycress planting and harvesting costs and all inputs.

Pennycress Production Information
Projected Yield - Average 1600 kg/hectare ranging from 896 to 2690 kg/hectare
Estimated cost - about $269/hectare

Would you be willing to grow pennycress at a price of $0.11/kg if picked up at your farm at the time of harvest?
○ Yes
○ No

Figure 2. Interest in growing pennycress (**A**) and willingness to grow pennycress at specified farmgate prices survey questions (**B**).

Table 1. Sample farm and farmer attributes of the responding row crop farmers surveyed in seven US states compared with US Department of Agriculture Census of Agriculture.

Farm or Farmer Attribute	Sample		2017 USDA Census of Agriculture [a]	
Hectares Farmed (hectares)	492 (*n* = 160)		142 with 128 hectares harvested	
Farm Income				
Less than $10,000	4.50%		37.00%	
$10,000–$24,999	8.11%		17.00%	
$25,000–$49,999	14.41%		13.00%	
$50,000 and greater	72.97% (*n* = 111)		33.00%	
Farmer Age	58.11 (*n* = 166)		59.4	
Farmer State of Residence	Percent by State		Farms with Corn for Grain	
	Respondents	vs. Corn Farmer Respondents	Operations	Percent
Alabama	3.5%	1.4%	1463	2.4%
Arkansas	3.5%	1.4%	1440	2.4%
Illinois	53.8%	63.0%	34,792	56.8%
Kentucky	6.9%	4.3%	5760	9.4%
Missouri	19.7%	18.8%	13,184	21.5%
Mississippi	2.9%	2.9%	1427	2.3%
Tennessee	9.8%	8.0%	3172	5.2%
Total Operations	(*n* = 173)	(*n* = 138)	61,238	

[a] US Department of Agriculture-National Agricultural Statistics (USDA-NASS) [24].

2.2. Economic Model

An underlying unobservable latent, variable $Accept_i^*$ (preference for growing pennycress at the price bid level offered), is assumed to be influenced by P_i which is pennycress price or bid level offered, and a vector of non-price variables $x_{i,-P}$ (farmer demographics, farm attributes, and farmer attitudes for the ith farmer), such that

$$Accept_i^* = P_i\beta_P + x_{i,-P}\beta_{-P} + u_{1i} \quad (1)$$

where β_P is a parameter on price to be estimated, β_{-P} is a vector of parameters for non-price variables to be estimated, and u_{1i} is an error term. The names and definitions of the variables that comprise x_{-P} are shown in Table 2. While the latent variable cannot be observed, a binary outcome can be (will accept bid to grow pennycress or not). This binary outcome is observed such that:

$$\begin{array}{l} Accept_i = 0 \ if \ Accept_i^* \leq 0 \\ Accept_i = 1 \ if \ Accept_i^* > 0 \end{array} \quad (2)$$

Table 2. Variable names, definitions, and means for variables used in the probit model with sample selection for interest in and willingness to accept the price bid to grow pennycress among row crop farmers surveyed in seven US states.

Variable Name	Definition	Mean (N1 = 137) [a]	Mean (N2 = 79) [b]
Interest	1 if interested in growing pennycress, 0 otherwise	0.577	—
Accept	1 if would accept the farmgate pennycress price and grow pennycress at the price offered, 0 otherwise	—	0.544
Price	$0.11, $0.22, $0.33, $0.44, $0.55 per kg at the farmgate	—	0.328
AgeLt40	1 if aged under 40 years old, 0 otherwise	0.080	0.089
AgeGt65	1 if aged greater than 65 years old, 0 otherwise	0.409	0.405
Education	Education level (1 = elementary/middle, 2 = some hs [c], 3 = hs [c] graduate, 4 = some college, 5 = bs [d] degree, 6 = post graduate or professional degree)	4.328	4.468
LogHectares	Log of total hectares in row crops (502.215 hectares, 579.105 hectares, respectively)	5.737	5.935
Share Rent	Share of crop hectares that are rented	—	0.484
Debt Free	1 if farm 0 debt in 2018, 0 otherwise	—	0.266
Late Adopter	1 if agree that tend to be reluctant about adopting new production methods or crops until see others adopt, 0 otherwise	0.314	—
Concerned Loss	1 if agree tend to be more concerned about a large loss to farming operation than missing a substantial gain	—	0.658
Winter Cover Crop	1 if regularly plant winter crops that are not harvested, 0 otherwise	0.445	0.494
NoTill	1 if use no till methods, 0 otherwise	0.693	0.658
Familiar	1 if familiar with pennycress, 0 otherwise	0.358	—
Production Concerns	Production concerns factor (See Table 3)	0.053	—
Social Benefits	Social benefit factor (See Table 4)	0.016	—
Financial Concerns	Financial concern factor (see Table 3)	—	0.088
Financial Benefits	Financial benefit factor (see Table 4)	—	−0.011
Importance of Potential Barrier on Decision to Grow Pennycress (1 = not at all, . . . , 5 = extremely)			
Cease Farming	Concern will cease farming due to retirement or other reasons soon	2.380	—
Pennycress Weed	Perceptions that pennycress is a weed	2.796	—
Knowledge Pennycress	Your knowledge about growing pennycress compared with growing other crops	3.336	—
Financial Resources	Concern about having financial resources and equipment needed to produce pennycress	—	2.911

[a] N1 is the number of observations used in the model of *Interest*. [b] N2 is the number of observations used in the model of *Accept*. [c] hs is high school. [d] bs is bachelor degree.

Table 3. Factor loadings for importance of potential concerns/barriers on decision to grow pennycress among crop farmers surveyed in seven US states.

Potential Barriers/Concern on Decision to Grow Pennycress (n = 179)	Factor 1 "Production Concerns"	Factor 2 "Financial Concerns"
Possible conflicts between planting and harvest period for pennycress and your other crops	**0.7250**	0.3796
Concern that pennycress could impact yields of other cash crops in the rotation	**0.7231**	0.3270
Concern about the market for pennycress as an energy crop	0.4154	**0.5810**
Profitability of growing pennycress crops compared with other farming alternatives	0.4664	**0.5796**

Table 4. Factor loadings for importance of benefits on decision to grow pennycress among crop farmers surveyed in seven US states.

Potential Benefits from Growing Pennycress (n = 176)	Factor 1	Factor 2
	"Financial Benefits"	"Social Benefits"
Additional source of farm income	**0.7446**	0.1737
Opportunity to diversify crop species grown on your farm	**0.7442**	0.2733
Provide habitat for pollinators and native wildlife on your farm	0.1479	**0.7031**
Contribute to national energy security by producing pennycress for sustainable aviation fuel	0.2230	**0.8436**
Help the environment by producing pennycress for sustainable aviation fuel	0.2318	**0.7935**

Let the dependent variable *Accept* only be observed when the grower expresses some interest in growing pennycress ($Interest_i = 1$). For example, some farmers may have non-pecuniary reasons for not wishing to adopt a new crop, such as lifestyle reasons or nearing retirement. Hence, for these farmers, no bid level is likely to induce them to grow pennycress, and they should not be considered as part of the price response. In this case, *Accept* is only observed when:

$$Interest_i^* = z_i\gamma + u_{2i} \ > \ 0 \tag{3}$$

or the ith respondent expresses interest in growing pennycress or $Interest_i = 1$ [25]. The z_i is a vector of demographics, farm attributes, and farmer attitudes for the ith farmer, while γ is a vector of parameters to be estimated. The names and definitions of the variables in z are shown in Table 2. The error terms u_1 and u_2 are distributed as standard normal and are correlated by ρ [26].

2.3. Statistical Analysis Methods

2.3.1. Factor Analysis of Farmer Attitudes toward Pennycress

The farmers were asked two sets of Likert opinion questions about growing pennycress. First, the farmers were asked several questions about the importance of eight potential barriers or concerns influencing their decision to plant pennycress. The respondents were asked how important each was using a Likert rating scale of 1 = not at all, . . . , 5 = extremely. These variable definitions and mean ratings are shown in Table 3. Second, the farmers were asked to rate the importance of seven potential opportunities from growing pennycress (1 = not at all, . . . , 5 = extremely). These potential opportunities are defined and their mean Likert ratings are shown in Table 4.

To help reduce the number of factors considered in the modeling process and to find underlying common factors among farmer attitudes, a factor analysis of each question set was conducted (eight potential influences and seven opportunities) [27,28]. Factor analysis is used to identify common m underlying factors that linearly reconstruct the original set of p variables considered. For example:

$$\begin{array}{c} y_1 = l_1 + \ l_{11}f_1 + l_{12}f_2 +, \ \ldots, \ +l_{1m}f_m + e_1 \\ y_p = l_p + \ l_{p1}f_1 + l_{p2}f_2 +, \ \ldots, \ +l_{pm}f_m + e_p \end{array} \tag{4}$$

where, for example $y_1, \ldots, y_p$ are the 1, … , p opinion variables, $f_1, \ldots, \ f_m$ are the 1, … , m common factors, $\boldsymbol{L}$ is the matrix of factor loadings p opinion variables onto the m factors, and $e_1, \ldots, e_p$ are the errors, or each variable's uniqueness factor. As part of the principal factor analysis, eigen values are provided and assist in identifying how many factors to extract as part of the overall factor analysis. The number of eigen values taking on a value of one or greater signals the potential number of common underlying factors to be extracted. Then, the variables which load onto common underlying factors retained are identified by their factor loadings and uniqueness factors. Variables with high factor loadings (>0.50) and low uniqueness factors (<0.50) are retained to predict values for the underlying common factor(s). The principal factors method is used with an orthogonal varimax rotation to aid in evaluating the underlying common factors [29]. A chi-squared likelihood-ratio test of the number of factors in the model against a saturated model is evaluated by Bartlett [30]. A regression scoring method is used to make predictions of the factors. Results from the factor analysis are used to obtain predicted values for the common underlying factors which are used as index variables in our model of interest in and willingness to grow pennycress, the formula for regression scoring is for factor $\boldsymbol{f_i}$ is

$$\widetilde{\boldsymbol{f_i}} = \hat{\boldsymbol{L}}' \boldsymbol{R^{-1}} \ (\boldsymbol{Y_i} - \overline{\boldsymbol{y}}) \tag{5}$$

where $\boldsymbol{L}$ is the matrix of factor loadings, $\boldsymbol{R^{-1}}$ is inverse correlation matrix between the j observed variables [31,32]. The resulting factor index variables are normally distributed and can range from –∞ to +∞. The STATA modules for "factor" and "factor postestimation" are used to conduct the factor analysis and predict the factor values [33].

2.3.2. Estimation of the Model for Interest in and Willingness to Accept the Bid to Grow Pennycress

A probit model with sample selection is used to estimate the model of interest (*Interest*) and among those interested, the willingness accept the bid offered to grow (*Accept*) pennycress. Hence a probit with sample selection is used to estimate Equations (1)–(3). The probit model with sample selection includes both a selection probit equation and a second stage equation that is also a probit where the second dependent variable is contingent upon the first dependent variable having a value of '1' or that the farmer is interested in growing pennycress if profits are sufficient. The probability of the respondent being interested in growing pennycress given the explanatory other variables, can be expressed as:

$$\Pr(Interest_i = 1) = \Phi_1 \ (z_i\gamma) \tag{6}$$

where Φ_1 is the standard normal distribution assuming the probit model. The probability of the respondent accepting the bid and being willing to grow pennycress conditional on their interest is:

$$\Pr(Accept_i = 1| \ Interest_i = 1) = \Phi_2 \ (P_i\beta_P + x_{i,-P}\beta_{-P}|Interest = 1) \tag{7}$$

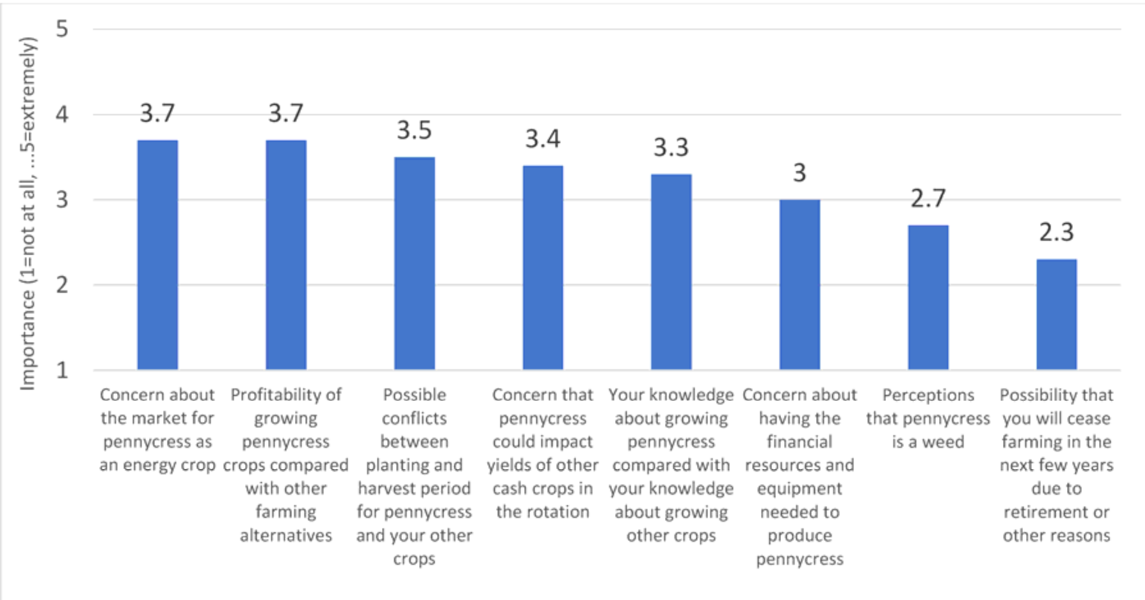
where Φ_2 the standard normal distribution assuming the probit model. If the measure of the correlation of the error terms, ρ, is 0, the two probits can be estimated separately.

The marginal effect of the kth explanatory variable, z_{ik}, on interest is $\frac{\partial \Pr(Interest_i=1)}{\partial z_{ik}} = \phi_1(\boldsymbol{z}_i\gamma) * \gamma_{z_k}$ where $\phi_1(\boldsymbol{z}_i\gamma)$ is the probability density function and γ_{z_k} is the parameter associated with the variable z_{ik}. The marginal effect of the jth explanatory variable, x_{ij}, on acceptance of the bid is $\frac{\partial \Pr(Accept_i=1|Interest=1)}{\partial x_{ij}} = \phi_2 \ (x_i\beta) * \ \beta_{x_j}$ where $\phi_2(x_i\beta)$ is the probability density function and β_{x_j} is the parameter associated with the variable x_{ij}. If a variable, say x_{ik} appears in both equations, the marginal effect of the variable on overall probability of being interested in growing and accepting the bid can be calculated. This is calculated as $\frac{\partial\, \Pr(Accept_i=1)}{\partial x_{ik}} = [\phi_1(z_i\gamma) * \gamma_{x_k} * [\phi_2(x_i\beta) * \beta_{x_k}]$. The standard errors around the marginal effects are calculated using the Delta method [34]. Given the referendum style of eliciting the willingness to accept the pennycress price bids, to calculate a willingness to accept (WTA) measure, the formula for the *i*th individual is $\mathrm{WTA_i} = -\frac{x_{i,-P}\beta_{-P}}{\beta_P}$. The mean WTA is then calculated using the individual values. The standard errors used to obtain a 95% confidence interval around the mean WTA measure are calculated using the Krinsky and Robb [35] method.

3. Results and Discussion

3.1. Farmer Opinions Regarding Influences on Decisions to Plant Pennycress and Potential Benefits from Planting Pennycress

Farmers were asked to rate the importance (1 = not at all, . . . , 5 = extremely) of seven potential concerns or barriers that could influence their decision to plant pennycress. As can be seen in Figure 3, these potential factors included crop management concerns, such as "Potential conflicts between planting and harvest period for pennycress and your other crops", "Concern that pennycress could impacts yields of other cash crops in rotation", "Perceptions that pennycress is a weed", and "Your knowledge about growing pennycress compared with your knowledge about growing crops". The factors also included financial and other farm concerns, "Concern about the market for pennycress as an energy crop", "Profitability of growing pennycress crops compared with other farming alternatives", "Possibility that will cease farming in the next few years due to retirement or other reasons", "Concern about having financial resources and equipment needed to produce pennycress". The most important concerns were about the market for pennycress as an energy crop, followed by possible conflicts between planting and harvest for pennycress and other crops, concern that pennycress could impact yields of other crops. The least important factor was the concerns that they would cease farming in the next few years.



(N = 179)

Figure 3. Importance of potential concerns/barriers on decision to grow pennycress among row crop farmers in seven US states.

The farmers were also asked to rate the importance (1 = not at all, . . . , 5 = extremely) of seven potential benefits from growing pennycress. Shown in Figure 4, these included farm financial benefits "Additional source of farm income" and "Opportunity to diversify crop species grown on farm". Other potential benefits included on-farm environmental benefits "Reduce soil erosion on your farm" and "Provide habitat". Potential benefits also included off-farm environmental and social benefits, "Contribute to national energy security by producing pennycress for sustainable aviation fuel", "Help the environment by producing pennycress for sustainable aviation fuel" and "Create jobs in your community". The most important were "Additional source of farm income," followed by "Reduce erosion on your farm," and "Opportunity to diversify crop species grown on your farm." Hence, these results suggest that both financial benefits as well as soil erosion benefits are important benefits to farmers. The least important benefit was creating jobs in the community.

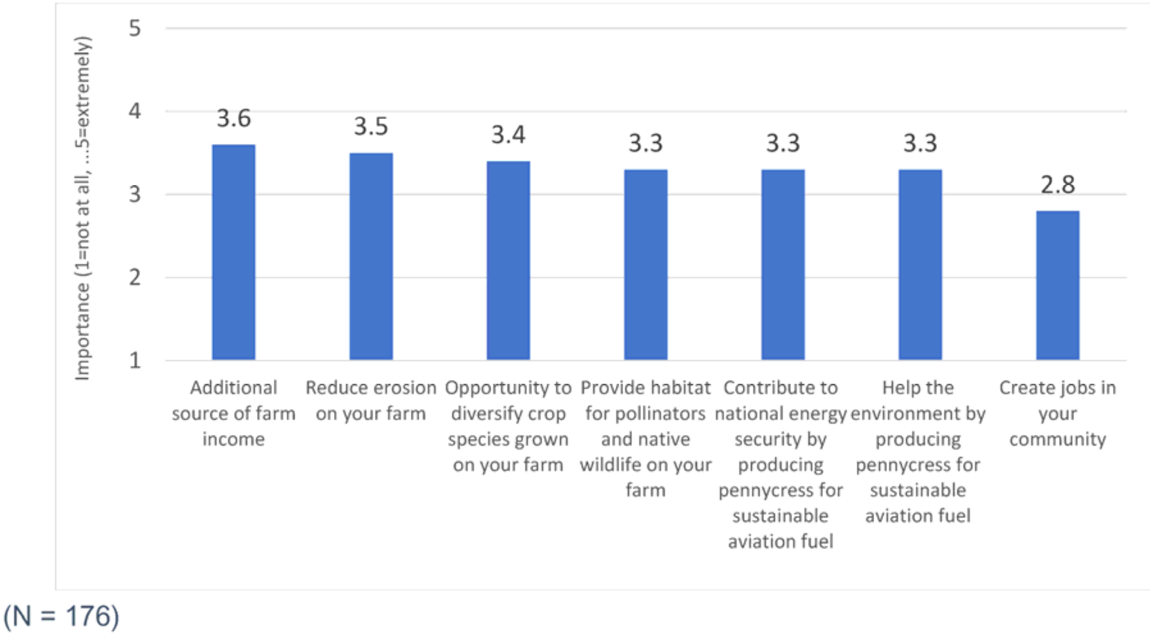


Figure 4. Importance of potential benefits decision to grow pennycress among row crop farmers in seven US states.

As noted in the methods section, to help reduce the number of opinion variables considered in the willingness to grow pennycress model, factor analysis was conducted on the two sets of questions. The purpose was to identify underlying factors that several variables shared. From the factor analysis, predicted factors can be generated that represent two or more of the opinion variables. The initial factor analysis of potential barriers/concerns influencing decision to plant pennycress showed uniqueness of the variances for "Possibility that you will cease farming in the next few years due to retirement or other reasons", "Perceptions that pennycress is a weed", "Your knowledge about growing pennycress compared with your knowledge about growing other crops", and "Concern about having the financial resources and equipment needed to produce pennycress". Hence these variables could be considered as individual variables in the model of willingness to grow pennycress. However, "Possible conflicts between planting and harvest period for pennycress and your other crops", "Concern that pennycress could impact yields of other cash crops in the rotation", "Concern about the market for pennycress as an energy crop", and "Profitability of growing pennycress crops compared with other farming alternatives" had uniqueness scores below 0.60. An additional factor analysis was conducted omitting the variables with high uniqueness scores. As can be seen in Table 3, when two factors are retained, two variables load onto each factor. For the first factor these two variables are possible conflicts between planting and harvest and concern that pennycress could impact yields. This factor will be called "Production concerns". For the second factor the two variables are concern about the market and profitability of growing pennycress. The second factor will be called "Profitability/Market Concerns".

A similar process was used to discover underlying common factors among the opinion variables about potential benefits from growing pennycress. From that factor analysis, the variables that had a high uniqueness were "Create jobs in your community" and "Reduce erosion on your farm" and could be treated as individual variables in the model of willingness to grow pennycress. As can be seen in Table 4, two variables were loaded onto a factor, "Additional source of farm income" and "Opportunity to diversify crop species grown on your farm." This factor will be called "Financial Benefits". The variables "Provide habitat for pollinators and native wildlife on your farm," "Contribute to national energy security by producing pennycress for sustainable aviation fuel," and "Help the environment by producing pennycress for sustainable aviation fuel" loaded onto a second factor, which is called "Social Benefits".

3.2. Estimated Probit Models for Farmer Interest in and Willingness to Accept the Farmgate Price to Grow Pennycress

As shown in Table 2, while 57.7% of the farmers were interested in growing pennycress if it offered suitable profits (*Interest*), among those who said they were interested, about 54.4% accepted the pennycress price offered to say they would grow pennycress (*Accept*). Hence, overall, just under 31.4% of the farmers were both interested in growing pennycress and would accept the farmgate price of pennycress offered. The percentage interested is similar to that found by Embaye et al. [16] for western farmers interested in growing oilseed crops in rotation with wheat and Lynes et al. [19] finding of 61% interest in growing annual bioenergy crops among Kansas wheat farmers.

Initially a Heckman probit model with sample selection was used to estimate the *Interest* and *Accept* equations. However, the estimated coefficient of correlation between the error terms from the equations for *Interest* and *Accept*, ρ, was not statistically significant. Therefore, the two decision points, *Interest* and *Accept*, could be modeled with two separate probits. The estimated probit models for each decision point and the marginal effects of the explanatory variables on probability of *Interest* = 1 and *Accept* = 1 are shown in Table 5. The log likelihood ratio (LLR) test for each model against an intercept model was significant, showing each model to be significant overall. The pseudo R^2 for *Interest* was 0.1415 while it was 0.2681 for *Accept*. The model for *Interest* correctly classified 67.15% of the observations while the model for *Accept* correctly classified 70.89%.

As can be seen in the first two columns of estimates in Table 5, probability of interest in growing pennycress is positively influenced by education level of the farmer (*Education*), farm size (in terms of log hectares, *LogHectares*), and perceived familiarity with pennycress (*Familiar*). Based on the estimates for each additional level of education, the probability of interest increased by about 10.2%. This positive influence of education level is similar to findings from previous research [16–19]. For *LogHectares*, the untransformed marginal effect is the marginal effect on the log variable divided by the average farm size among observations included in the model of *Interest*, 0.107/502.259 = 0.000213, or for each additional 100 hectares farmed the probability of interest increases by 2.13%. For each increase in level of familiarity with pennycress, the interest in growing it increased by 24.1%. The positive influence of familiarity with pennycress is similar to findings from prior research suggesting knowledge about bioenergy crops has a positive influence on willingness to grow them [16,17]. Use of no till practices in crop farming (*NoTill*) negatively influenced probability of interest in growing pennycress by 15%. This finding conflicts with prior research finding of positive influence of use of no-till practices on willingness to grow bioenergy feedstock [16,17]. However, pennycress is grown as a winter cover crop and farmers may not see the need for the cover crop if they are already adopting no-till practices or may be concerned about residue management for a cover following a high residue crop such as corn.

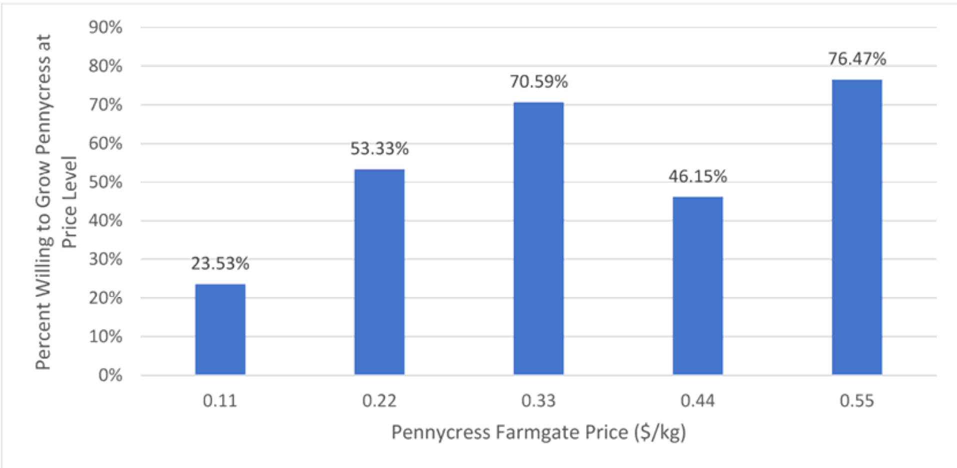
Table 5. Estimated probit models of interest in and willingness to accept the pennycress price to grow pennycress among row crop farmers surveyed in seven US states and estimated marginal effects.

	Probit Model of Probability of [a]			
	Farmer Interest in Growing Pennycress (*Interest* = 1)		Farmer Accepting the Pennycress Farmgate Price to Grow Pennycress (*Accept* = 1)	
Variable Name	**Estimated Coefficient**	**Marginal Effect**	**Estimated Coefficient**	**Marginal Effect**
Intercept	−2.581 **	—	−3.220 **	—
Price			3.441 ***	0.980 ***
AgeLt40	0.118	0.039	−1.470 **	−0.419 **
AgeGt65	0.294	0.097	−0.681 *	−0.194 *
Education	0.306 **	0.102 ***	0.230	0.065
LogHectares	0.321 ***	0.107 ***	0.236	0.067
Share Rent	—	—	0.853 *	0.243 *
No Debt	—	—	0.839 *	0.239 *
Familiar	0.725 ***	0.241 ***	—	—
Late Adopter	−0.134	−0.045	—	
Concerned Loss	—	—	−0.667 *	−0.190 *
Winter Cover Crop	0.315	0.105	0.529	0.151
NoTill	−0.451 *	−0.150 *	−0.810 **	−0.231 **
Production Concerns	0.357 *	0.119 *	—	—
Social Benefits	−0.149	−0.050	—	—
Financial Concerns	—	—	0.147	0.042
Financial Benefits	—	—	0.238	0.068
Cease Farming	0.113	0.037	—	—
Pennycress Weed	−0.045	−0.015	—	—
Knowledge Pennycress	−0.204 *	−0.068 *	—	—
Financial Resources	—	—	0.108	0.031
LLR Test Against Intercept Only Model	26.42 **		29.2 **	
n	137		79	
Pseudo R^2	0.1415		0.2681	
Percent Correctly Classified	67.15%		70.89%	

[a] *** = significant at α = 0.01, ** = significant at α = 0.05, * = significant at α = 0.10.

Neither farmer age nor use of non-harvested winter cover crops influenced interest. Among attitudes and concerns about pennycress, surprisingly the *Production Concerns* index had a positive effect. Because the *Production Concerns* index is a continuous factor generated from multiple opinion variables, interpretation of the marginal effects' magnitude is difficult. It is possible that farmers who were more concerned about the crop management aspects of growing pennycress are those who have more interest in the winter cover crop. The *Social Benefits* index had no significant effect. Greater farmer concerns about their knowledge level (*Knowledge*) about growing pennycress compared with other crops negatively influenced interest in growing pennycress, with each increased level reducing probability by 6.8%. This finding is similar to those from prior research about the effects of perceived knowledge level on willingness to grow bioenergy crops [16,17]. Neither concerns that the farmer might cease farming soon (*Cease*) nor perceptions that pennycress is a weed (*Weed*) influenced interest.

The two right-hand columns of Table 5 show the probit model of *Accept*, or given interest in growing pennycress, probability of willingness to accept the price bid and grow pennycress. The percent accepting the price at each *Price* point is shown in Figure 5. As can be seen in Figure 5, with the exception of $0.44/kg, as the pennycress farmgate price was increased, the% of interested farmers who stated they would be willing to grow pennycress at that price increased. Shown in Table 5, as would be anticipated the estimated coefficient on and marginal effect for price is positive. The positive coefficient on the price of pennycress in the model shows that offering a higher farmgate price had a positive effect on probability of accepting the price and being willing to grow pennycress. The marginal effect shows that for each price increase of a $0.01 per kg, the probability that the farmer would accept the bid increased by 0.98%.



(N = 79)

Figure 5. Percent of row crop farmers in seven US states who were willing to grow pennycress at the pennycress farmgate price offered.

Other variables with a positive effect on *Accept* include having no debt (*No Debt*) and share of crop hectares rented (*Share Rent*). If the farmer had no debt, this increased the probability they would accept the bid by 23.9%. This finding is anticipated, as farmers with lower debt may perceive that they have greater financial ability to try new cropping systems and be more likely to accept the pennycress farmgate price. As the share of hectares rented increased by 0.01 or 1%, the probability the farmer would accept the bid increased by 0.243%. This finding is unexpected and is in conflict with findings from prior research [16–18].

If the farmer was more concerned about taking a large loss than making a profit (*Concerned Loss*), this decreased the probability they would accept the pennycress price and indicate they would grow pennycress by 19%. As in prior research [16,18], this suggests that more risk-averse farmers may require higher pennycress prices to enter the market. This could suggest that contracting will be desired and could serve to attract more row crop farmers to produce pennycress for use in biofuels production. As a follow up, among those who were interested in growing pennycress, over 88% would prefer to do so under a production contract. Their preference for contracting likely reflects the farmers' concerns about riskiness of evolving markets for pennycress.

In addition, if the farmer used *No Till*, this decreased the probability of accepting the pennycress price and being willing to grow pennycress by 23.1%. Neither education, farm hectares nor currently growing winter cover crops influenced the probability of *Accept* = 1. The indices measuring *Financial Concerns* and *Financial Benefits* did not significantly affect probability of *Accept* = 1. Concerns about having financial resources and equipment to product pennycress also did not significantly influence the probability of accepting the pennycress price and agreeing to grow pennycress.

Using the estimated coefficients from the model and the data, an overall measure of willingness to accept the farmgate pennycress price is calculated at $0.28/kg or 28 cents per kg. The 95% confidence lower interval is $0.08/kg while the upper confidence interval is $0.40/kg. The estimated average willingness to accept a value of $0.28/kg is higher than the estimated farmgate price of about $0.21/kg that a crushing facility could pay farmers and achieve a modified internal rate of return of 12.5% (Trejo-Pech et al., 2019). Farmer price expectations may factor in their perceived risks about growing pennycress. It should be noted that this is a willingness to accept measure for those who were interested in growing pennycress. Referring back to Table 1, about 57.7% of the farmers who responded were interested in growing pennycress if it offered suitable profits. Hence, this estimate represents the willingness to accept the farmgate pennycress price among that 57.7% who were at least interested in growing pennycress.

4. Conclusions and Implications

Pennycress, while traditionally viewed as a weed by many farmers, can potentially have dual benefits to row crop farmers. First, it can be used as a renewable energy crop harvested for its oilseed that can be converted into biofuel. Pennycress can also be adopted as a winter cover crop to provide supplemental income to summer cash crops. While pennycress has potential benefits to row crop farmers and promise as a biofuels feedstock, no prior research has been conducted to assess farmer interest in growing it as a bioenergy feedstock crop or to ascertain the prices required by farmers to adopt it. This research seeks to fill this important information gap. This study provided both estimates of interest in growing pennycress by row crop farmers and also their response to differing farmgate prices of pennycress.

This study does have several limitations. First it is limited to analysis for farmers located in seven states; further research should likely expand this study region. Furthermore, the study represents one snapshot in time. As farmers learn more about pennycress, their willingness to adopt it could change. As the study results are examined, these limitations should be taken into consideration for development of future studies to extend this research.

The results from this study suggest that nearly 6 in 10 farmers in the survey sample indicated that they had an interest in growing pennycress if profitable. This finding is similar to that from prior research regarding farmer interest in growing annual bioenergy crops [16]. This suggests that farmers may view pennycress similarly acceptable to other annual bioenergy crops, despite its reputation among some farmers as a weed. Among those who were interested, the overall willingness to accept farmgate price was about $0.28/kg. At average production rates yielding 1600 kg of pennycress oilseed per hectare, this would generate revenues of about $448/hectare. If estimated costs are around $269 per hectare, this would yield per hectare profit of $179.

Factors influencing interest included farm size, farmer education level, and their familiarity with pennycress. This positive influence of larger farm size is similar to prior research [16] and suggests that farmers with larger operations may be the early adopters of pennycress if the market for biofuels use develops. The positive effect of familiarity on willingness to adopt pennycress mirrors findings from prior studies of farmer willingness to adopt bioenergy feedstocks [16–19]. The positive influence of familiarity with pennycress could suggest that more farmer education about the potential benefits of growing pennycress increase their interest in planting it. The result that concern about knowledge on growing pennycress had a negative effect on interest reinforces this hypothesis. Unlike prior research findings regarding the effects of no-till on interest in adopting switchgrass and other oilseeds [16,17], the results from this study showed that use of no-till practices had a negative effect on willingness to grow pennycress. The negative effect of no-till practices on interest in growing pennycress and willingness to accept the pennycress price may reflect that farmers may perceive winter cover crops to be more helpful on tilled farms, although winter cover crops can be used in concert with no till practices. Educational programs about how winter cover crops can be used with no-till systems may be needed. Although prior research has found negative [18] or no significant effects [16] on farmer willingness to adopt bioenergy feedstock crops, the results from this study showed that mid-age range farmers were more likely to accept the pennycress farmgate price offered. This could signal that younger farmers who are starting out farming and older farmers who are nearing retirement would be less likely to take on production of a new crop. Like prior studies of farmer adoption of bioenergy feedstock crop production [16–18], this study found more risk averse farmers were less likely to accept the pennycress price. This could suggest that contracting will be desired and could serve to attract more row crop farmers to produce pennycress for use in biofuels production. The study results also suggested that the vast majority of those interested in growing pennycress would prefer to do so under a production contract.

Author Contributions: Conceptualization, X.V.Z., K.L.J., J.A.L. and B.C.E.; data curation, X.V.Z., K.L.J., J.A.L. and B.C.E.; formal analysis, X.V.Z., K.L.J., J.A.L. and B.C.E.; funding acquisition, K.L.J., J.A.L. and B.C.E.; methodology, X.V.Z., K.L.J., J.A.L. and B.C.E.; project administration, X.V.Z., K.L.J., J.A.L. and B.C.E.; writing—original draft, X.V.Z. and K.L.J.; writing—review and editing, J.A.L. and B.C.E. All authors have read and agreed to the published version of the manuscript.

Funding: This research was made possible with funding from the Federal Aviation Administration (FAA) Office of Environment and Energy as a part of Aviation Sustainability Center (Ascent) Project 1 under FAA Award number 13-C-AJFEUTENN-Amd 5. This research was also funded by USDA through Hatch Project TN 000574 and Hatch multi-state project 1012420.

Institutional Review Board Statement: The study was conducted according to the guidelines of the Declaration of Helsinki, and approved by the Institutional Review Board (or Ethics Committee) of THE UNIVERSITY OF TENNESSEE (protocol code UTK IRB-19-05487-XM and date of approval 23 January 2020).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Data for this study were collected using appropriate human subjects protocols. As part of the protocol used in this study, confidentiality to the survey participants was promised. As such, the individual data are not available. Only summary results from the survey may be provided.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Fan, J.; Shonnard, D.R.; Kalnes, T.N.; Johnsen, P.B.; Rao, S. A life cycle assessment of pennycress (*Thlaspi arvense* L.) -derived jet fuel and diesel. *Biomass Bioenergy* **2013**, *55*, 87–100. [CrossRef]
2. U.S. Environmental Protection Agency (US EPA). *Regulation of Fuels and Fuel Additives: Changes to Renewable Fuel Standard Program*; Final Rule; US EPA: Washington, DC, USA, 2010.
3. Kim, S.; Dale, B.E. Life cycle assessment of various cropping systems utilized for producing biofuels: Bioethanol and biodiesel. *Biomass Bioenergy* **2005**, *29*, 426–439. [CrossRef]
4. Urbanchuk, J.M. *An Economic Analysis of Legislation for a Renewable Fuels Requirement for Highway Motor Fuels*; AUS Consultants: Mount Laurel, NJ, USA, 2001.
5. Zhou, X.V.; Clark, C.D.; Nair, S.S.; Hawkins, S.A.; Lambert, D.M. Environmental and economic analysis of using SWAT to simulate the effects of switchgrass production on water quality in an impaired watershed. *Agric. Water Manag.* **2015**, *160*, 1–13. [CrossRef]
6. Markel, E.; English, B.C.; Hellwinckel, C.; Menard, R.J. Potential for pennycress to support a renewable jet fuel industry. *Ecol. Pollut. Environ. Sci.* **2018**, *1*, 95–102.
7. Centre for Agriculture and Bioscience International (CABI). *Thlaspi arvense* (Field Pennycress). Available online: https://www.cabi.org/isc/datasheet/27595 (accessed on 6 January 2019).

8. Trejo-Pech, C.O.; Larson, J.A.; English, B.C.; Yu, T.E. Cost and Profitability Analysis of a Prospective Pennycress to Sustainable Aviation Fuel Supply Chain in Southern USA. *Energies* **2019**, *12*, 3055. [CrossRef]
9. U.S. Department of Energy. *2016 Billion-Ton Report: Advancing Domestic Resources for a Thriving Bioeconomy*; Volume 1: Economic Availability of Feedstocks; ORNL/TM-2016/160; Oak Ridge National Laboratory: Oak Ridge, TN, USA, 2016.
10. Carr, P. Potential of Fanweed and Other Weeds as Novel Industrial Oilseed Crops. In *New Crops*; John Wiley and Sons: New York, NY, USA, 1993.
11. Isbell, T.; Chermak, S. Thlaspi arvense (Pennycress) germination, development and yield potential. In Proceedings of the Association for the Advancement of Industrial Crops Conference, Fort Collins, CO, USA, 19–22 September 2010.
12. Phippen, W.; Phippen, M. Evaluation of field pennycress (Thlaspi arvense) populations. In Proceedings of the Association for the Advancement of Industrial Crops Conference, Fort Collins, CO, USA, 19–22 September 2010.
13. Alhotan, R.A.; Wang, R.L.; Holser, R.A.; Pesti, G.M. Nutritive value and the maximum inclusion level of pennycress meal for broiler chickens. *Poult. Sci.* **2017**, *96*, 2281–2293. [CrossRef] [PubMed]
14. Miller, P.; Sultana, A.; Kumar, A. Optimum scale of feedstock processing for renewable diesel production. *Biofuels Bioprod. Biorefining* **2012**, *6*, 188–204. [CrossRef]
15. Moser, B.R.; Knothe, G.; Vaughn, S.F.; Isbell, T.A. Production and Evaluation of Biodiesel from Field Pennycress (*Thlaspi arvense* L.) Oil. *Energy Fuels* **2009**, *23*, 4149–4155. [CrossRef]
16. Embaye, W.T.; Bergtold, J.S.; Archer, D.; Flora, C.; Andrango, G.C.; Odening, M.; Buysse, J. Examining farmers' willingness to grow and allocate land for oilseed crops for biofuel production. *Energy Econ.* **2018**, *71*, 311–320. [CrossRef]
17. Jensen, K.; Clark, C.D.; Ellis, P.; English, B.; Menard, J.; Walsh, M.; Ugarte, D.D.L.T. Farmer willingness to grow switchgrass for energy production. *Biomass Bioenergy* **2007**, *31*, 773–781. [CrossRef]
18. Qualls, D.J.; Jensen, K.L.; Clark, C.D.; English, B.C.; Larson, J.A.; Yen, S.T. Analysis of factors affecting willingness to produce switchgrass in the southeastern United States. *Biomass Bioenergy* **2012**, *39*, 159–167. [CrossRef]
19. Lynes, M.K.; Bergtold, J.S.; Williams, J.R.; Fewell, J.E. Willingness of Kansas farm managers to produce alternative cellulosic biofuel feedstocks: An analysis of adoption and initial acreage allocation. *Energy Econ.* **2016**, *59*, 336–348. [CrossRef]
20. Fewell, J.E. Essays on Kansas Farmers' Willingness to Adopt Alternative Energy Crops and Conservation Practices. Ph.D. Thesis, Kansas State University, Manhattan, KS, USA, 2013.
21. Biodiesel Magazine. Making Pennycress Pay Off. Available online: http://www.biodieselmagazine.com/articles/2047/making-pennycress-pay-off/ (accessed on 10 January 2019).
22. Oak Ridge National Laboratory (ORNL). Image Gallery Gateway, U.S. Department of Energy Office of Biological and Environmental Research. Available online: https://public.ornl.gov/site/gallery/highressurvey.cfm (accessed on 10 January 2019).
23. Blamey, R.K.; Bennett, J.W.; Morrison, M.D. Yea-Saying in Contingent Valuation Surveys. *Land Econ.* **1999**, *75*, 126. [CrossRef]
24. NASS USDA. 2017 Census of Agriculture. Available online: https://www.nass.usda.gov/Publications/AgCensus/2017/index.php (accessed on 1 June 2020).
25. Heckman, J.J. Sample Selection Bias as a Specification Error. *Econometrica* **1979**, *47*, 153. [CrossRef]
26. Van de Ven, W.P.; Van Pragg, B.M. The demand for deductibles in private health insurance: A probit model with sample selection. *J. Econom.* **1981**, *17*, 229–252. [CrossRef]
27. Harper, D.; Kim, J.-O.; Mueller, C.W. Introduction to Factor Analysis: What It Is and How to Do It. *Contemp. Sociol. A J. Rev.* **1980**, *9*, 562. [CrossRef]
28. Kim, J.O.; Mueller, C.W. *Factor Analysis: Statistical Methods and Practical Issues*; SAGE Publications: Thousand Oaks, CA, USA, 1978.
29. Kaiser, H.F. The varimax criterion for analytic rotation in factor analysis. *Psychometrika* **1958**, *23*, 187–200. [CrossRef]
30. Bartlett, M.S. The effect of standardization on a X2 approximation in factor analysis. *Biometrika* **1951**, *38*, 337–344.
31. DiStefano, C.; Zhu, M.; Mindrila, D. Understanding and using factor scores: Considerations for the applied researcher applied researcher. *Pract. Assess. Res.* **2009**, *14*, 20.
32. Thomson, G.H. *The Factorial Analysis of Human Ability*; University of London Press: London, UK, 1951.
33. STATA. *Release 16*; StataCorp: College Station, TX, USA, 2019.
34. Greene, W. *Econometric Analysis*, 8th ed.; Pearson Education: New York, NY, USA, 2018.
35. Krinsky, I.; Robb, A.L. On Approximating the Statistical Properties of Elasticities. *Rev. Econ. Stat.* **1986**, *68*, 715. [CrossRef]