**TABLE OF CONTENTS**

Acknowledgment

Legal Notice

**PROJECT GOVERNANCE AND RESEARCH RELATED ACTIVITIES**

Project Administration and Governance ............................................................................................................ 1

**Objective 3.1 - Agronomic Management**

Objective 3.1.1 - Yield Trade-off Leveraging Corn Relative Maturity and Desiccants (CRM) .... 3

Objective 3.1.2 - Corn Residue Management (DISC) .......................................................................................... 5

Objective 3.1.3 - Novel Seed Treatment for Improved Pennycress Performance (PELLET) ............. 9

Objective 3.1.4 - Tools for Integrated Weed Management (WEEDS) ............................................................. 12

Objective 3.1.5 - Monitor Soybean Cyst Nematode (*Heterodera Glycines*, SCN) in the cropping rotation ........................................................................................................................................ 12

Objective 3.1.6 - Contribute to the identification and development of soybean varieties specifically adapted to pennycress inter-cropping systems (SELECT) .............................................................. 14

**Objective 3.2 - Breeding and Genomics – Pennycress Improvement**

**Southern Breeding Program**

Illinois State University ........................................................................................................................................ 17

Western Illinois University ................................................................................................................................. 18

**Northern Breeding Program**

University of Minnesota ....................................................................................................................................... 25

**Objective 3.3 - Characterization of Pennycress Ecosystem Services**

Illinois State University ........................................................................................................................................ 28

ADDENDUM: Pollinators & Pennycress Ecosystem Services ............................................................................. 36A

**Objective 3.4 - Life Cycle Supply Chain Development** ...................................................................................... 37
EDUCATION, EXTENSION, AND OUTREACH ACTIVITIES

Objective 3.5 – Education and 3.6 Extension and Outreach ..................................................38

FIGURES

Figure 1. Corn yields in replicated pennycress treatments in kilograms per hectares ..............32
Figure 2. Soil organic matter in the north and south fields showing the differences, but there was no effect of pennycress relative to reference plots .................................................................33
Figure 3. Soil nitrate levels in pennycress treatment plots versus reference plots ...............33

PHOTOS

Photo 1. This year, CRM hybrids were hit with disease much harder than other varieties used on ISURF, but yields were still favorable .................................................................5
Photo 2. In contrast to the black-seeded pennycress, golden pennycress seeds can be seen when broadcast on the soil surface .................................................................7
Photo 3. Black-seeded and golden-seeded pennycress germinating in the silage corn plots on Oct. 21, 2021 .........................................................................................................................8
Photo 4. Volunteer corn in the grain plots made visualization difficult prior to our first freeze, which was in November this year ..........................................................................................8
Photo 5. On Nov. 3, 2021, volunteer corn is dead, and pennycress is filling in .................9
Photo 6. PELLET experiment was planted on Oct. 1, 2021. Pelleted pennycress seeds and some crumbed pelletization material were broadcast-seeded into soybean stubble ..........11
Photo 7. Win Phippen and WIU staff planting state trials and other pennycress experiments at ISU, Sep. 24, 2021 ..............................................................................................................20
Photo 8. Planting pennycress plots at WIU. Sep. 25, 2021 ....................................................21
Photo 9. Tad Wesley no-till drilling pennycress plots at WIU, Sep. 25, 2021 ....................21
Photo 10. Filling grain drill with golden pennycress at WIU, Sep. 25, 2021 .....................22
Photo 11. New irrigation system for water pennycress breeding plots at WIU, Sep. 2021 .....23
Photo 12. WIU research farm pennycress plots for 2021-2022 growing season, Oct. 31, 2021..23
Photo 13. Covercress™ production plots from 2021 growing season illustrating seed carryover of black seeded varieties compared to new commercial golden seeded pennycress .................24

Photo 14. Delivery of 2,000 lbs. of dry bulk black seeded pennycress to AURI in Waseca, MN, for seed storage and processing experiments........................................................24

Photo 15. We have a robust stand of pennycress, Oct. 26th, which is the best crop we have had so far..................................................................................................................29

Photo 16. Harvesting silage corn (top) and leaving test strips of 95-day corn to monitor yields (bottom)..............................................................................................................30

Photo 17. Harvesting test strips of corn..........................................................................................................................31

Photo 18. Planting golden pennycress seeds with Nichols Heller..........................................................31

Photo 19. Stands of golden seed pennycress this fall ..........................................................................................32

Photo 20. Aerial view of pennycress in north fields (top) and south fields (bottom)..................35

Photo 21. A rain event showing high water levels..............................................................................................36

EXHIBITS

Exhibit A. IPREFER (Yr. 2) Annual Meeting Evaluation

Exhibit B. Undergraduate student furthers pennycress research during summer internship experience
ACKNOWLEDGMENT

IPREFER is supported by Agriculture and Food Research Initiative Competitive Grant No. 2019-69012-29851 from the National Institute of Food and Agriculture.

NOTICE

This IPREFER project quarterly report was prepared by Western Illinois University (WIU) and IPREFER research colleagues from Agricultural Utilization Research Institute (AURI), CoverCress, Inc. (CoverCress), Illinois State University (ISU), McLean County Soil and Water Conservation District (MCSWCD), Southern Illinois University (SIU), The Ohio State University (OSU), United States Department of Agriculture-Agricultural Research Service (USDA-ARS), University of Illinois (UI), University of Minnesota (UMN), and the University of Wisconsin-Platteville (UW Platteville) in the course of performing academic research supported by Agriculture and Food Research Initiative Competitive Grant No. 2019-69012-29851 from the United States Department of Agriculture National Institute of Food and Agriculture (“USDA-NIFA”).

The opinions expressed in this report do not necessarily reflect those of WIU and IPREFER research colleagues from AURI, CoverCress, ISU, MCSWCD, SIU, OSU, USDA-ARS, UI, UMN, and the UW Platteville and reference to any specific product, service, process, or method does not constitute an implied or expressed recommendation or endorsement of it.

Further, WIU and IPREFER research colleagues from AURI, CoverCress, ISU, MCSWCD, SIU, OSU, USDA-ARS, UI, UMN, and the UW Platteville make no warranties or representations, expressed or implied, as to the fitness for a particular purpose or merchantability of any product, apparatus, or service, or the usefulness, completeness, or accuracy of any processes, methods, or other information contained, described, disclosed, or referred to in this report.

WIU and IPREFER research colleagues from AURI, CoverCress, ISU, MCSWCD, SIU, OSU, USDA-ARS, UI, UMN, and the UW Platteville and the authors make no representation that the use of any product, apparatus, process, method, or other information will not infringe privately owned rights and will assume no liability for any loss, injury, or damage resulting from or occurring in connection with, the use of the information contained, described, disclosed, or referred to in this report.
PROJECT ADMINISTRATION AND GOVERNANCE

We accomplished the following project governance and administrative tasks during the second quarter of Year 2.

1. Planned Activities

- We will hold a (virtual) Year 2 annual meeting on Aug. 10-11, 2021. The meeting will highlight Year 2 accomplishments and organize Year 3 activities.

- We will begin organizing the 3rd IPREFER annual meeting scheduled for Aug. 1-2, 2022.

- We will adjust the size and scope of the IPREFER Advisory board by adding representatives for large-scale producers for both southern and northern regions. Adjust for retiring members.

- We will provide Year 3 funding to subcontractors (collaborators).

- We will use annual meeting evaluations to provide feedback to organizers, collaborators, and Advisory Board members.

- We will prepare a second annual report and USDA NIFA ReEPORT.

- Win Phippen will continue to meet weekly with program manager Anne Kinzel and hold monthly meetings with the Executive Leadership Team (ELT) and quarterly meetings with the Advisory Board.

- We have asked CoverCress to share quarterly commercialization updates with the entire research team. The goal is to identify areas where greater collaboration is needed and to improve the transparency of our commercialization effort.

2. Actual Accomplishments

- We held our Year 2 (virtual) second annual meeting on Aug. 10-11, 2021. Each project objective provided information on their most salient Year 2 accomplishments. The 2021
Undergraduate Interns presented their project in a 5-minute ‘lightning’ style video. Project collaborators also spent time organizing for Year 3. (See Exhibit A)

- We adjusted the ELT and AB membership to account for organizational changes at CoverCress, Inc.
- We started organizing our in-person Year 3 annual meeting at the Danforth Center in St. Louis, Missouri, tentatively scheduled for Aug. 1-2, 2022.
- We have provided Year 3 funding to all subcontractors.
- We posted the undergraduate intern student projects to the IPREFER website (https://www.iprefercap.org/about/2021-undergraduate-research-experience/).
- We completed the second annual report and the USDA-NIFA ReePORT (See https://www.iprefercap.org/resources/reports/#tab-5c1808384e165e4b14a). We provided bound copies to NIFA leadership.

3. **Explanation of Variance**

Western Illinois University is loosening COVID-19 restrictions. Students are free to conduct experiments in the field and in University buildings. Student workers are now fully employed and assisting in field, greenhouse, and laboratory experiments. Travel is approved as long as permission is granted prior to traveling.

4. **Plans for Next Quarter**

- Post a 2022 call for summer interns on the project website
- Finalize protocols for data management deposits to UMN data banks
- Continue working with CoverCress to organize an in-person conference in 2022.

5. **Stakeholder Engagement, Presentations, Publications, and Proposals Submitted**

- **Presentations, Professional Conferences, and Meetings**
  - Phippen, Win. Classroom guest lecturer, AGRI-120 *Agriculture in Today’s Society* regarding pennycress production and the IPREFER project. Fifty undergraduate students participated in 50 min lectures in two class sections. Oct. 13, 2021. We included a laboratory tour demonstrating seed cleaning and chemical analysis equipment.
  - Phippen, Win. Open house demonstration and presentation on pennycress and the IPREFER project at the WIU School of Agriculture to 15 potential incoming
undergraduate students and their parents. Sep. 17, 2021, two 45 min presentations. This included a demonstration of the new plot combine and the IPREFER project.

- **Publications**


**OBJECTIVE 3.1 - AGRONOMIC MANAGEMENT**

1. **Yield Trade-off Leveraging Corn Relative Maturity and Desiccants. (“CRM”)**

   (Objective 3.1.1)¹

   Recent work suggests that corn grain yield and grain moisture at harvest are increased by 88 kg ha⁻¹ (1.4 bu ac⁻¹) and 0.5%, respectively, per one-day increase in corn relative maturity (CRM). Although early-maturing corn hybrids have lower yield potential than full-season counterparts, they can be harvested earlier (e.g., late August). The application of desiccants can further shorten the time for corn to reach harvestability. The team will assess corn and pennycress yield trade-offs through evaluating a range of corn CRM by assessing varieties differing in relative maturity in Ohio, Minnesota, and Illinois during Project Years 1 – 3. Participating Site(s): Minnesota (USDA and RROC), Western Illinois University, Ohio State University, and Illinois State University.

   **A. Planned Activities**

   - Monitor grain moisture in CRMs. Harvest occurs at 16%.
   - Harvest silage ‘check’ plot at ½ milk line, remove all stover, and drill pennycress/Covercress™.
   - Hand harvest for grain CRM plots and process in the lab for yield determinations.
   - Use the combine to clear off the remaining corn, chop, and size residue.
   - Plant pennycress/Covercress™ following each CRM harvest.
   - Assess stand establishment and percent cover prior to freeze up.

---

¹ Russ Gesch (USDA-ARS) leads the CRM team.
- Harvest soybeans in 2020-21 CRM cycle.
- Input all data into a standardized spreadsheet.
- Submit background soil samples (both CRM cycles) for analysis.
- Complete NMR analysis from 2021 harvests.

B. Actual Accomplishments

- All CRMs have been harvested, and pennycress/Covercress™ planted at 4/5 of the sites. Stand establishments have been reported across the network as good.
- Collected corn hand samples and recorded yield determinations.
- Standardized spreadsheets for data are up to date.
- Soybeans from Cycle 1 have been harvested, and yields determined at 4/5 of the sites.
- Soils from each site have been received and processed for background analysis.
- 2021 harvested pennycress/Covercress™ seed have been analyzed by NMR for oil content.
- **Illinois State University**
  - In cycle 1, the double-crop soybeans have been harvested and yields established.
  - In cycle 2, all corn samples were harvested for silage or grain. Pennycress was planted following each harvest date. Data collection on pennycress establishment will happen at the end of fall growth. We have had lots of fall rain and the plots look great (See Photo 1).

C. Explanation of Variance

One 2021-22 CRM site (WIU) was dropped due to poor stand establishment of the corn crop

D. Plans for Next Quarter

- Complete fall stand establishment and percent cover measurements at each site.
- Send corn grain samples from each CRM to Dr. Gesch for quality analysis.
- Complete preliminary analysis on Cycle 1 data.

E. Stakeholder Engagement, Presentations, Publications, and Proposals Submitted
Presented IPREFER research at the 2021 Annual Association for the Advancement of Industrial Crops meeting in Bologna, Italy (Sep. 7, 2021).

Photo 1. In 2021, CRM hybrids were hit with disease much harder than other varieties used on ISURF, but yields were still favorable. 95, 100, and 105-day corn has been harvested here. 110-day and 113-day corn is still standing and much more brown than the corn in the background. (Credit: Nicholas Heller, Illinois State University).

2. Corn Residue Management ("DISC") (Objective 3.1.2)2

Due to ecological and economic benefits, an increasing number of farms are now practicing no-tillage and other conservation tillage farming. Establishing pennycress in no-till fields is a struggle due primarily to the sheer amount of corn residue remaining after harvest. Several corn residue treatments will test the hypothesis that the residue can be sized small enough to not interfere with pennycress establishment. Pennycress establishment and subsequent seed yield in high-residue environments will be compared to reduced-surface stover treatments where its production has proven successful (e.g., silage corn removal and prepared seedbeds). Participating Site(s): Minnesota (USDA and RROC), Western Illinois University, Ohio State University, and Illinois State University.

A. Planned Activities

- Complete NMR analysis on 2021 harvested pennycress seed.
- Harvest soybeans in Cycle 1 plots for yield.

2 DISC is the abbreviation for the IPREFER corn stover management project. Nicholas Heller (Illinois State University) is the DISC research lead.
• Remove corn as silage in half of Cycle 2 plots, wait for grain harvest in the other half of plots.

• Combine grain corn at 16% moisture, sample each plot for yield, and collect subsample for quality (send to Morris, MN USDA).

• Once the grain has been removed, chop the remaining residue and apply vertical tillage.

• Broadcast plant plots with pennycress/Covercress™ at determined rates.

• Collect fall establishment data and enter it into a spreadsheet.

B. Actual Accomplishments

• NMR analysis on 2021 harvested pennycress/Covercress™ is complete.

• Four or five sites have harvested soybeans from Cycle 1 and determined yield, closing out Cycle 1 data collection.

• Corn has been harvested, tillage applied, and pennycress/Covercress™ has been planted at five sites for Cycle 2. In Cycle 2, all corn samples were harvested for silage or grain. Pennycress was planted following each harvest date.

• Fall establishment measurements at the Northern Sites are complete.

• Illinois State University
  o In Cycle 1, the double-crop soybeans have been harvested and yields established.
  o In Cycle 2, all corn samples were harvested for silage or grain. Pennycress was planted on the same date after the grain harvest. All plots were broadcast seeded, and because we have had lots of fall rain, the plots look great. Data collection on pennycress establishment will happen at the end of fall growth (See Photos 2, 3, 4, and 5).

C. Explanation of Variance

None to report at this time.

D. Plans for Next Quarter

• Complete fall establishment measurements at the Southern sites.

• All datasets will be updated and submitted to the project leader.
• Complete preliminary analysis on Cycle 1 data.

Photo 2. In contrast to the black-seeded pennycress, golden pennycress seeds can be seen when broadcast on the soil surface – shown here in a silage corn plot following light vertical tillage. (Credit: Nicholas Heller, Illinois State University). Golden pennycress seeds are shown in the circles.

Photo 4. Volunteer corn in the grain plots made visualization difficult prior to our first freeze, which was in November this year. This photo was taken Oct. 21, 2021, and most of the green seen on top of the corn stover is volunteer corn, our inadvertent cover crop. (Credit: Nicholas Heller, Illinois State University).
Photo 5. On Nov. 3, 2021, volunteer corn is dead, and pennycress is filling in. Broadcast pennycress seeds fell into the crevices left by the vertical tillage tool to a large degree, but pennycress plants are growing in between these “rows,” too. (Credit: Nicholas Heller, Illinois State University).

E. Stakeholder Engagement, Presentations, Publications, and Proposals Submitted

- Heller, Nicholas. Poster. 2021. ASA/CSSA/SSSA Annual Meeting, Salt Lake City, UT, Nov. 7-10. Links to these posters and abstracts are not yet available. Additional information will be included on the website and future reports as it becomes available.


3. Novel Seed Treatment for Improved Pennycress Performance ("PELLET") (Objective 3.1.3)³

The use of seed coating and fungicide treatments in concert with certain strategies may improve establishment, especially if planted in fall when rain can be sporadic. In other species like *Brassica juncea*, hydro-priming (controlled pre-planting hydration) improves germination even in water-stressed environments. Another issue that may impact pennycress

³ “PELLET” is the abbreviation we use for the “Novel Seed Treatment for Improve Pennycress Performance” part of the project. This IPREFER objective is led by Alex Lindsey at Ohio State University.
production is crown disease. Deterioration of the crown may impact maturation, induce lodging, and hamper mechanical harvest. Preventing infection of a pathogen causing crown rot or other seedling pathogens in the fall through the use of seed treatment may improve establishment, crown integrity and minimize losses at harvest due to lodging. A field trial will be established in Ohio, Illinois, and Minnesota to determine the impact of seed treatments on fall establishment, spring crown integrity, and lodging. Participating Sites: Illinois State University, Minnesota (USDA and RROC), Ohio State University, University of Wisconsin-Platteville, and Western Illinois University.

A. Planned Activities

- Reserve land for PELLET studies across a range of residue environments.
- Collect a composite 8” soil sample to characterize the site (analyze for CEC, percent OM, pH, soil P, K, Ca, and Mg – base soil analysis) and send it to OSU for analysis. Also include the information related to the predominant soil series from the Web Soil Survey.
- Send out seed packets and protocols to each location hosting PELLET (10 sites across the network).
- In mid-September, seed envelopes should be broadcast into plots (4 ft x 4 ft), with a 2 ft border around each plot to allow for sampling. One envelope should be used per plot using the provided plot map.
- At planting, assess plots for surface moisture and residue; record the data for each plot.
- Collect counts and percent cover measurements before freeze up.

B. Actual Accomplishments

- The PELLET project established 10 sites across the IPREFER network.
- Composite soil samples from each site have been sent to OSU for site characterization.
- Surface moisture and residue at plant have been recorded for each plot at each site.
- Northern sites have completed fall counts and percent cover measurements.
- **Illinois State University**
  - Following the soybean harvest, the ISU Site was planted in Normal, IL (no-till). Data will be collected when fall growth ceases.
C. Explanation of Variance

One MN site (Saint Paul) was lost due to the presence of wild pennycress and significant winter annual weed pressure.

D. Plans for Next Quarter

- Complete fall establishment sampling at Southern sites.
- Enter all establishment data in a standardized spreadsheet and return the data to OSU for preliminary analysis.

Photo 6. PELLET experiment was planted on Oct. 1, 2021. Pelleted pennycress seeds and some crumbed pelletization material was broadcast-seeded into soybean stubble (shown in the background). (Credit: Nicholas Heller, Illinois State University).

E. Stakeholder Engagement, Presentations, Publications, and Proposals Submitted

None this quarter.
4. Tools for Integrated Weed Management (“WEEDS”) 3.1.4

Where herbicides are used as the primary weed management tool, there will be herbicide residues in the soil that may impact the successful establishment of pennycress similar to the impact that herbicide residues may have on the establishment of more traditional winter cover crops. We will evaluate commercial pennycress varieties for their tolerance to likely concentrations of common corn herbicides that will be found in the soils of pennycress fields. Identifying herbicides to which pennycress is less sensitive will allow us to develop herbicide recommendations for the preceding crop that will decrease the likelihood of pennycress injury or death during its establishment. We will test the effects of common corn herbicides used to control summer annual weeds and quantify pennycress population density and biomass in the fall, survival of plants the following spring, and pennycress seed yield.

A. Western Illinois University

- **Planned Activities**
  - Establish pennycress stands for IR-4 trials.
  - Spray fall PRE-treatments.
  - Rate establishment following fall spray treatments.

- **Actual Accomplishments**
  - Established fall trials.
  - Treatments have been applied.

- **Explanation of Variance**
  None noted at this time.

- **Plans for Next Quarter**
  Establish plants for winter greenhouse herbicide trials.

- **Stakeholder Engagement, Presentations, Publications, and Proposals Submitted**
  None this quarter.

5. Monitor Soybean Cyst Nematode (*Heterodera glycines*, SCN) in the cropping rotation (“SCN”) (Objective 3.1.5)

---

4 Mark Bernards (Western Illinois University) leads the WEEDS Team.
5 Cody Hoerning and Senyu Chen (University of Minnesota) lead the SCN Team.
Minimizing yield trade-offs between pennycress and soybean in a relay cropping system is paramount. Recent research detected sizeable differences in light transmittance-related properties between pennycress crop canopies. This indicates that both canopies represent different stress environments for the relay-planted soybean, potentially requiring different soybean cultivars to be relay-planted. Further, the good performance of the relay-planted soybean cultivars suggests a stronger competitive ability that might decrease the yield potential of the cover crop. Taken together, those findings highlight the possibility of optimizing the cover crop-cash crop associations by identifying summer crop-cover crop cultivar combinations that maximize yields. To address the yield gap, a soybean selection (i.e., SELECT) was initiated fall of 2019 with the bulk planting of pennycress ‘MN106’. A large number of soybean cultivars are slated for relay cropping into the pennycress spring of 2020 with the expressed goal of revealing large variations in soybean yield response to relay planting. A large number of cultivars will, therefore, increase chances to identify uniquely superior cultivars. In addition, such group size will maximize the chances of identifying superior cultivars. Participating Site(s): Minnesota (RROC and USDA).

A. Planned Activities

- Collect yield samples for soybean.
- SCN soil sampling for fall soybean harvest sampling period.
- Process SCN samples for egg counts.
- Preliminary sampling of field sites for new spring site establishment.
- Screen additional pennycress lines for resistance to SCN.
- Continue growth chamber evaluation experiment to examine temperature effects on SCN development on pennycress.
- Analyze data from field and microplot experiments.
- Set up a repeat of the microplot experiment at the Illinois site.
- Plant pennycress in a field experiment at the Illinois site.

B. Actual Accomplishments

- All the above-planned activities for the period were accomplished.
- Agronomic field measurements, yield measurements, and soil sample measurements were taken from field plots.
- SCN soil samples were processed for egg counts.
• Field plots in Illinois were planted with pennycress treatments.
• Microplot repeat experiment was established in Illinois.
• Pennycress germplasm screening occurred for SCN.
• The first run of the growth chamber temperature evaluation experiment was completed.
• Data analysis and manuscript presentation are ongoing.

C. **Explanation of Variance**

All planned activities were accomplished. As was noted in the previous report, the Rosemount field experiment had SCN field population values that were too low to continue the experiment at that site. The experiment at this site was stopped. Another site is being sought to reestablish the experiment in 2022.

D. **Plans for Next Quarter**

• Process fall soil samples for SCN egg counts.
• Process samples from Illinois microplot experiment.
• Continue data analysis and manuscript preparation for previously completed experiments.

E. **Stakeholder Engagement, Presentations, Publications, and Proposals Submitted**

• **Presentations**


6. **Contribute to the identification and development of soybean varieties specifically adapted to pennycress inter-cropping systems (“SELECT”) (Objective 3.1.6)**

Minimizing yield trade-offs between pennycress and soybean in a relay cropping system is paramount. Recent research detected sizeable differences in light transmittance-related properties between pennycress crop canopies. This indicates that both canopies represent different stress environments for the relay-planted soybean, potentially requiring different soybean cultivars to be relay-planted. Further, the good performance of the relay-planted

---

6 Aaron Lorenz (University of Minnesota) leads the SELECT Team.
soybean cultivars suggests a stronger competitive ability that might decrease the yield potential of the cover crop. Taken together, those findings highlight the possibility of optimizing the cover crop-cash crop associations by identifying summer crop-cover crop cultivar combinations that maximize yields. To address the yield gap, a soybean selection (i.e., SELECT) was initiated fall of 2019 with the bulk planting of pennycress ‘MN106’. A large number of soybean cultivars are slated for relay cropping into the pennycress spring of 2020 with the expressed goal of revealing large variations in soybean yield response to relay-planting. A large number of cultivars will, therefore, increase chances to identify uniquely superior cultivars. In addition, such group size will maximize the chances of identifying superior cultivars. Participating Site(s): Minnesota (RROC and USDA).

A. Planned Activities

- Collect field notes on plant height, lodging, shattering, and days to maturation at both sites.
- Harvest soybeans in October for yield determination.
- Plant pennycress for 2021-22 cycle at both locations.
- Run a second replication of growth chamber study on soybean tolerance to pennycress allelopathy.

B. Actual Accomplishments

- Recorded forty traits in the field for 40 soybean genotypes intercropped with pennycress.
- Harvested soybeans for yield in early October, seeds samples were collected for NIR seed quality analysis
- Planted pennycress at Morris and Rosemount, MN for 2021-22 Soyselect activities.
- Conducted stand assessments on pennycress and herbicides were applied for volunteer wheat at Rosemount, MN.
- Completed the second replication of the growth chamber study on pennycress allelopathy.

C. Explanation of Variance

Two of the 12 soybean blocks (1 at each location) were not harvested due to high weed pressure.

D. Plans for Next Quarter
• Compile and analyze yield data from the SOYSELECT locations.

• Scan 2021 SOYSELECT seed samples for protein and oil quality scores.

• Five plants from 480 SOYSELECT plots will be imaged and analyzed for internode number, branch number. Pod counts for main stem vs. side branches will also be taken.

• Initiate a greenhouse experiment to ascertain the genetic architecture underlying soybean tolerance to pennycress glucosinolates.

• Graduate student Lucas Roberts will present a research poster at the Plant and Animal Genome conference in San Diego Jan 8-12, 2022, Characterization and Genetic Variation for Soybean Traits Relevant to a Soybean-Winter Oilseed Intercropping System.

E. Stakeholder Engagement, Presentations, Publications, and Proposals Submitted

• Presentations, Professional Conferences, and Meetings

  o Lucas Roberts presented a short talk at the IPREFER annual meeting on the progress of SOYSELECT on Aug 10-11, 2021.


  o Wells, Samantha. "Emerging Oilseeds: Futures in Biofuels and Beyond?" Invited presentation to the ASA/CSSA/SSSA C6-Crop Sci Symposium on Biofuels: "From Niche Crop to Normal - Challenges and Successes of Novel Crop Adoption." ASA/CSSA/SSSA Annual Meeting, Salt Lake City, UT, Nov. 9, 2021. Dr. Wells’ presentation framed the adoption of pennycress and winter camelina through the lens of the Multi-Level Perspective. He outlined the landscape pressures, regimes, and niche innovators (IPREFER and COVERCRESS) as an upward force addressing landscape pressures to change the regimes (i.e., the American agricultural system). Dr. Wells gave specific advancements in agronomy, breeding, and genetics and addressed that those innovations outside of entrepreneurial energy will fall short and not clear the "valley of death." She used Covercress™, and the Winter Camelina Grower Plot scale-up to illustrate how niche innovations can change the regime.
OBJECTIVE 3.2 - BREEDING AND GENOMICS – PENNYCRESS IMPROVEMENT

Southern Breeding Program

1. Illinois State University

A. Planned Activities

Our research teams have generated high-yielding pennycress breeding lines through multi-state testing and identified/validated trait-improving mutations and natural variants. These were our planned activities for the first quarter (Yr. 3):

- Utilize marker-assisted selection and CRISPR gene editing to complete introgression of these traits into elite breeding lines.

- Extend our replicated yield testing program to a cooperative regional program and rapidly identify the best lines for each Midwest location (IL, MN, OH, WI) in conjunction with a commercial launch.

- Perform field evaluations and seed increases of lines with commercial potential.

- Develop additional genetic/genomic resources for the long-term success of breeding programs.

B. Actual Accomplishments

- We planted over 30 CRISPR-edited lines into the ISU field nursery for evaluation, including single and stacked mutations affecting a variety of compositional and growth traits.

- We continue to gather data on the effects, if any, these various agronomic trait-improving mutations have on plant growth, stress resilience, and seed yields.

- We continue to stack different mutation combinations as well as generate CRISPR-induced mutations in new gene targets.

C. Explanation of Variance

COVID still limits opportunities for in-person attendance and networking at national and international meetings.

D. Plans for Next Quarter

Continue work on the aims stated above.

E. Stakeholder Engagement, Presentations, Publications, and Proposals Submitted
• Stakeholder Engagement

• Presentations, Professional Conferences, and Meetings
  - Sedbrook, John. “Employing CRISPR genome editing to rapidly domesticate pennycress into an oilseed cash cover crop called Covercress.” Invited (virtual) presentation at the American Chemical Society AGRO Division, 262nd ACS National Meeting & Exposition, Aug. 25, 2021.

2. Western Illinois University

A. Planned Activities

- Organize experiments for Fall 2020 planting experiments.
- Analyze data from 2021 summer research projects.
- Design experiments for fall 2021 planting season.
- Hire new undergraduate students to assist with field, greenhouse, and laboratory experiments.
- Collect and distribute seed packets for multi-state trials to be planted in 9 sites: 2 MN, 2 WI, 4 IL, and 1 OH.
- Plant state trials and other pennycress experiments at ISU in Normal IL on Sep. 24, 2021.
- Plant all WIU research starting on Sep. 25, 2021, in Macomb, IL.
Experiments planned include spring-applied nitrogen trials, gibberellic acid seed treatment duration study, replicated variety trials, repeat Teflan herbicide tolerance screen, breeding line seed increases, and evaluate new traits to improve commercialization efforts.

- Plant PELLET study at Macomb for testing seed coat treatments
- Conduct seed depth planting experiment of new reduced stem elongation mutant from UMN.
- Plant a large seed increase of promising triple mutant line from UMN for further experiments.
- Address possible seed carryover experiments between black and golden seeded pennycress.
- Provide seed samples to collaborating institutions and possible new collaborators.

**B. Actual Accomplishments**

- Completed the analysis of data from 2021 summer research projects.
- Designed experiments for the fall 2021 planting season.
- Hired four undergraduate students for the fall and spring semesters to assist with IPREFER projects.
- Coordinated seed collection for state trials. Sent all seed to Covercress™ to receive commercial seed treatment. Organized and distributed top ten breeding line seed packets for multi-state trials to be planted at nine sites: 2 MN, 2 WI, 4 IL, and 1 OH.
- This is the first year three commercial lines from Covercress™ were included in the trials.
- Planted state trials and other pennycress experiments at ISU in Normal, IL, on Sep. 24, 2021 (See Photo 7).
- Plant all WIU research starting on Sep. 25, 2021, in Macomb, IL (See Photos 8, 9, and 10).
- Purchased irrigation system to water pennycress plots. Macomb had received less than ½ in. rain over 60 days.
- Experiments included: spring-applied nitrogen trials, gibberellic acid seed treatment duration study on both black and golden seeded pennycress lines, replicated variety
trials of wild pennycress populations, repeated Teflan herbicide tolerance screen, breeding line seed increases, and evaluation plots of new traits to improve commercialization efforts. Collected data on emergence from all experiments.

- Planted PELLET study from OH at Macomb for testing seed coat treatments. Collected data on emergence and took CANPEO photos to calculate percent ground cover.

- Planted seed depth planting experiment of new reduced stem elongation mutant from UMN. Collected data on emergence.

Photo 7. Win Phippen and WIU staff planting state trials and other pennycress experiments at ISU, Sep. 24, 2021 (Credit: Win Phippen, Western Illinois University).
Photo 8. Planting pennycress plots at WIU. Sep. 25, 2021 (Credit: Win Phippen, Western Illinois University).

• Planted large seed increase of promising triple mutant line from UMN for further experiments.

• Visited last year’s commercial pennycress production site to photograph carryover concerns with black and golden seeded pennycress. Golden seeded pennycress does not have the carryover concerns as are seen with the wild black seeded pennycress populations (See Photo 13).

• Provided seed samples to collaborating institutions and possible new collaborators.

• Sent thick-stemmed and hollow stem mutants to UCONN for lignin analysis.

• Delivered 2,000 lbs. of dry bulk black seeded pennycress to AURI in Waseca, MN, for seed storage and processing experiments (See Photo 14).

Photo 10. Filling grain drill with golden pennycress at WIU. Sep. 25, 2021 (Credit: Win Phippen, Western Illinois University).
Photo 11. New irrigation system for water pennycress breeding plots at WIU, Sep. 2021 (Credit: Win Phippen, Western Illinois University).

Photo 12. WIU research farm pennycress plots for 2021-2022 growing season, Oct. 31, 2021 (Credit: Win Phippen, Western Illinois University).
Photo 13. Aerial photo of Covercress™ production plots from 2021 growing season illustrating seed carryover of black seeded varieties compared to new commercial golden seeded pennycress, Oct. 31, 2021 (Credit: Western Illinois University).

Photo 14. Delivery of 2,000 lbs. of dry bulk black seeded pennycress to AURI in Waseca, MN for seed storage and processing experiments, Sep. 1, 2021 (Credit: Win Phippen, Western Illinois University).

C. Explanation of Variance
Western Illinois University is loosening the COVID-19 restrictions. Students are free to conduct experiments in the field and buildings. Student workers are now fully employed and assisting in field, greenhouse, and laboratory experiments. Travel is approved as long as permission is granted prior to traveling.

D. Plans for Next Quarter

- Complete emergence and fall data collection on all field experiments in Macomb.

- Meet with Southern breeding team members to identify breeding lines for winter grow out in the greenhouse during the winter months.

- Select and germinate advanced breeding lines with traits including compact flower stem, early flowering, improved germination, stem thickness, heat tolerance, and reduced seed coat fibers.

- Complete computer algorithms for running optical seed sorter to recognize seed size and shape.

- Install automation system on TD-NMR for processing increased samples for 2022.

- Develop protocols for analyzing glucosinolates in pennycress seeds.

- Initiate greenhouse growing experiments.

E. Stakeholder Engagement, Presentations, Publications, and Proposals Submitted

- Stakeholder Engagement – Seed Sharing
  - We sent 5 lbs. of Golden seeded pennycress to collaborators at UTENN for oilseed comparisons against camelina and canola. The seed will be used to establish plots in Tennessee to compare seed yield and evaluate heat tolerance.
  
  - We sent 5 lbs. of Golden seeded pennycress for oil extraction experiments to USDA-ARS NCAUR in Peoria, IL.

  - We sent 15 g of black seeded spring-type pennycress to a new collaborator at UMN for molecular experiments.

Northern Breeding Program

1. University of Minnesota

   A. Planned Activities
Our research teams have generated high-yielding pennycress breeding lines through multi-state testing and identified/validated trait-improving mutations and natural variants. These were our planned activities for Year 3-Q1.

- Utilize marker-assisted selection and CRISPR gene editing to complete the introgression of traits into elite breeding lines.

- Extend our replicated yield testing program to a cooperative regional program and rapidly identify the best lines for each Midwest location (IL, MN, OH, WI) in conjunction with pennycress commercial launch.

- Perform pennycress field evaluations and seed increases of lines with commercial potential.

- Develop additional genetic/genomic resources for long-term pennycress breeding program success.

B. Actual Accomplishments

- We are in the process of stacking useful traits into MN106 using allele-specific markers (KASP). We have focused on the traits that improve the seed quality by reducing erucic acid, glucosinolates, poly-unsaturated fatty acids, and seed fiber. In addition, we have identified traits that improve yield by reducing seedpod shatter. We are now on track to have all of these traits stacked into a single line (MN106 background) by next summer, and we may have sufficient quantities of seeds for the multi-state evaluation studies for the fall of 2022. Several more traits that reduce seed dormancy and that potentially shorten time to maturity will soon be added. These lines were created using EMS mutagenesis and carry residual mutations from the EMS treatments. For this reason, the lines are also being backcrossed to MN106. These backcrossed lines with fewer mutations will be used for restacking the traits to recreate improved stacked lines in the future.

- Over the past two years, new mutant EMS populations have been created. DNA from over 500 lines has been submitted for whole-genome sequencing. Together with existing sequenced lines, this population will carry in total multiple mutations in nearly every gene in pennycress. This population will serve as a new source of useful traits and will be shared with the scientific community to serve as a resource to address basic questions in plant science.

- The seed for the IPREFER variety trials was successfully planted in the St. Paul fields in September 2021 by Dr. Jim Anderson's group. Early analyses provide useful information on the ranking of the fall establishment among the ten lines in the trial.
• A seed increase is currently underway for a pennycress line that carried mutations that confer high oleic acid content in the seeds and that exhibits reduced seedpod shatter. These traits were introgressed into the MN106 background and last year's multi-state variety trials showed that the improved line yielded as well or better than the parental line at most locations. We are working with a company that will use the high oleic oil to make precursors for the synthesis of biodegradable plastics.

C. Explanation of Variance

With the departure of Dr. Katherine Frels, the breeding program using materials derived from the intermated lines has been slowed. However, in conversation with Dr. Jim Anderson, he has indicated that Dr. Frels’ replacement will soon be hired, and that aspect of the project will continue.

D. Plans for Next Quarter

We will continue to work on the aims stated above.

E. Stakeholder Engagement, Presentations, Publications, and Proposals Submitted

• Stakeholder Engagement

A local farmer (Robert Harris) near Trempealeau, WI, allowed us to test the sowing of seeds of three pennycress varieties into standing corn in his field in August 2021. All three lines established well and survived the corn harvest. The farmer will allow the lines to be evaluated this coming spring ahead of his planned soybean planting. So far, perhaps due to robust establishment, the lines are only partially covered with stover residue. This farmer seemed interested in our future commercialization efforts.

We also had a conversation with Mike Elmaro, the owner of the Elmaro winery. He has substantial land holdings in the area and is interested in cover crops. We feel this is an ideal location for future pennycress studies as most fields are irrigated, and the sandy soil is very permeable to excess nutrients resulting in elevated N levels in most residential wells.

• Publications

OBJECTIVE 3.3 - CHARACTERIZATION OF PENNYCRESS ECOSYSTEM SERVICES

The goal of the water quality component of the Ecosystem Services group is to assess pennycress's potential to function as a cover crop.

1. Planned Activities

- Harvest our 95-day corn as silage from all plots while leaving a test strip for hand harvest and combine yield estimates. (Photos 15 and 16).

- Plant golden seed pennycress to establish robust crops this fall, which we hope will lead to robust stands. (Photo 17).

- Sample soil fertility and soybean cyst populations.

- Install lysimeters and begin samples fall soil porewaters near the root zone of the cover crops (30cm) compared to reference plots.

- Repair ISCO automated samplers, troubleshoot subsurface drainage sampling, and begin taking select storm samples.

- Complete assessment of mineralization rates of pennycress, genetically edited pennycress relative to cereal and annual rye.

- Sample soil organic matter from carbon sequestration plots and measure soybean yield.

---

7 Bill Perry (Illinois State University) leads the Characterization of Pennycress Ecosystem Services Objective.
2. Actual Accomplishments

- Silage corn was harvested on Sep. 7, 2021 (Photo 16). Hand samples of corn yields were taken on Sep. 26, and final test strips were harvested on Sep. 27, 2021 (Photo 17). We are still waiting to analyze the yield data estimated from the combine.

- Manual estimates of corn yields did not differ between reference, pennycress, or nitrogen amended plots of pennycress (F2,7 = 0.1258, P= 0.8837). There was also no significant effect of north and south fields on the yields (Fig. 1). Soybean yields were also not significantly different from the previous year.

- Golden pennycress was planted with a seed drill on Sep. 9th at a rate of 6 lbs. per acre in the treatment plots (Photo 17). We were able to establish robust stands of pennycress this year (Photos 15, 19, 20), but weeds were an issue as well, with henbit being the dominant weed (Photo. 20).

- Reference plots were treated with glyphosate and 2,4 D herbicide on Nov. 9th to control volunteer pennycress and henbit that was emerging (Photo 20).
Photo 16. Harvesting silage corn (top) and leaving test strips of 95-day corn to monitor yields (bottom). (Credit: Bill Perry, Illinois State University).
Photo 17. Harvesting test strips of corn (Credit: Bill Perry, Illinois State University).

Photo 18. Planting golden seed pennycress with Nicholas Heller (Credit: Bill Perry, Illinois State University).
Figure 1. Corn yields in our replicated pennycress treatments in kilograms per hectares. The yields were variable using hand estimates, but there is no significant effect of pennycress on corn yields. We are still waiting on the combine estimates.

Photo 19. Stands of golden seed pennycress this fall. Looking south from the border of plots 1 and 2.

- Soil fertility parameters have not changed substantially since the spring sampling. Soil organic matter as % loss on ignition differs between the north and south blocks ($F_{1,23} = 180.56$, $p < 0.0001$) and there is no effect of pennycress on soil organic matter ($F_{2,23} = 0.8717$, $p = 0.4316$) (Fig. 2). Soil nitrate/nitrogen was significantly different in the north and south fields ($F_{1,23} = 4.5374$, $p = 0.441$) and there was no significant different in pennycress plots relative to reference plots ($F_{2,23} = 3.2319$, $p = 0.0580$) (Fig. 3).
Figure 2. Soil organic matter in the north and south fields showing the differences, but there was no effect of pennycress relative to reference plots.

Figure 3. Soil nitrate levels in pennycress treatment plots versus reference plots.

- Our samples of SCN populations have also shown no differences between pennycress and reference plots. The soybeans we plant have lost resistance to SCN, which has resulted in average egg counts of 2500 eggs per 100 cc of soil.
• We have installed lysimeters to sample soil pore water and have collected two sample periods this fall after rain events (Photo 19). In the lower right is a white post that is a lysimeter.

• We have also worked out the sampling of subsurface drainage water leaving the plots after the same rain events. The pore water samples were taken, and we are waiting on nutrient analyses of these data. The subsurface water samplers are now recording water velocity and water level and allows us to calculate discharge even when the stream backs up into the sapling chambers (Photo 21).

• Samples of soil organic matter have been taken from a replicated cover crop plot with treatments of a) rye, b) pea, clover, and radish, c) pennycress, and d) a fallow treatment. These samples were taken after pennycress harvest and in the middle of the growth of soybeans. The soil samples taken after pennycress harvest have been analyzed, and the samples from within soybeans are now being analyzed.

• We have completed a study of the decomposition of wild-type pennycress and golden seeded pennycress with no glucosinolates relative to cereal and annual rye. We are preparing a manuscript showing that pennycress decomposes slower than both rye species. This work was done with Ryan Meyer, a graduate student, and Alex Hafner, an IPREFER intern (See Exhibit B).

3. **Explanation of Variance**

   Everything is on track for completion, and we have completed a new pennycress mineralization study to better understand the effects on subsequent cover. We have also added a project to study changes in soil organic matter in 2 cm increments of the soil profile.

4. **Plans for Next Quarter**

   The plans for the winter and spring are to:

   • Monitor soil pore water after storms of greater than 0.5 inches of rain and capture subsurface losses of water and nutrients in drainage tiles when conditions allow.

   • We will assess spring samples of pennycress and weed biomass three times before harvest.

   • Sample soil fertility and soybean cyst nematodes in the spring after pennycress harvest.

   • **Carbon Sequestration**

     • Collect samples after harvest of soybeans as cover crops are planted and estimate soil organic matter and other soil parameters. Start year 2 of the impact of cover crops on
carbon sequestration. Year 2 treatments included a pea, clover, radish, oat mix, wild-type pennycress, and cereal rye. Two additional treatments will be added: golden pennycress and annual ryegrass.

- Finish analysis of pennycress mineralization and submit the manuscript.

Photo 20. Aerial view of pennycress in north fields (top) and south fields (bottom). Note the weed stands in the reference plots include pennycress volunteers. Plot outlines are hand-drawn and estimated. (Credit: Jerry Komas, Drone Pilot, Illinois State University).
Photo 21. A rain event showing high water levels in the stream. The white enclosure hoses the ISCO sampler. On the other side is the Agridrain that intercepts the subsurface drainage and allows us to estimate water discharge and sample that water for nitrogen and phosphorus.

- **Stakeholder Engagement, Presentations, Publications, and Proposals Submitted**
  - **Professional Conferences and Meetings**
    - Ryan Meyer, Alex Hafner, Jack Wang, Nichola Heller, and William Perry. Potential of pennycress as a cover crop: reduction of soil and porewater nutrients. Illinois Innovation Network, Sustainability Research Conference. 1 School of
OBJECTIVE 3.4 - LIFE CYCLE SUPPLY CHAIN DEVELOPMENT

1. Planned Activities
   - Continue long-term grain storage studies and present data from AURI and CoverCress on storage of WT Pennycress and Golden Pennycress grain, oil, and meal.
   - Continue updating and optimizing economic modeling.
   - CoverCress to supply IPREFER with Golden Pennycress for next season’s IPREFER studies.

2. Actual Accomplishments
   - CoverCress and WIU have delivered Golden Grain Pennycress to all areas of the program
   - CoverCress’ long-term grain storage studies show stability at six months. The final time point is Dec 2021.
   - CoverCress has described all its supply chain approach based on partnerships and is pursuing actionable large-scale grain handling.
   - AURI’s long-term storage studies for oil and meal (yellow and black pennycress) are underway, showing stability thus far and quick dissipation of yeast and mold in both groups.

3. Explanation of Variance
   No variances were noted.

4. Plans for Next Quarter
   - AURI is planning an oilseeds field day at the Waseca plant.
   - AURI and CoverCress will complete long-term storage and stability studies and analyze data.
Time in Quarter 1 was spent primarily in identifying insect pollinators captured in flowering pennycress plots and fields during April and May 2021 across the four test locations: Morris MN, Rosemount MN, Macomb IL, and Lexington IL. Hymenoptera (bees, sans wasps) and Diptera (flies) were emphasized for taxonomic delineation, typically to the species level. Results for bees are shown graphically below. (Flies were much more abundant and still are being identified by a taxonomic specialist.)

Bees were captured in sweep nets in a consistent and systematic manner on a weekly basis throughout the flowering season at the four research sites. The most common individuals belonged to species within three genera: *Lasioglossum* and *Halictus* (both sweat bees), and *Andrena* (mining bees). Two other genera were identified, but they were rare: *Ceratina* (carpenter bee) and *Hylaeus* (masked bee).

Total numbers of individuals captured as well as the number of species represented by these captured individuals are shown in the following chart. Both species numbers and number of individuals were highest at the Morris site and lowest at the Lexington site.

The site at Morris is known as the Swan Lake Research Farm. As the name implies, the site abuts a lake with extensive shoreline vegetation, wetlands, sloughs, woodlands, and mown roadsides nearby. In contrast, the site at Lexington is characterized as almost totally comprised of cropland. The two other sites are rather similar to one another in terms of the extents of their cropland as well as the numbers of bees and bee species captured.

If each site is characterized by the extent of cropland within a 1-km radius of the sampled pennycress site, distinct correlations result for both the number of individual bees captured as well and the number of species identified among the captured bees. The correlations are nonlinear and suggest that bee numbers and species diversity increase exponentially as the percentage of non-cropped area increases adjacent to pennycress fields. Non-cropped areas almost certainly represent nesting habitat for the sampled bee species, all of which are native to the Midwestern USA.

Early-flowering and mass-flowering crops, like pennycress, likely represent a potentially abundant and valuable early-season forage resource for these native pollinators.
We will proceed with alternate on-site grain cleaning efforts.

CoverCress will complete feed studies to determine needed seed treatments and feed inclusion rates.

5. **Stakeholder Engagement, Presentations, Publications, and Proposals Submitted**

None at this time.

**Objective 3.5 - Education, Extension, and Outreach**

1. **Planned Activities**

- Obtain state 4-H approval for the Cover Crop Science Project Book.

- Provide demonstration seed for 30 total growers in central Illinois and northeast central Missouri. This will allow growers to experience seeding Covercress™ and learn how the seeds germinate and grow through the fall and into the spring. Growers will be able to terminate their crop and plant normally this year. Participating growers will also be asked to provide feedback on their experiences. The Beck Ag company will support this work.

- Meet with IPREFER researchers to obtain feedback on the internship program, address concerns and identify individual intern research projects for 2022.

- Work with IPREFER researchers to develop a collaborative research project for a team of three to four interns during summer 2022.

- Announce and promote 2022 internship opportunities.

- Analyze survey responses of 2021 interns, present results, and use feedback to modify the program.

- Recruit a Masters’ level student to develop internship program materials and identify tools and methods to evaluate the development of collaborative research skills of undergraduate researchers.

- Work with IPREFER 4H educators at ISU to disseminate educational materials to 4H educators in MN.

- Speak with Matthew Leiphon, AURI, regarding FFA’s interest in working with winter oilseed crops.
2. Actual Accomplishments

- Obtained state 4-H approval for the Cover Crop Science Project Book.
- Held outreach events at McLean County 4-H Fair, Illinois State Fair, and the Peoria Fine Art Fair.
- Twenty growers seeded about 200 acres of demonstration plots this fall.
- IPREFER research mentors and education team members met on Oct. 4, 2021, and discussed the improvement of the internship program. Recommendations included advanced planning for internship projects, mentor training, inclusion of on-site training with social activities for the intern cohort during the summer, and further exploration of internships with collaborators in supply chain development and IPREFER advisory board members. Several participants identified the timing of the pennycress growing season as a major challenge to hosting interns. Participants expressed limited interest in identifying collaborative research projects for interns.
- Improvements were made to the online system for posting and applying for internships to facilitate use by project collaborators and student applicants.
- We have received descriptions of four internship positions; three more descriptions have been promised but have not been received. We are working to generate five more positions. We will begin announcing internship positions by mid-November and continue adding positions as they are received.
- Aaron Hauger, a Ph.D. student at UMN, began work with the Education team. He will develop internship curricula aimed at building interdisciplinary competencies and develop a mixed-methods approach to evaluate the effectiveness of the internship program.
- Three instructors who teach courses in crop production at Central Lakes Community College and MN West Community College have been identified and will be contacted about their interest in pennycress instructional materials.

3. Explanation of Variance
• Because of delays in harvesting and excess rain in much of the demonstration target area, a little over 20 growers were able to seed before Oct 30.

• Aaron Hauger began work with the Education Team in mid-September. He is currently summarizing pre- and post-internship SURE survey responses. He is on track to complete this work by mid-December. The summary will inform follow-up interviews with students this winter.

• Additional conversations with 4H educators in MN regarding opportunities to use pennycress educational materials are needed before requesting access to the materials that ISU team members developed.

• We are in the process of contacting MN community college instructors about interest in instructional materials and a professional development workshop on pennycress and the production of biofuel feedstock.

4. Plans for Next Quarter

• Continue evaluating and revising the Cover Crop Science Project Book.

• Work with 4-H staff to set up a series of club meeting presentations and follow-up SPIN (SPecial INterest) Clubs. Note: presentations will likely begin in January, with clubs starting in March.

• Host outreach events at the Girl Scouts STEMinar, Marquette Heights Public Library, and other locations, as requested.

• CoverCress Inc. has hired Beck Ag, a marketing firm, to train selected retail partners on growing Covercress™ seed. This group of agronomists will be the main support network for securing growers and contract with growers to grow the launch crop scheduled for the fall of 2022. The training materials for the sessions are being constructed in November for training to begin in December and January.

• Promote summer internship positions (10 – 12) via Pathways to Science, emails to crop science and biology departments at diverse institutions throughout the US, announcements to IPREFER institutions and social media platforms.

• Complete summary and analysis of SURE survey responses and complete follow-up interviews with at least six participants from 2021. Use results to inform programming for 2022 and prepare a presentation of survey and interview responses.

• Initiate development of new curricula and develop evaluation methods for the summer 2022 internship program.
• Initiate planning for an on-site component of the internship program that will be held at one or more collaborating institutions.

• Streamline program logistics and record-keeping (applicant data, recipient data, travel arrangements, intern stipends, and program expenses).

• Contact MN 4H educators and facilitate access to pennycress educational materials.

• Meet with community college instructors regarding the development of instructional materials and/or professional development events.

• Complete slide set on pennycress production

• Reconvene agronomy team to solicit feedback on production guides

5. **Stakeholder Engagement, Presentations, Publications, and Proposals Submitted**

• **Publications**
  


• **Presentations, Professional Conferences, and Meetings**

  o Hagaman, M. Hosted IPREFEER booth. Peoria Fine Art Fair.

  o Hagaman, M. “Products from pennycress: Fallow land to fruitful products.” Illinois State Fair STEM Playground.

Evaluation Respondents (N = 28)

- Advisory Board member
- Executive Leadership Team member
- Invited speaker
- iPREFER Intern/undergraduate student
- Breeding & Genetics team member
- Agronomy/Coop Management team member
- Ecosystem Services team member
- Supply Chain Management team member
- Education/Extension/Outreach team member
- Other (please describe)

Returning previous intern iPREFER member
Multiple teams
What more might project administration have done during the past year that would have helped you meet your team's objectives?

- Project admin has been helpful in accomplishing ed team objectives. I can't think of anything else that could have been done.
- Nothing!
- I despise administrative burden, but I do believe that some scorecards / progress charts would be effective communication tools.
- Cannot think of anything
- Adopt slack.
- I felt that the team's objectives were met, at least for the undergraduate internship side of the program.
- No suggestions.
- A whole project meeting (if only going to be virtual) could happen more often than once per year. Traveling to a common place once a year makes sense. Quarterly 2-hour meetings might be good - 20 min per area?

What do you anticipate needing from administration in Year 3?

- Continued support.
- I think it is always important to remind all teams that inter-objective communication is critical.
- help pushing regulatory efforts through and using university lawyers and connections
- Cannot think of anything
- Adopt slack.
- I do not anticipate continuing to be on one of the IPREFER programs for Year 3.
- commercial quality seed
- Continued support of our commercialization efforts.
- Same as previous.
### How effective was the meeting in achieving each objective?

<table>
<thead>
<tr>
<th>Objective</th>
<th>Median</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identify the most critical issues that must be resolved to launch pennycress commercially.</td>
<td>Very effective (12)</td>
<td>Moderately effective (8)</td>
<td>Extremely effective (8)</td>
</tr>
<tr>
<td>Educate attendees on the critical challenges that must be resolved to achieve commercial launch.</td>
<td>Very effective (15)</td>
<td>Slightly effective (1)</td>
<td>Extremely effective (7)</td>
</tr>
<tr>
<td>Share what each team has achieved in Year 2.</td>
<td>Extremely effective (13)</td>
<td>Moderately effective (6)</td>
<td>Extremely effective (13)</td>
</tr>
<tr>
<td>Share what each team plans to address in Year 3.</td>
<td>Moderately effective (11)</td>
<td>Not at all effective (1)</td>
<td>Extremely effective (6)</td>
</tr>
</tbody>
</table>

### Statement

<table>
<thead>
<tr>
<th>Statement</th>
<th>Median</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>After this meeting, I feel I understand the critical challenges that must be resolved to launch pennycress commercially.</td>
<td>Somewhat agree (15)</td>
<td>Neither (1)</td>
<td>Strongly agree (11)</td>
</tr>
<tr>
<td>The format of the meeting was conducive to learning about other teams' activities.</td>
<td>Somewhat agree (13)</td>
<td>Somewhat disagree (2)</td>
<td>Strongly agree (11)</td>
</tr>
<tr>
<td>There was enough time to network with project colleagues.</td>
<td>Somewhat agree (11)</td>
<td>Somewhat disagree (5)</td>
<td>Strongly agree (6)</td>
</tr>
<tr>
<td>The time set aside for networking was structured well, so that networking was possible in the virtual environment.</td>
<td>Somewhat agree (9)</td>
<td>Somewhat disagree (5)</td>
<td>Strongly agree (7)</td>
</tr>
<tr>
<td>I have a better understanding of IPREFER objectives as a result of this annual meeting.</td>
<td>Somewhat agree (13)</td>
<td>Neither (3)</td>
<td>Strongly agree (9)</td>
</tr>
<tr>
<td>I was able to stay engaged throughout the annual meeting.</td>
<td>Somewhat agree (12)</td>
<td>Somewhat disagree (1)</td>
<td>Strongly agree (9)</td>
</tr>
<tr>
<td>This meeting effectively fostered a sense of teamwork across the IPREFER project.</td>
<td>Strongly agree (14)</td>
<td>Somewhat disagree (1)</td>
<td>Strongly agree (14)</td>
</tr>
</tbody>
</table>
If we must do a virtual meeting next year, what suggestions do you have for improving the structure of the annual meeting?

• The breakout room options were nice, but since it was optional and not strongly encouraged, not much happened in that space.
• Don't do it.
• thought the structure was great
• Please, no more virtual annual meetings.
• It’s perfect.
• Add ways to promote discussion during each section, whether that be poll questions, more time for questions/answers, or any method to let students and faculty to be more engaged in what is being presented.
• more time for the reports
• This was an extremely well done virtual event.
• “Presentations were too short. Don’t divide people up - I liked the open conversation with everyone. Talks started with people still in breakout rooms - need to empty room before next presentation (or better yet get rid of rooms)."

Please share any additional comments you have below.

• I hope that there will be more info about farmer’s opinions, experiences and attitudes toward incorporating pennycress on their farms.
• Thanks for hosting the meeting again, Anne & Win!
• In-person fosters better communication and collaboration.
• Great meeting.
• Thanks for all your hard work in organizing a great virtual event!
• liked this meeting more than 2020’s
• Was okay. Convenient to be online, in our office, but I think we need time away from our office not multitasking, eating together, ...
Redbird Scholar

Undergraduate student furthers pennycress research during summer internship experience

By Ela Messina  October 5, 2021
Alex Hafner, a senior from Mahomet, decided to pursue a major in molecular and cellular biology due to his interest in research. This same passion drew him to Western Illinois University's undergraduate research experience this summer, where he continued his participation in the Integrated Pennycress Research Enabling Farm & Energy Resilience (IPREFER) Project.

This long-term research project heavily involves Illinois State faculty and students who are working with colleagues at Western Illinois University and other entities to transform wild pennycress into a genetically modified, high-yield oilseed crop that would be grown in the winter in fields devoted in warmer months to corn and soybeans. Cover crops are beneficial to farming as they allow the field to retain nutrients which...
decreases the need for harmful fertilizers and helps maintain the quality of the soil. Additionally, domesticated pennycress can be processed into biofuel, jet fuel, animal feed, and other products.

“Normally cover crops aren’t able to generate any profit, but this crop in particular has the potential to since it can be turned into oil as well,” Hafner said. “So while it’s in the field, it’s providing good things for the environment, but then after it’s harvested. It doesn’t just go to waste.”

This summer was not the first time Hafner participated in research with IPREFER. After finding out about the study from a teaching assistant in his freshman biology class, Hafner spent
his sophomore and junior years assisting in pennycress research in Dr. John Sedbrook's genetics lab. Sedbrook is leading the pennycress project at Illinois State. Hafner then went on to hold a summer intern position with IPREFER in St. Louis last year, where his work was lab-based rather than field-based, and the focus was creating mutations in the plant’s genome that would speed up flowering time to optimize pennycress as a cover crop.

During his internship this summer, he monitored the efficiency of pennycress when it is actually put to use.

To test whether pennycress is an efficient cover crop, four crops—cereal rye and annual rye (common cover crops), wild pennycress, and genetically modified pennycress—were planted in fall 2020. The two rye crops and the wild pennycress were planted at the University farm at Lexington, and the modified pennycress was provided by IPREFER collaborators. Throughout the course of the 12-week internship, Hafner pulled and analyzed soil samples to learn more about crop decomposition speed and nutrient release rates.

Because the corn growing season has not finished, Hafner’s team has yet to gather all the data; however, the preliminary research highlights the crop’s decomposition rate—an important aspect of the life cycle of pennycress. Decomposition rate is important to the consideration of pennycress as a cover crop, as corn has a set growing season, and must be fertilized at a specific time. Understanding how quickly pennycress releases nutrients into the soil will provide an idea of when in the corn-growing season the soil is fertile.

“We can see now early on that these cover crops are decomposing at the same rate. So that way farmers will be able to make decisions on what cover crops they want to plant based on that,” Hafner said. This allows farmers to offset fertilizer applied during the year, saving them money and reducing harmful runoff.
Details on Hafner's research and preliminary findings were shared at IPREFER's annual meeting, which took place August 10–11 over Zoom.

After completing his undergraduate education, Hafner hopes to build upon what he’s learned at Illinois State as well as what he learned throughout the internship to continue studying plant genetics, and pursue further research on how they can be used to better the environment.

“I learn best by doing, so the opportunity to apply the concepts I learn about in class in both lab and field work is very rewarding,” Hafner said, “This experience has allowed me the opportunity to get hands-on experience in the field and learn many new techniques. I am very thankful to Dr. (Bill) Perry for working with me and teaching me some of what he knows this summer. I feel more comfortable pursuing a career in research because of this experience.”

---

Units

*Biological Sciences, College of Applied Science and Technology, College of Arts and Sciences, Research and Sponsored Programs, University Farm*

---

**Related Articles**
“Our mission is to optimize off-season pennycress oilseed production by overcoming production and supply chain bottlenecks.”

Dr. Winthrop B Phippen
Project Director
Professor of Plant Breeding & Genetics
Western Illinois University
School of Agriculture
1 University Circle
Macomb IL 61455-1390
Tel: 309.298.1251
wb-hippen@wiu.edu

Anne Kinzel
Project Manager
Western Illinois University
School of Agriculture
anne.kinzel@iprefercap.org