RR 22-001

FARMER VIEWS ON ADOPTION OF PENNYCRESS AS ENERGY FEEDSTOCK

RESULTS FROM THE 2020 PENNYCRESS SURVEY

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EXECUTIVE SUMMARY

Pennycress is a novel winter oilseed crop. It can be used as a biofuel feedstock for producing sustainable aviation fuel (SAF). This study assessed crop farmer views on growing pennycress and other winter oilseed crops as aviation biofuel feedstocks. An email invitation to complete a web survey was sent by Farm Journal to 14,000 row-crop farmers in Alabama, Arkansas, Illinois, Kentucky, Missouri, Mississippi and Tennessee in February and March 2020. The survey questionnaire also asked farmers about their farm characteristics and demographics.

A total of 224 farmers agreed to participate in the survey and answered at least one of the survey questions. The response rate over the 14,000 farmers from the seven states was 1.6 percent. The response rate was close to other email surveys sent by Farm Journal. More than a third (34 percent) of 213 respondents to the question on whether familiar with pennycress reported that they were somewhat or very familiar.

More than half (55 percent) of 206 respondents to the question on whether interested in planting pennycress indicated so. The farmer interest was positively correlated with importance rating of “additional source of farm income” ($P<0.01$) and negatively correlated with agreement rating of “reluctant about adopting new production methods or crops until seeing them working for others” ($P<0.05$).

Of the 114 respondents answering the question on whether they were willing to grow pennycress, about three-fifths (61 percent) were willing to do it at the offered price. Farmers’ willingness to grow pennycress was positively correlated to the offered price ($P<0.01$). In addition, more than four-fifths (82 percent) of those indicating interest in growing pennycress would do so under contracts.

“Profitability of growing pennycress compared with other farming alternatives” and “concern about the market for pennycress as an energy crop” were the most important obstacles to interest in growing pennycress. “Additional source of farm income” was the most important incentive, followed by “reduce erosion on farm.” Less than four-fifths (73 percent) showed their agreement levels for risk attitudes of pennycress adoption. Most of them agreed that “they are more willing to take financial risks than others;” the rest consented that “they are reluctant about adopting new production methods or crops until they see it work for others” or “they are more concerned about a large loss to farming operation than about missing a substantial gain.”

The most frequently used information sources farmers used to learn about pennycress and other winter oilseed crops was farmer or commodity magazines, followed by other farmers, friends or neighbors. This suggests more outreach by university Extension through workshops or field days could inform farmers how to grow pennycress and provide them greater access to pennycress information.

INTRODUCTION

The consumption of jet fuel for transportation in the U.S. was 636 million barrels with total expenditures of $53 billion in 2019 (US EIA, 2019). Jet fuel expenditures are the single largest operation cost for the aviation industry (Tao et al., 2017; Markel et al., 2018). Due to increasing uncertainty about costs for jet fuel, the U.S. Air Force has set a goal for all aircraft and systems to use a 50:50 blend of fossil-based and alternative fuels by 2025 (Blakeley, 2012; Tao et al., 2017; Lane, 2014). The purpose is to ensure that half of the domestic aviation fuel used by the Air Force comes from an alternative fuel source (Blakeley, 2012; Tao et al., 2017; Lane, 2014). The Energy Independence and Security Act of 2007 (EISA) also set goals of renewable transportation fuel consumption to 136 million cubic meters by 2022 to relieve dependence on imported oil, avoid price uncertainty and reduce greenhouse gas (GHG) emissions (Fan et al., 2013; Kim and Dale, 2005; Urbanchuk, 2001; US EPA, 2010; Zhou et al., 2015).

Pennycress (*Thalaspi arvense L.*) is a novel winter oilseed crop that can be used as a biofuel feedstock for producing sustainable aviation fuel (SAF). Pennycress seeds contain up to 36 percent oil content, almost twice the oil content of soybean (Fan et al., 2013). Harvested seeds from pennycress can be crushed and processed into bio-oil that can be further processed into Hydroprocessed Esters and Fatty Acids (HEFA) fuel for the aviation industry (Markel et al., 2018; Moser et al., 2009). Pennycress meets the feedstock requirements for biodiesel production under the United States American Society for Testing and Materials D6751 regulation (Alhotan et al., 2017; Markel et al., 2018; Miller et al., 2012; Moser et al., 2009; Trejo-Pech et al., 2019). Thus, pennycress is being considered as a feedstock for sustainable aviation fuel production.

Wild pennycress is widely found throughout the U.S. (Fan et al., 2013; Moser et al., 2009; Markel et al., 2018; Centre for Agriculture and Bioscience International (CABI), 2016). Field pennycress germinates in the fall and flowers in the spring of the next year. Unimproved pennycress can produce prolific seed yields of up to 2,200 pounds per acre (Carr, 1993; Fan et al., 2013; Isbell and Chermak, 2010; Markel et al., 2018; Phippen and Phippen, 2010). Pennycress has the potential to be adopted as a winter cover crop for farmers to make extra profits from supplying oilseeds for processing into sustainable aviation fuels. For example, pennycress can be added as a double crop with soybeans in a two-year rotation of corn and soybeans (Markel et al., 2018; Trejo-Pech et al., 2019). The corn-soybean rotation is practiced by most row-crop farmers in the U.S. Planting pennycress as a winter crop may also improve soil quality through increased soil surface residues, enhanced soil organic matter and moisture, reduced soil erosion, and diminished weed and pest pressures (Archer, 2016; Markel et al., 2018; Trejo-Pech et al., 2019).

Notwithstanding the potential benefits of pennycress, farmer's willingness to include pennycress in their crop mix is unknown. The future of pennycress as a feedstock for sustainable aviation fuels depends greatly on farmer perceptions of the potential benefits, costs and barriers related to adding the crop to their farming operation. The information contained in this report summarizes responses to a web survey about pennycress production that was sent to farmers in Alabama, Arkansas, Illinois, Kentucky, Missouri, Mississippi and Tennessee in February and March 2020. Findings contained in this report about farmer willingness to grow pennycress as a bioenergy crop and their potential concerns about adopting the crop should be useful to researchers and stakeholders to estimate a potential pennycress supply chain and the associated economic feasibility. In addition, the report provides information that should be useful for university Extension and industry personnel for developing effective outreach materials about pennycress as a potential winter oilseed crop alternative.

METHODS

Data were collected from an internet survey of row-crop farmers in seven states including Alabama, Arkansas, Illinois, Kentucky, Missouri, Mississippi and Tennessee. The email invitation to take the survey and the survey web link was sent to 14,000 corn, cotton or soybean farmer subscribers to the Farm Journal (Ag Web). The invitation to take the survey was sent to farmers three times in 2020: February 22, March 11 and March 28.

The survey included a cover letter explaining the purpose, brief information on pennycress and a questionnaire (arec.tennessee.edu/research/beag/). Farmers were asked questions related to: 1) their interest in pennycress production if it is profitable; 2) their opinions about pennycress production; 3) financial information related to their farming operation; 4) farm and primary farm decision maker characteristics and demographics; and 5) their risk attitude towards adopting new crops or technologies (Zhou et al., 2021). In addition, farmers who showed interest in planting pennycress were asked whether they would accept an offered price and be willing to produce it, given estimated production cost. The offered price was randomly selected among five hypothetical values of $0.05, $0.10, $0.15, $0.20 or $0.25/lb, which were based on estimated breakeven price range for pennycress (Trejo-Pech et al., 2019).

A total of 224 responses were obtained from the survey. Statistical analysis was conducted using STATA (StataCorp, 2019) for estimating number of responses and/or observations, means, standard deviations, maximum values and minimum values for each survey question. Spearman correlation coefficients were also estimated using STATA to evaluate factors related to farmer responses for selected survey questions. Farms with corn for grain were used as a comparison for respondent distribution across the seven states between the survey and 2017 U.S. Department of Agriculture (USDA) Census of Agriculture since all farms contain a variety of croplands — not only for grains but also for fruits, vegetables, etc.

RESULTS

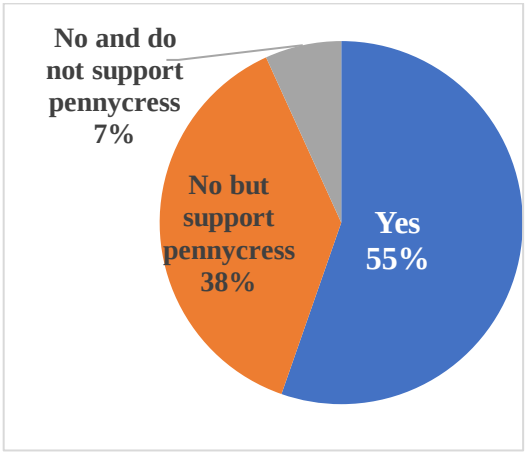
Survey Response Rate for the Seven States

The survey response rate for the seven states was 1.6 percent, calculated from the 224 survey respondents who participated in the survey and divided by the 14,000 crop farmers to whom the web survey was sent within the seven states. This response rate is similar to ones of other email blasts conducted by Ag Web.

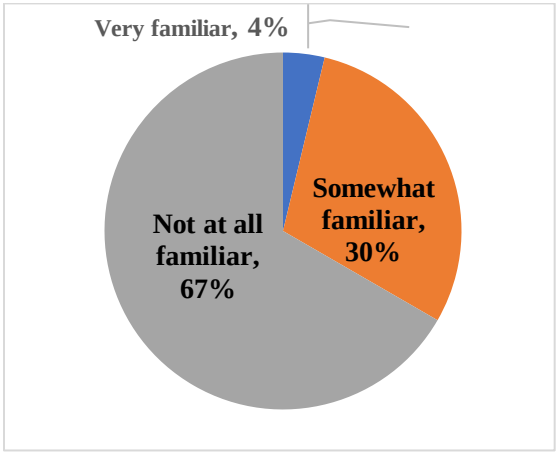
Farmer Interest and Familiarity with Producing Pennycress

Of the 224 survey respondents, 206 (92 percent) answered the question about whether they are interested in producing pennycress and other winter oilseed crops if profitable. More than half of the farmers answering the question (55 percent, 114 respondents) indicated that they were interested in producing pennycress and other winter oilseed crops if profitable. Another 38 percent (78 respondents) of farmers were not interested in growing pennycress, but they supported planting the crop as a feedstock for sustainable aviation fuel. Only 7 percent (14 respondents) of farmers were not interested in producing pennycress, and they did not support planting it (Figure 1, Panel A). Survey results indicated that most (93 percent) of the 206

respondents were interested in planting pennycress if it was profitable or supported planting of pennycress as feedstock for sustainable aviation fuels (Figure 1, Panel A).



Panel A: Interest in growing pennycress (n=206)[a]



Panel B: Familiarity with pennycress (n=213)

Figure 1. Farmer Interest in Growing Pennycress Versus Farmer Familiarity with Pennycress.

[a]The specific wording for the three choices that farmers were asked to choose from on the survey: Yes—Yes, interested in producing pennycress; No but support pennycress—No, not interested, but support planting pennycress as a feedstock for sustainable aviation fuel; or No and do not support pennycress—No, not interested and do not support planting pennycress as a feedstock for sustainable aviation fuel.

Farmer answers to two opinion and risk attitude questions were most associated with their interest in growing pennycress. Farmers who ranked "additional source of farm income" higher on a scale of 1 to 5 (1=not at all, 2=not very, 3=somewhat, 4=very or 5=extremely) in the survey were more likely to indicate that they were interested in growing pennycress (Spearman correlation rho= 0.3102, $P<0.01$). Meanwhile, the less that farmers agreed on a scale of 1 to 5 with "reluctant about adopting new production methods or crops until seeing them working for others," the more likely they were to be interested in growing pennycress (Spearman correlation rho= -0.2072, $P<0.05$). Complete results for the additional source of farm income and reluctance to adopt questions are described in the Barriers and Motivations to Growing Pennycress and Farmer Risk Attitude sections of the results.

Of the 224 survey respondents, 213 (95 percent) farmers responded to the question on how familiar they were with pennycress and other winter oilseed crops prior to this survey. Two-thirds (67 percent, 142 respondents) of the farmers answering the question indicated that they were not familiar with the crop at all. Another 30 percent (63 respondents) of farmers expressed being somewhat familiar while the rest (4 percent, 8 respondents) were very familiar with pennycress (Figure 1, Panel B). Thus, only 34 percent (71 respondents) of farmers were familiar or somewhat familiar with pennycress and other winter oilseed crops, compared with 55 percent interested in planting them if profitable (Figure 1, Panel B). Survey results indicate educational

outreach efforts may be very important to provide farmers information about the potential of winter oilseed crops as an additional crop enterprise for their farms.

Farmer Willingness to Grow Pennycress

Half of the 224 farmers (51 percent, 113 respondents) replied to one of the five randomly offered pennycress prices of $0.05, $0.10, $0.15, $0.20 or $0.25/lb, given estimated production cost of $109/acre for projected average yield of 1600 lbs./acre ranging from 800 to 2,400 lbs./acre. Six of 10 responding farmers (61 percent, 70 respondents) accepted the randomly offered pennycress price and indicated their willingness to grow pennycress at that price. Meanwhile, the rest of the farmers (39 percent, 44 respondents) did not agree with the price offered and indicated that they were not willing to grow pennycress at the offered price.

As expected, farmer willingness to grow pennycress was positively associated with the offered price (Spearman correlation rho= 0.3703, P<0.01). Farmers were more likely to accept the price and indicate that they would grow pennycress with higher offer prices except $0.20/lb (Figure 2). Only 29 percent of farmers (seven out of 24 respondents) offered the lowest price of $0.05/lb indicated that they were willing to grow pennycress at that price; whereas, 83 percent of farmers (19 out of 23 respondents) offered the highest price of $0.25/lb signaled they would grow pennycress at that price. Average area that farmers said they would plant in pennycress if they accepted the offer price was similar across prices with 116 acres at $0.05/lb and 129 acres at $0.25/lb (Table 1). In general, farmers who did not accept the offered pennycress price, indicated that they would require much higher prices before they would be willing to grow the

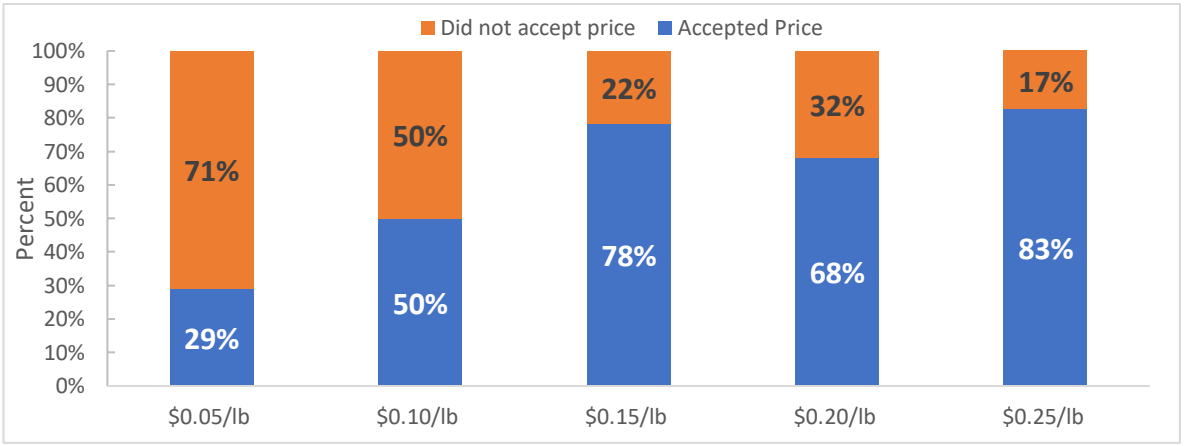


Figure 2. Percentage of Farmer Respondents Who Accepted (did not accept) the Price Offered for Pennycress Oilseed (number of respondents to $0.05, $0.10, $0.15, $0.20 and $0.25 offer prices were 24, 22, 23, 22 and 23, respectively).

crop (Table 1). Farmer willingness to grow pennycress was positively correlated to their importance rating of pennycress production as an additional source of farm income (described in the section of Opinion Questions, Spearman correlation rho= 0.2346, P=0.06). Specifically,

the more important farmers perceived pennycress production as a potential source of additional farm income, the more likely farmers were willing to indicate that they would grow it. An in-depth statistical analysis of factors affecting farmer responses to pennycress price offers is in Zhou et al. (2021).

Table 1. Statistics for Farmer Responses to Five Pennycress Oilseed Offer Prices

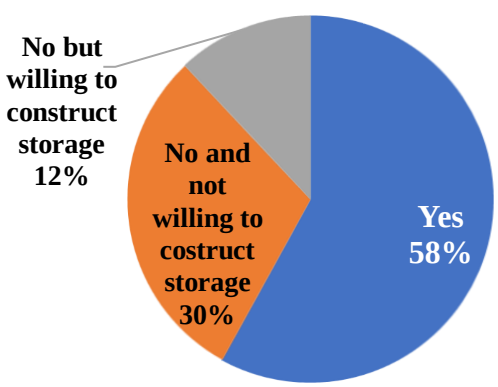
Item	N†	Mean	Standard Deviation	Minimum	Maximum
$0.05/lb Offered			*7 Agree and 17 Disagree*		
Acres farmers were willing to plant at $0.05/lb?	7	116	173	5	500
If not agree with $0.05/lb. At what price?	12	0.33	0.41	0.10	1.50
Acres farmers would be willing to plant?	13	121	144	20	500
$0.10/lb Offered			*11 Agree and 11 Disagree*		
Acres farmers were willing to plant at $0.10/lb?	11	160	283	10	1000
If not agree with $0.10/lb. At what price?	10	0.25	0.10	0.15	0.50
Acres farmers would be willing to plant?	10	83	52	8	200
$0.15/lb Offered			*18 Agree and 5 Disagree*		
Acres farmers were willing to plant at $0.15/lb?	17	91	111	1	400
If not agree with $0.15/lb. At what price?	5	0.31	0.11	0.20	0.45
Acres farmers would be willing to plant?	5	340	261	200	800
$0.20/lb Offered			*15 Agree and 7 Disagree*		
Acres farmers were willing to plant at $0.20/lb?	15	113	91	28	300
If not agree with $0.20/lb. At what price?	5	0.38	0.07	0.32	0.50
Acres farmers would be willing to plant?	5	206	140	50	400
$0.25/lb Offered			*19 Agree and 4 Disagree*		
Acres farmers were willing to plant at $0.25/lb?	19	129	127	20	500
If not agree with $0.25/lb. At what price?	4	0.40	0.07	0.35	0.50
Acres farmers would be willing to plant?	4	182	221	17	500

† N is the number of responses. Any observation with a value of zero was not included in the calculation of statistics but was counted for the number of observations.

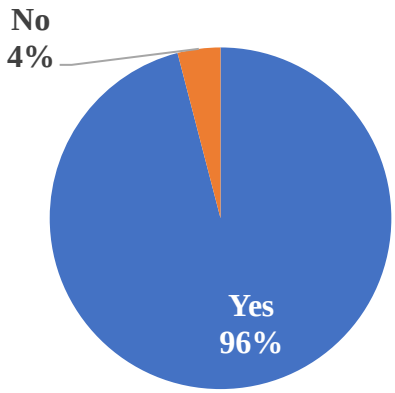
Pennycress Storage and Contracting

The ability of farmers to store pennycress oilseed after harvest may be an important consideration related to farmer willingness to grow the crop. A total of 106 of the 224 farmers reported whether they have existing storage bins where pennycress oilseed could be stored. Of the 106 respondents, 58 percent (61 respondents) reported they had bins, whereas 12 percent (13 respondents) reported they did not but indicated that they would be willing to construct bins. The other 30 percent (32 respondents) of the 106 farmers indicated that they did not have bins and would not be willing to construct one to store pennycress (Figure 3, Panel A).

Farmers were also asked about their willingness to store pennycress if they were compensated for storage costs. A third (74 respondents) of the 224 survey respondents answered the question. Of the 74 respondents, 96 percent (71 respondents) would be willing to store pennycress if compensated, with 58 percent of the 74 farmers saying they had existing bins that could be used to store the oilseed (Figure 3, Panel B). The average time that farmers indicated that they would be willing to store pennycress was 95 days (66 respondents answering the question).



Panel A: Have storage for pennycress (n=106)

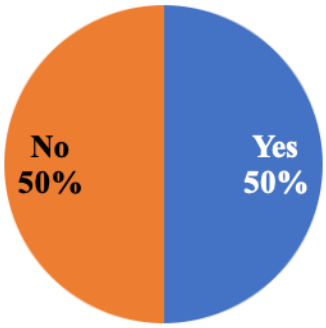


Panel B: Store pennycress on farm if reasonably compensated (n=74)

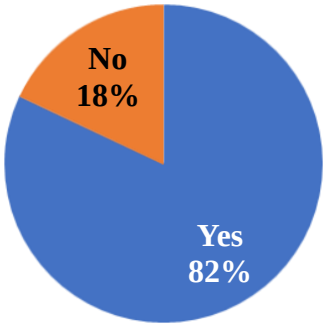
Figure 3. Percentage of Respondents Who Had Bins to Store Pennycress and Were Willing to Store Pennycress if Storage Cost Was Compensated.

Production contracts may also motivate farmer willingness to grow pennycress. Farmers were asked about their experience with producing commodities under production contracts with 166 of the 224 the farmers in the sample responding. Half (50 percent) of the responding farmers indicated that they had experience with production contracts and the other half did not

(Figure 4, Panel A). Farmers were also asked whether they would prefer to grow pennycress under production contracts and for how long they would like to have the contract. Of the 100 farmers responding to the question, 82 percent indicated that they would grow pennycress under a contract (Figure 4, Panel B). The average production contract length preferred by farmers averaged 2.44 years with a range of one to 10 years.



Panel A: Prior experience producing commodities with production contracts s (n=166)



Panel B: Prefer contract to grow pennycress (n=100)

Figure 4. Respondents Who Preferred to Grow Pennycress Under Production Contracts Compared With Percentage Who Accepted the Offered Price for Production Store Pennycress if Storage Cost Was Compensated.

Pennycress Information Sources

Almost one-third (31 percent, 69 respondents) of the 224 survey respondents reported one or more information sources they used to learn about pennycress and other winter oilseed crops. Eleven source options were provided such as magazine, other mess media, Extension, etc. (Table 2). The 69 farmers gave a total of 170 answers (Table 2). The information source which farmers used most frequently was farmer or commodity magazines, followed by other farmers, friends or neighbors and then university research stations or other university sources.

Table 2. Sources Used By Farmers to Obtain Information on Pennycress and Other Winter Oilseed Crops

Information Sources	Number of Answers	% of 69 Respondents[a]	% of Total Answers
1. Farmer or commodity magazines	54	78%	32%
2. Other mass media (internet, radio, TV, newspapers, magazines)	14	20%	8%
3. Extension	14	20%	8%
4. University research stations or other university sources	20	29%	12%
5. Federal agricultural agency (for example, USDA, NRCS)	11	16%	6%
6. State agricultural agency	3	4%	2%
7. Farmer or commodity organizations	14	20%	8%
8. Crop consultant	8	12%	5%
9. Other farmers, friends or neighbors	22	32%	13%
10. Input suppliers	6	9%	4%
11. Other	4	6%	2%
Total Answers	170		

[a] The 69 Respondents gave 170 answers because each respondent could check more than one information source.

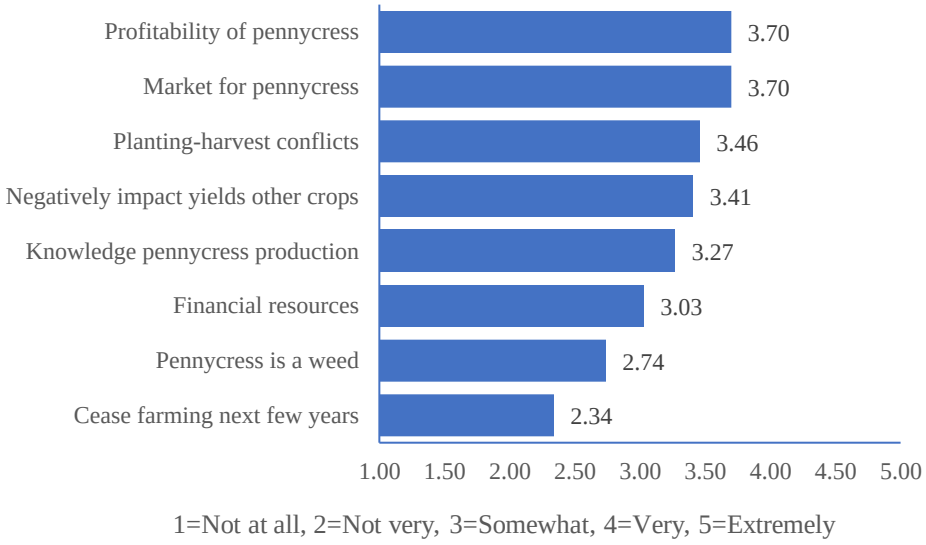
Farmer Participation in University Workshops or Field Days

Farmer participation in university Extension workshops or experiment station field days in 2019 was reported by less than three-quarters (74 percent, 166 farmers) of the 224 survey respondents. On average, farmers attended 1.5 workshops or field days with 12 workshops attended at most and one at least.

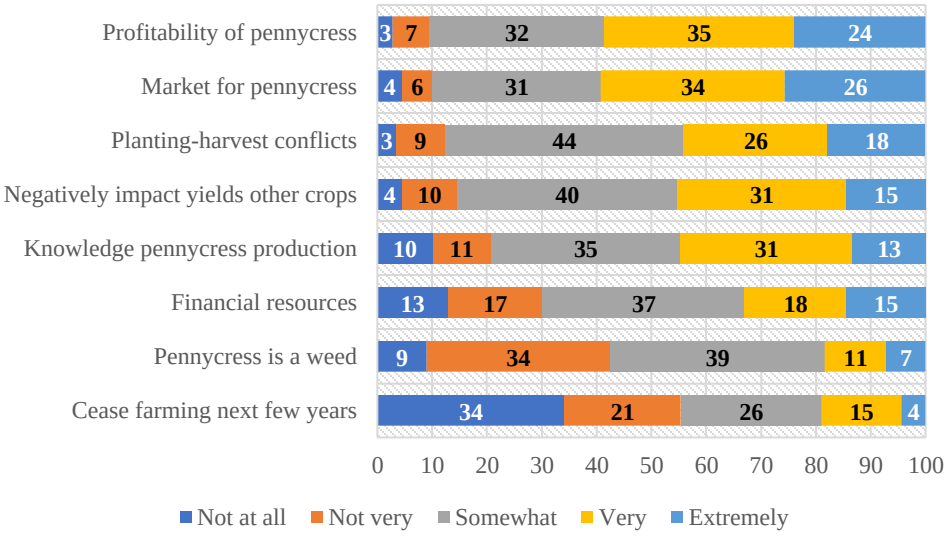
Barriers and Motivations to Growing Pennycress

The survey queried farmers about barriers to growing pennycress as a winter oilseed crop on their farm. A total of 179 of the 224 survey respondents answered the questions about barriers to growing pennycress (Figure 5, Panel A). Each respondent made a single choice among the five levels of importance (1=not at all, 2=not very, 3=somewhat, 4=very or 5=extremely) for the eight concerns/barriers. The most important barriers to growing pennycress were the profitability of pennycress compared with other farming alternatives and concern about the market for pennycress as an energy crop. Farmers gave the two barriers an average rating of 3.70 on a scale of 1 to 5 with about 60 percent of respondents rating the two barriers as very or extremely important (Figure 5, Panel A). Farmers were less concerned about financial resources and equipment to grow pennycress and perceptions that pennycress is a weed. Less than 20 percent of respondents indicated that they were concerned about pennycress as a weed problem or indicated that they were going to cease farming in the next few years (Figure 5, Panel B).

Farmers were also asked about their potential motivations for growing pennycress as a winter oilseed crop on their farm. A total 176 of the 224 survey respondents rated levels of importance (1=not at all, 2=not very, 3=somewhat, 4=very or 5=extremely) for seven different potential motivating factors (Figure 6, Panel A). Each respondent was asked to make a single choice among the five levels of importance for each potential motivation. The most important motivation for growing pennycress was an additional source of farm income with an average rating of 3.63 on a scale of 1 to 5 (Figure 6, Panel A). A total of 61 percent of the 176 respondents rated the source of additional income as very or extremely important (Figure 6, Panel B). The second-most important motivation was related to reducing soil erosion with an average rating on a scale of 1 to 5 of 3.54 (Figure 6, Panel A). About 56 percent of farmers rated the potential for reducing soil erosion very or extremely important (Figure 6, Panel B). The least important factor that would motivate farmers to grow pennycress was the potential job creation with 22 percent of respondents rating it as very or extremely important.

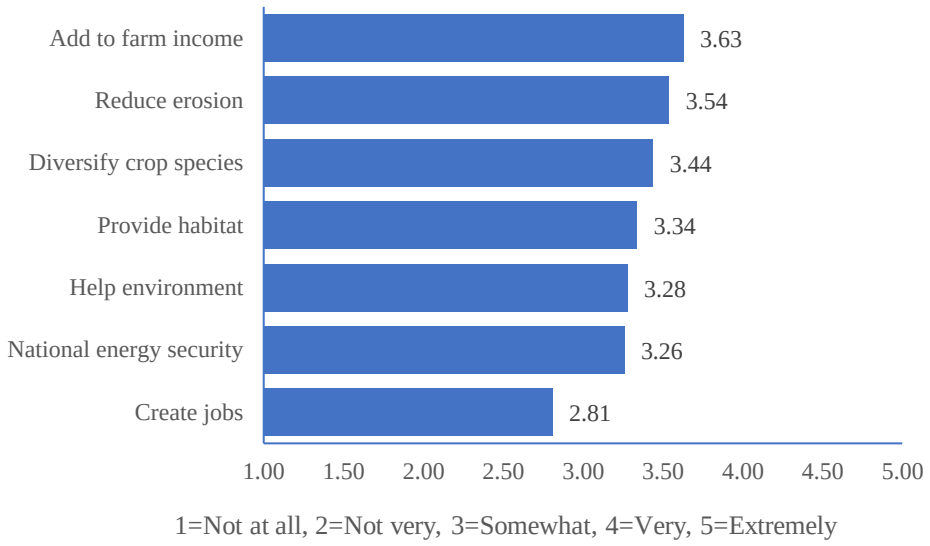


Panel A: Average Ratings by 179 Respondents

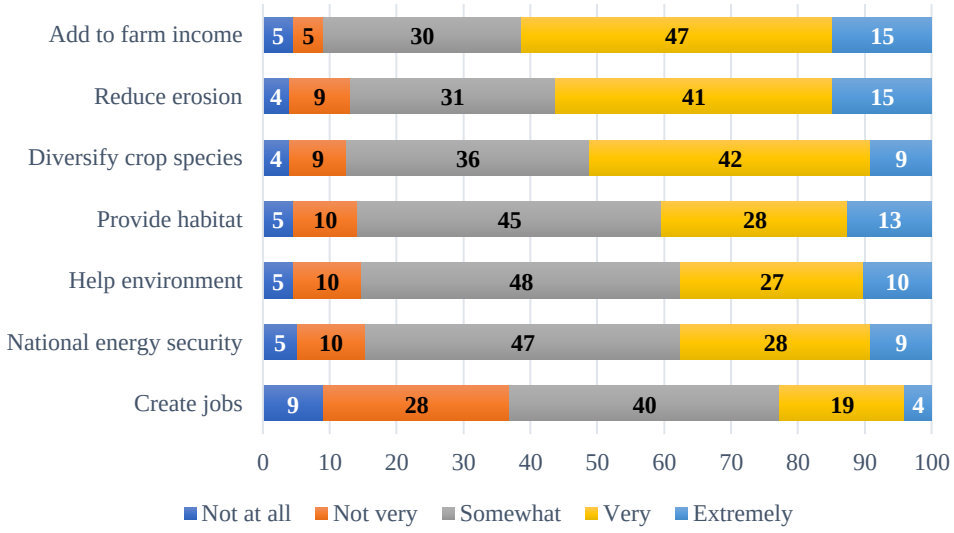


Panel B: Percent of 179 Respondents

Figure 5. Farmer Ratings on a Scale of 1 (not at all) to 5 (extremely) of Barriers Related to Growing Pennycress as a Winter Oilseed Crop on Their Farm (179 respondents).



Panel A: Average Rating by 179 Respondents



Panel B: Percent of 179 Respondents

Figure 6. Farmer Ratings on a Scale of 1 (not at all) to 5 (extremely) of the Potential Motivations to Grow Pennycress as a Winter Oilseed Crop on Their Farm (179 respondents).

Farmer Risk Attitudes

Farmers' attitudes towards risks related to their farming operations may influence their willingness to grow pennycress on their farm. About three-quarters (73 percent, 164 respondents) of the 224 respondents reported their agreement levels on a scale of 1 to 5 (1=strongly disagree; 2=disagree; 3=no opinion; 4=agree; and 5=strongly agree) to the following statements (Figure 7).

- I am the kind of farmer who is more willing to take financial risks than others.
  - 42 percent of farmers agreed or strongly agreed.
  - 52 percent of farmers disagreed or strongly disagreed.
  - Average agreement level of 3.1 on a scale of 1 to 5.
- I am reluctant about adopting new production methods or crops until I see them working for others.
  - 31 percent of farmers agreed or strongly agreed.
  - 69 percent of farmers were indifferent, disagreed or strongly disagreed.
  - Average agreement level of 2.7 on a scale of 1 to 5.
- I am more concerned about a large loss to my farming operation than about missing a substantial gain.
  - 60 percent of farmers agreed or strongly agreed.
  - Average agreement level of 2.7 on a scale of 1 to 5.

Farmers in the sample generally indicated an aversion to large losses on their farming operation (60 percent). However, farmers were generally open to adopting new production methods and crops (69 percent). Farmers who disagreed with the statement that they were "reluctant about adopting new production methods or crops" were more likely to be interested in growing pennycress as reported in the section on Farmer Interest and Familiarity with Producing Pennycress (Spearman correlation rho= -0.2072, $P<0.05$).

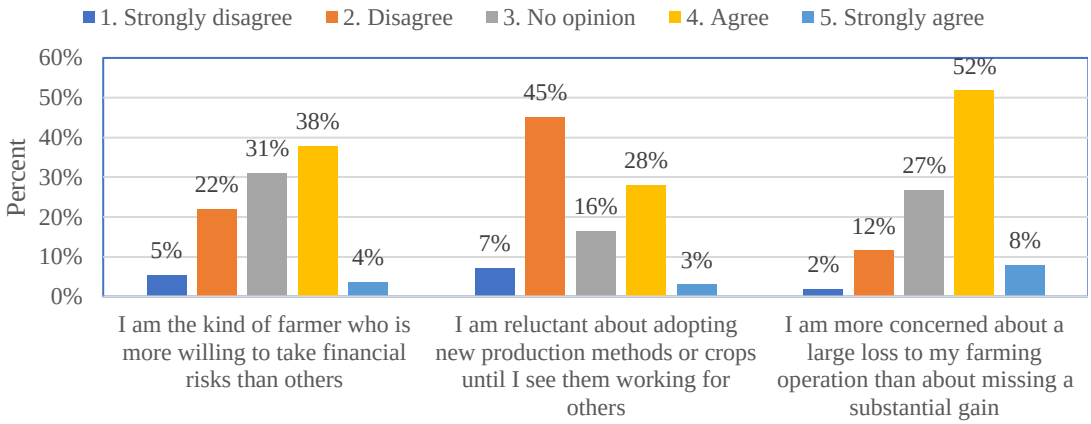


Figure 7. Farmer Ratings on a Scale of 1 (strongly disagree) to 5 (strongly agree) of Their Attitudes Towards Risk on Their Farming Operation (164 respondents).

Farm Characteristics

Farm Location

A total of 174 of the 224 survey respondents reported the state where their farm operations were primarily located. About half of the respondents (53 percent, 93 respondents) were located in Illinois with the rest residing in Missouri (20 percent, 34 respondents), Tennessee (10 percent, 17 respondents), Kentucky (7 percent, 12 respondents), Alabama (3 percent, six respondents), Arkansas (3 percent, six respondents) and Mississippi (3 percent, six respondents) (Figure 8). The percentage distribution of farmer respondents from each state was similar to the percentage distribution of corn farms in each state from the 2017 USDA Census of Agriculture. In addition, percentages of respondents from each state that grew corn and soybeans were also (Figure 8) compared with the percentage of corn farms in each state from the 2017 USDA Census of Agriculture. Percentage distributions for corn and soybean producers of this study were similar to that of corn farms in the 2017 USDA Census of Agriculture. This indicated that the survey respondents may be representative for corn or soybean producers in the seven states.

Crop Farm Characteristics

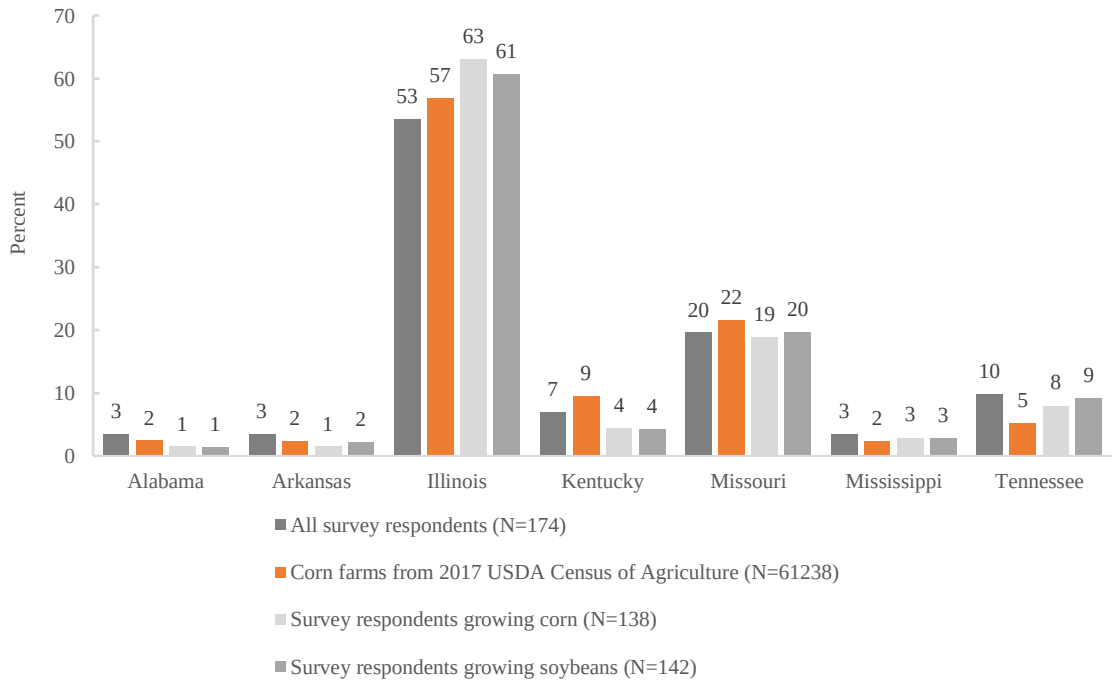


Figure 8. Distribution of Survey Respondents by State Compared with Distribution of Corn Farms by State from the 2017 USDA Census of Agriculture.

About three-quarters (76 percent, 171 respondents) of the 224 survey respondents reported area planted in corn, cotton, soybean and/or other cash crops for 2019 (Table 3). Soybean was the crop most frequently grown by farmers (83 percent, 142 respondents), followed by corn (81 percent, 138 respondents), other cash crops (32 percent, 54 respondents), and cotton (8 percent, 14 respondents). The largest average farm crop area was planted in soybeans, followed by corn and cotton.

Table 3. Crops that Survey Respondents Planted on Their Farms in 2019

Crop Acres	N†	Mean	Standard Deviation	Minimum	Maximum
Corn	138	700	889	7	6,000
Cotton	14	605	589	65	2,000
Soybean	142	728	1125	10	10,500
Other	54	258	387	15	2,200
Aggregate crop acres	161	1382	1817	7	12,000

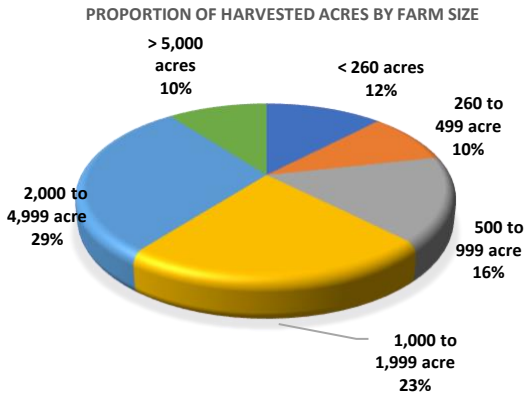
† Number of observations. Any observation with a value of zero was not included in the calculation of statistics but was counted for the number of responses.

Owned and rented crop area in 2019 was reported by 164 of the 224 survey respondents. The average owned crop area was 605 acres and average rented crop area was 897 acres in 2019 (Table 4). The average total farm size in 2019 for farmers in the survey sample was 1,216 acres. Results indicate that farmers who responded to the survey had larger farm sizes on the average than the 351 acres average reported in the 2017 USDA Census of Agriculture for the seven states. Figure 9 illustrated that "less than 500 acres" accounted for 5 percent of the total farm acres for the pennycress survey, compared with 22 percent of the total harvested cropland acres over the seven states from the 2017 USDA Census of Agriculture. Farms sized 1,000 to 1,999 acres made up 35 percent of the pennycress survey sample, compared with 23 percent over the seven states from the 2017 USDA Census of Agriculture. Similarly, farms with more than 5,000 acres were 18 percent of the pennycress survey sample, compared with only 10 percent in the 2017 USDA Census of Agriculture (Figure 9). Results indicated that survey respondents had larger farm sizes than those reported in the Census.

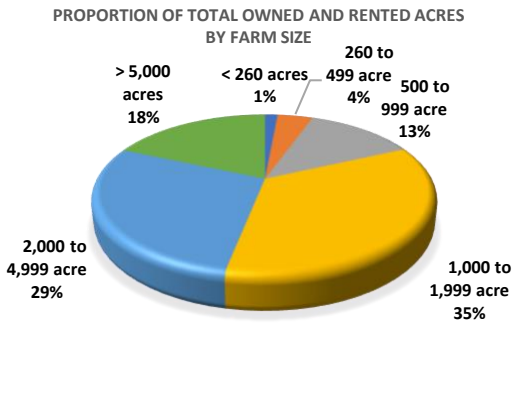
Table 4. Owned and Rented Crop Acres Planted in 2019, Reported by Survey Respondents

Acres	N†	Mean	Standard Deviation	Minimum	Maximum
Owned Acres	142	605	762	10	6,000
Acres rented from others	121	897	1,005	35	5,000
Aggregate owned and rented acres	160	1,216	1,249	10	7,350

† Number of observations. Any observation with a value of zero was not included in the calculation of statistics but was counted for the number of responses.



Panel A: 2017 USDA Census of Agriculture



Panel B: 2020 Pennycress Survey

Figure 9. Comparison of 2017 USDA Census of Agriculture and Pennycress Survey for Proportion of Farm Acres by Size.

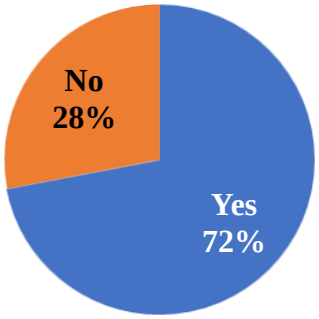
Cropland Rental Rates

More than half (58 percent, 131 respondents) of the 224 survey respondents reported rental rate they paid per acre and/or number of years they rented for farms, or marked "prefer not to answer."

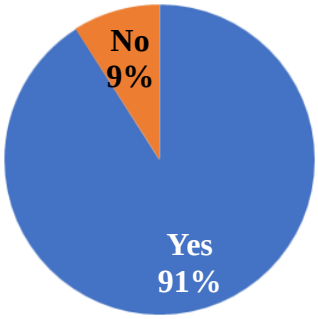
- The average rent paid was $165 per acre with a range from $35 to $290 (59 farmers reporting).
- The average years rented was 19 years with a range of 3 to 41 years (63 farmers reporting).

Farmer Crop Rotation Practices

Of the 224 survey respondents, around three-quarters (76 percent, 170 respondents) reported whether they regularly rotated two or more cash crops on the same field in a planned sequence. Of the 170 respondents, 123 farmers (72 percent) rotated cash crops and 47 (28 percent) did not (Figure 10, Panel A). Then, the follow-up question on whether they rotated soybeans with corn or cotton was answered by 123 respondents, of which, 91 percent confirmed that they did and 9 percent did not (Figure 10, Panel B).



Panel A: Rotate two or more crops in the same field in a planned sequence (n=170)



Panel B: Rotate soybeans with corn or cotton (n=123)

Figure 10. Survey Respondents that Regularly Rotated Two or More Cash Crops and Rotated Soybean with Corn or Cotton.

Farmer Cover Crop Practices

Of the 224 survey respondents, around three-quarters (170 respondents) expressed whether they currently planted winter cover crops that were not harvested. Of the 170 respondents, 77 farmers (45 percent) planted winter covers and 93 farmers (55 percent) did not (Figure 11, Panel A). Respondents (76 farmers) reported cover crop acres for single species legume only (nine respondents), single species non-legume only (50 respondents) or mixture of species (22 respondents) (Table 5). The largest mean cover area was mixture of species, almost the sum of both single species legume and non-legume mean cover acres (Table 5).

Table 5. Acres for Each Cover Species Currently Planted on Farms

	N†	Mean	Standard Deviation	Minimum	Maximum
Cover Crops Not Harvested					
Single species legume only[a]	9	200	153	25	500
Single species non-legume only[b]	50	279	474	20	3000
Mixture of species[c]	22	415	559	5	2000
Cover Crops Harvested					
Single species legume only[a]	2	150	71	100	200
Single species non-legume only[b]	17	178	185	25	800
Mixture of species[c]	6	92	66	10	200

† Any observation with a value of zero was not included in the calculation of statistics but was counted for the number of responses.

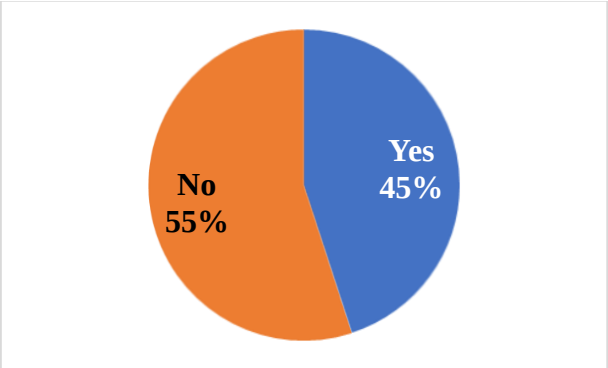
[a] e.g., Austrian peas, crimson clover, hairy vetch or other.

[b] e.g., radish, turnips, winter rye, winter wheat or other.

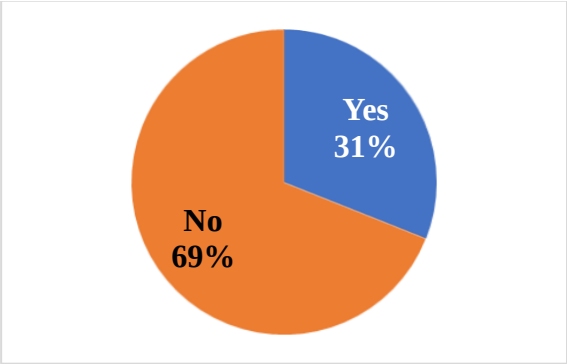
[c] e.g., legume with non-legume species, soil health mix or other.

Of the 224 survey respondents, 77 farmers (34 percent) reported whether they currently planted winter cover crops that were harvested for forage or other on-farm use. About one-third (31 percent, 24 respondents) did and the rest (69 percent, 53 farmers) did not (Figure 11, Panel B). Respondents (22 farmers) filled out cover crop acres for single species legume only (two respondents), single species non-legume only (17 respondents) or mixture of species (six respondents) (Table 5). The largest mean cover area was single species non-legume, followed by single species legume and then mixture of species (Table 5). The estimation results could be biased due to few observations.

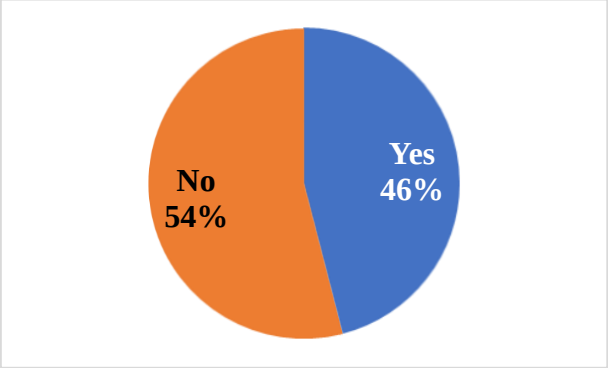
Of the 224 survey respondents, around one-tenth (11 percent, 24 respondents) reported whether they currently double crops with soybean following winter barley, canola, oats or wheat crops, which are harvested for grain or seed. Of the 24 respondents, less than half (46 percent, 11 respondents) rotated soybean with those winter covers, and the rest (54 percent) did not (Figure 11, Panel C). The 11 respondents also reported double crop sequences they currently plant. Of the 11 respondents, more than four-fifths (82 percent, nine respondents) specified soybean-winter wheat, and the rest (two respondents) did other sequences. Finally, 24 respondents reported whether they received government cost-share payments to plant winter cover crops that are not harvested. More than a third (37.5 percent, nine respondents) did and the rest (62.5 percent, 15 respondents) did not (Figure 11, Panel D).



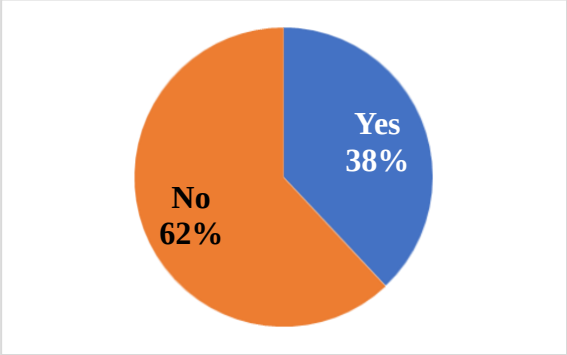
Panel A: Plant cover crops that were not harvested (n=170)



Panel B: Plant cover crops that were harvested for forage or on-farm use (n=77)



Panel C: Double croppped soybeans-wheat (n=24)

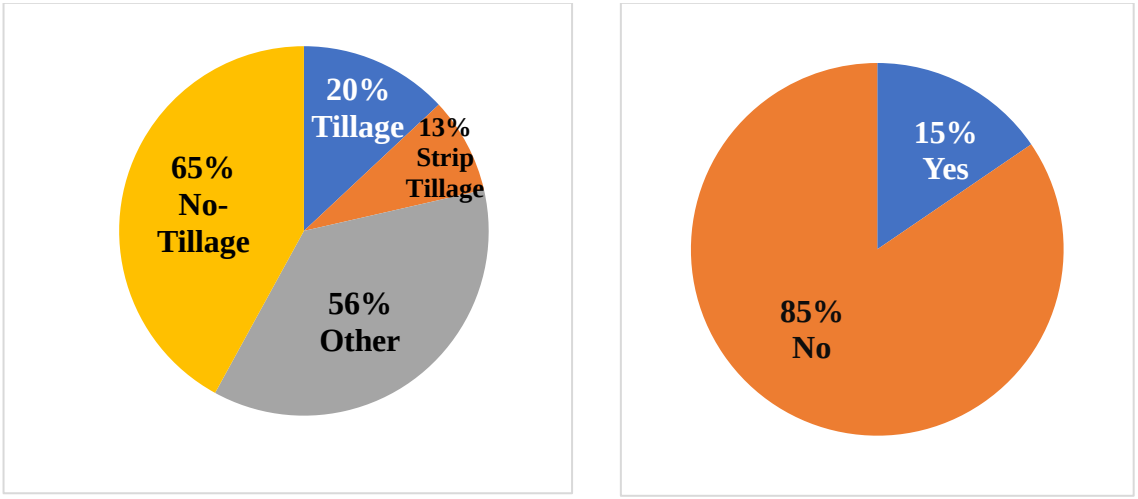


Panel D: Received cost share payments for cover crops that were not harvested (n=24)

Figure 11. Farmers Who Planted Winter Cover Crops and Received Government Cost-share Payments.

Tillage Practices

About two-thirds (69 percent, 155 respondents) of the 224 survey respondents reported crop area in conventional tillage, strip-tillage, other conservation tillage or no-tillage practices. Of the 155 respondents, no tillage (65 percent) accounted for the highest proportion, followed by other conservation tillage (56 percent) (Figure 12, Panel A). The lowest proportion was strip tillage (13 percent). Meanwhile, the largest mean area was strip-tillage, followed by other conservation tillage, and then no tillage and conventional tillage (Table 6). A follow-up question asking whether they received government cost-share payments for no-tillage were answered by 168 respondents. Less than one-fifth (15 percent, 26 respondents) did receive the payments (Figure 12, Panel B).



Panel A: Percentage for farmers using tillage method (n=155)

Panel B: Received government cost-share payments for no-tillage planting (n=168)

Figure 12. Percentages of Farmers Who Used Each Tillage Method and Whether They Received Government Cost Share.

Table 6. Acres of Each Tillage Method Practiced on Farm

	N†	Mean	Standard Deviation	Minimum	Maximum
Conventional tillage	31	615	760	20	3000
Strip-tillage	20	980	913	30	4000
Other conservation tillage	87	752	915	10	5000
No-tillage	100	659	636	15	3600

† Any observation with a value of zero was not included in the calculation of statistics, but was counted for the number of responses.

Irrigation Questions

Three-quarters (168 respondents) of the 224 survey respondents reported whether they irrigated crops. Of the 168 respondents, more than one-tenth (13 percent, 22 farmers) did irrigate crops and the rest (87 percent, 146 farmers) did not (Figure 13). A total of 21 respondents filled out the follow-up question on number of crop acres irrigated on farms. The average irrigated acres were 1,516 acres estimated over a range from 3 to 7,000 acres with standard deviation of 1,968 acres. The more farmers irrigated on farms, the more likely they were interested in planting pennycress and other winter oilseed crops (Spearman correlation rho = 0.0701, $P<0.10$) and the more they were willing to grow them (Spearman correlation rho= 0.0817, $P<0.10$). Farmers who adopt management-intensive technologies such as irrigation may be more willing to adopt new technologies such as winter oilseed crops.

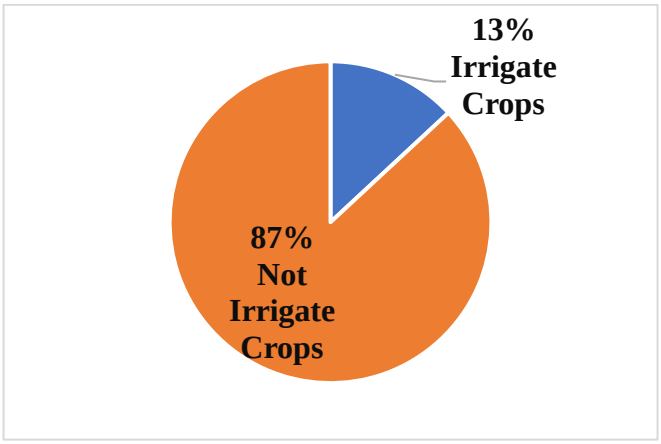


Figure 13. Percentage of Farmers Who Irrigated and Not Irrigated Crops (n=168).

Demographics

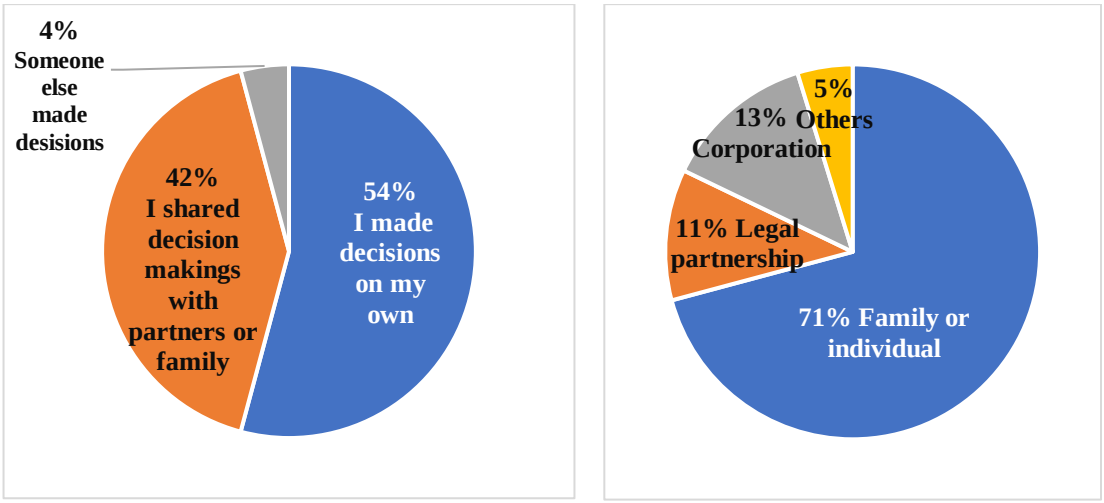
Family Decision Roles and Farming Operation's Legal Status

Family roles in making decisions on which crops to grow on their farms were reported by three-quarters (168 respondents) of the 224 survey respondents.

- 54 percent (91 respondents) made decisions on their own (Figure 14, Panel A).
- 42 percent (70 respondents) shared the decision making with their partners or families.
- 4 percent (seven respondents) depended on someone else for decision making.

Primary farming operation's legal status for tax purposes in 2019 was reported by 168 respondents.

- 71 percent (119 respondents) were family or individual operations (Figure 14, Panel B).
- 13 percent (22 respondents) were organized as corporations.
- 11 percent (19 respondents) were organized as legal partnerships.
- 5 percent (8 respondents) were categorized as other.



Panel A: Farmer family roles in making decisions (n=168)

Panel B: Primary farming operation's legal status for tax purposes in 2019 (n=168)

Figure 14. Farmer Family Roles and Primary Farming Operation's Legal Status.

Income

Farming operation's net income from farming in 2018 was described (before tax) by half (50 percent, 111 respondents) of the 224 survey respondents. Number of respondents and proportion for each income category were compared to those from the 2017 USDA Census of Agriculture (Table 7). The proportions for "Less than $9,999" and "$10,000-$24,999" categories were much lower for this survey than the 2017 USDA Census of Agriculture. Meanwhile, the proportion for "$500,000 or more" was much higher for this survey than the 2017 USDA Census of Agriculture. Thus, this survey was over representative for high-income farmers and less representative for low-income ones.

Table 7. Pennycress Survey Respondents' Farm Operation Net Income Compared With 2017 USDA Census of Agriculture

	Pennycress Survey		2017 USDA Census of Agriculture	
	Number of Respondents†	Proportion	Number of Respondents	Proportion
Farming operation's net income from farming in 2018 (before taxes)	**111**	% of 111	**787,387**	% of 787,387
1. Less than $9,999;	5	5%	223,316	28%
2. $10,000-$24,999;	9	8%	153,619	20%
3. $25,000-$49,999;	16	14%	114,269	15%
4. $50,000 or more	81	73%	296,183	38%

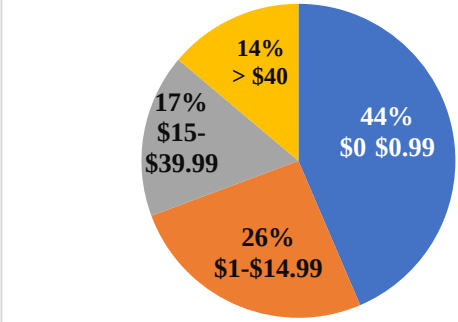
† Totally, 168 respondents answered this question with 57 respondents preferring not to disclose. To be compared with 2017 USDA Census of Agriculture, 111(=168-57) was used as a denominator to calculate percentages.

Every $100 of farm assets for farming operation financed with debt in 2018 were reported by 101 respondents.

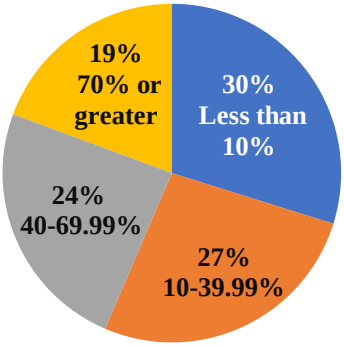
- About four in 10 farmers (44 percent) described their debts as less than $0.99 per $100 of farm assets, accounting for the highest proportion (Figure 15, Panel A).
- The lowest proportion of farmers (14 percent) reported their debts greater than $40 per $100 of assets.

Households' 2018 net income from off-farm sources was reported by 124 respondents.

- Three of 10 farmers (30 percent) earned less than 10 percent of total income from off-farm sources (Figure 15, Panel B).
- Another three-tenths (27 percent) made off-farm income between 10-39.9 percent of total income.
- About one-quarter (24 percent) had off-farm income as 40-69.9 percent of total income.
- The other one-fifth of farmers (19 percent) made off-farm income as 70 percent or more of total.



Panel A: Proportions for How Many Dollars of Every $100 of Farm Assets for Farming Operation Financed with Debt in 2018 (n=101)



Panel B: Proportions for Households' 2018 Net Income from all Sources that Came from Off-Farm Sources (n=124)

Figure 15. Proportions for Farming Operation Financed With Debts and Proportions for Households' Net Income from Off-farm Sources in 2018.

Farmer Age and Education

Farmer ages were reported by 166 of the 224 survey respondents. The average age was 58 years old with the youngest of 20 and eldest of 83. The age distribution for farmers in the sample were compared with data from the 2017 USDA Census of Agriculture (Table 8). The average age from this survey was similar to the 2017 USDA Census of Agriculture average of 59 years old. Proportions from this survey were close to 2017 USDA Census of Agriculture for categories of "Under 35 years," "35 to 44 years" and "45 to 54 years."

Table 8. Pennycress Survey Respondents' Age Compared with 2017 USDA Census of Agriculture

	Pennycress Survey Age		2017 USDA Census of Agriculture Primary Producer Age	
Age Group	Respondents	%	Respondents	%
Total Number	**165**		**2,042,220**	
1) Under 35 years	10	6%	121,754	6%
2) 35 to 44 years	15	9%	207,348	10%
3) 45 to 54 years	28	17%	351,677	17%
4) 55 to 64 years	57	35%	580,769	28%
5) 65 to 74 years	49	30%	498,595	24%
6) 75 years and over	6	4%	282,077	14%
Average years	58		59	

About three-quarters (74 percent, 166 respondents) of the 224 survey respondents reported their highest education levels.

- About four in 10 farmers (39 percent, 65 respondents) had some college or technical school, accounting for the highest proportion of the sample (Figure 16).
- Another three of 10 (28 percent, 46 respondents) had achieved a Bachelor's degree.
- Less than one-fifth (17 percent, 28 respondents) had elementary/middle/high school.
- Less than one-fifth (16 percent, 27 respondents) achieved post graduate or professional degrees.

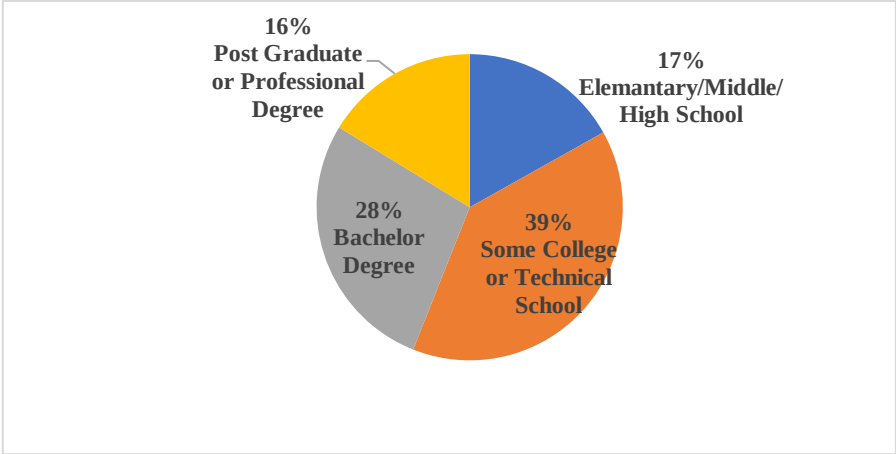


Figure 16. Percentage of Respondents' Education Levels.

Farming Experience

Farming experience was reported by 166 (74 percent) of the 224 survey respondents. The average years in farming was 38 with farmers indicating up to 71 years of experience. Number of respondents and proportions were compared to the 2017 USDA Census of Agriculture (Table 9). For the first category up to 10 years, the number of respondents and proportions were far less for this pennycress survey (6 percent) when compared with data from the 2017 USDA Census of Agriculture (23 percent). For the category of 11 years and above, the respondents and proportions were more for this survey (95 percent) than data from the 2017 USDA Census of Agriculture (77 percent). Thus, our survey was less representative for farmers with less than 10 years of farming experience and over representative for farmers with 10 years and more experience.

Table 9. Pennycress Survey Respondents' Farm Experience Years Compared with 2017 USDA Census of Agriculture

	Pennycress Survey		2017 USDA Census of Agriculture	
	Years of Farm Experience		Primary Producer's Years of Farm Experience	
Age Group	Respondents	%	Respondents	%
Respondents	**166**		**2,042,220**	
10 years or less	10	6%	472,360	23%
11 years or more	156	94%	1,569,860	77%

CONCLUSION

This study evaluated crop farmers' interest and willingness to produce pennycress and other winter oilseed crops as energy feedstocks for sustainable aviation fuels. It also provided information on farmer characteristics and demographics. A web survey was sent by Farm Journal to 14,000 farmers across seven states including Alabama, Arkansas, Illinois, Kentucky, Missouri, Mississippi and Tennessee during February and March of 2020. Statistical analysis was conducted using STATA (StataCorp, 2019) for estimating number of responses, means, standard deviations, maximum values and minimum values for each survey question. Spearman correlation coefficients were estimated using STATA.

In summary, a total of 224 farmers responded to the survey, resulting in a 1.6 percent response rate over the 14,000 farmers from the seven states. While the sample is small, a comparison with the 2017 USDA Census of Agriculture indicated that the proportion of respondents from each state is similar to the proportion of corn farmers in each state from the Census. More than a third of those respondents were familiar or somewhat familiar with pennycress. More than half showed interest in planting if profitable. Some farmers saw it as an additional source of income, while others were hesitant to adopt new production methods until they saw others adopting them.

More than three-fifths of those interested in growing pennycress were willing to do so at the price offered. The willingness was positively correlated to the offered price. As the price increased, farmers were more willing to grow pennycress. In addition, around four-fifths preferred to grow pennycress under production contract with an average contract length of 2.4 years.

Barriers to growing pennycress were "profitability of growing pennycress compared with other farming alternatives" and "concern about the market for pennycress as an energy crop." Motivations to plant pennycress included having an additional source of farm income and reducing erosion on farm.

The most frequently used information source by farmers to learn about pennycress and other winter oilseed crops was farmer or commodity magazines, followed by other farmers, friends or neighbors. University Extension education should enhance factsheets, workshops or field days to provide more opportunities for farmers to learn potential benefits and methods of growing pennycress. In addition, government subsidy programs may need to be implemented to incentivize farmers to plant pennycress or other oilseed cover crops for feedstocks for sustainable aviation fuels.

REFERENCES

Alhotan, R.A., R.L. Wang, R.A. Holser, and G.M. Pesti. 2017. “Nutritive value and the maximum inclusion level of pennycress meal for broiler chickens.” Poultry Science 96: 2281-2293.

Archer, D.W. 2016. “Oilseeds for use in biodiesel and drop-in renewable jet fuel.” Billion-Ton Report: Advancing Domestic Resources for a Thriving Bioeconomy. Department of Energy, Oak Ridge National Laboratory, Oak Ridge, TN.

Blakeley, K. 2012. “DOD alternative fuels: policy, initiatives and legislative activity.” Congressional Research Service, Washington, D.C.

Carr, P. 1993. Potential of Fanweed and Other Weeds as Novel Industrial Oilseed Crops. New Crops. New York: John Wiley & Sons Inc.

Centre for Agriculture and Bioscience International (CABI). 2016. Thlaspi arvense (field pennycress). Centre for Agriculture and Bioscience International. Wallingford, UK.

Fan, J., D.R. Shonnard, T.N. Kalnes, P.B. Johnsen, and S. Rao. 2013. “A life cycle assessment of pennycress (Thlaspi arvense L.) -derived jet fuel and diesel.” Biomass and Bioenergy 55: 87-100.

Isbell, T., and S. Chermak. 2010. “Thlaspi arvense (Pennycress) germination, development and yield potential.” Association for the Advancement of Industrial Crops Conference, September 19-22. Fort Collins, CO: Association for the Advancement of Industrial Crops.

Kim, S., and B.E. Dale. 2005. “Life cycle assessment of various cropping systems utilized for producing biofuels: bioethanol and biodiesel.” Biomass and Bioenergy 29: 426-439.

Lane, J. 2014. “US Navy, DOE, USDA award $210 M for 3 biorefineries and milspecfuels.” Key Biscayne: Biofuels Digest.

Markel, E., B.C. English, C. Hellwinckel, and R.J. Menard. 2018. “Potential for pennycress to support a renewable jet fuel industry.” Ecology, Pollution and Environmental science 1: 95-102.

Miller, P., A. Sultana, and A. Kumar. 2012. “Optimum scale of feedstock processing for renewable diesel production.” Biofuels Bioproducts Biorefining 6: 188-204.

Moser, B.R., G. Knothe, S.F. Vaughn, and T.A. Isbell. 2009. “Production and evaluation of biodiesel from field pennycress (Thlaspi arvense L.) oil.” Energy Fuels 23: 4149-4155.

Phippen, W., and M. Phippen. 2010. “Thlaspi arvense (Pennycress) germination, development and yield potential.” Association for the Advancement of Industrial Crops Conference, September 19-22. Fort Collins, CO: Association for the Advancement of Industrial Crops.

Tao, L., A. Milbrandt, Y. Zhang, and W. Wang. 2017. “Techno-economic and resource analysis of hydroprocessed renewable jet fuel.” Biotechnol Biofuels 10: 261.

Trejo-Pech, C.O., J.A. Larson, B.C. English, and T.E. Yu. 2019. “Cost and profitability analysis of a prospective pennycress to sustainable aviation fuel supply chain in Southern USA.” Energies 12: 3055.

Urbanchuk, J.M. 2001. “An economic analysis of legislation for a renewable fuels requirement for highway motor fuels.” AUS Consultants.

U.S. Environmental Protection Agency. 2010. Crop Production Summary for 2009. Regulation of fuels and fuel additives: changes to renewable fuel standard program. Final Rule. Report Number: EPAeHQeOARe2005e0161. Environmental Protection Agency. Washington, D.C.

U.S. Energy Information Administration. 2019. Jet fuel consumption, price, and expenditure estimates. http://www.eia.gov/state/seds/data.cfm?incfile=/state/seds/sep_fuel/html/fuel_jf.html

Zhou, X.V., C.D. Clark, S. Surendran Nair, S.A. Hawkins, and D.M. Lambert. 2015. "Environmental and economic analysis of using SWAT to simulate the effects of switchgrass production on water quality in an impaired watershed." Agricultural Water Management 160:1-13.
Zhou, X.V., K.L., Jensen, J.A. Larson, and B.C. English. 2021. "Farmer Interest in and Willingness to Grow Pennycress as an Energy Feedstock." Energies 14: 2066.

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