



AWARD YEARS 2022 AND FORWARD

This annual Performance Progress Report (PPR) must illustrate the progress made toward the completion of your project. If this project is completed at the time of the annual PPR submission, the project report should be marked as final. Please note character limits (abbreviated "char.") throughout.

PROJECT INFORMATION

Project Title (250 char.)	Increasing the Economic Viability of Year-Round High Tunnel Production in South Dakota's Climate
Organization Name (250 char.)	Wayward Springs LLC
Project Start Date	09/30/2022
Project End Date	09/29/2025

ORGANIZATION POINT OF CONTACT

Full Name	Shannon Mutschelknaus
Phone Number	605-695-0663
Email Address	shannon.mutschelknaus@gmail.com

BACKGROUND INFORMATION

PROJECT PROGRESS

Please provide the total percentage of work completed on the project.	100%
Is this a final report? Please select the box to the right if the answer is "yes".	☐

PROJECT BACKGROUND (REQUIRED FOR FINAL REPORTS)

Provide enough information for the reader to understand the importance or context of the project and any key findings. This section may draw from the background and justification contained in the accepted project plan. As the project has been completed, write this section in past tense. If this is an annual report, please skip this section. (1200 char.)

The project engineered and tested a passive solar design to make high-tunnel production more viable in cold climates. Traditional tunnels extend the season by only about a month, but this system combined traditional materials such as double-inflated polyethylene film, but added an insulated north wall, and two-foot-thick black concrete blocks as thermal mass to capture and release solar heat. The design stabilized temperatures through winter and summer extremes, reducing frost damage and overheating. During the 2023–2024 season, it extended the frost-free period from 162 days outdoors to 276 days inside, a gain of 118 days without added heat. Crops such as Capsicum chinense peppers thrived through early December, proving the system's effectiveness for long-season and tropical crops. Using readily available, low-cost materials, the project showed that near-year-round production is possible for small farms, improving local food access, resilience, and sustainability while lowering fossil-fuel use.

OBJECTIVE(S) (REQUIRED)

Please provide the approved project's objectives from the accepted project plan. Use the boxes to indicate if the objective is in progress, has been completed, or is not (and will not be) completed. At the final report, if "no" is selected for any of the listed objectives, you must expand upon this in the Challenges and Developments Section. Additional objectives may be added as needed.

+	#	Objective (2,000 char.)	Objective Completed?
-	1	Reduce initial cost & improve performance of in-ground heat storage systems enabling year-round production in a South Dakota cold northern climate.	Yes
-	2	Build & test a fully passive (no fan) heat storage system in north wall to provide guidelines for what climates & crop types do not need a more costly in-ground heat storage system.	Yes
-	3	Measure available sunlight (DLI, Daily Light Integral) throughout the year to characterize the maximum potential active vegetative and fruiting season available in a high tunnel system for various crops and compare that to the level of season extension achieved throughout this project and present that study in project results/presentations.	Yes
-	4	Publish recommended design, assembly & disassembly guidelines for various climates/applications in northern USA in easy-to-understand mediums such as YouTube videos and drawings that will be freely available to the public.	Yes
-	5	Encourage & equip other producers with knowledge regarding solar high tunnel performance, costs, and potential benefits for their farm operations.	Yes

OUTCOMES

Please only report on the outcomes and indicators that are selected and approved for this project. Use the check boxes to indicate which outcomes and indicators are selected. Select the "N/A" box for any indicators that are not applicable.

1. INCREASING CONSUMPTION AND CONSUMER PURCHASING OF SPECIALTY CROPS

☐

2. INCREASING ACCESS TO SPECIALTY CROPS AND EXPANDING SPECIALTY CROP PRODUCTION AND DISTRIBUTION

☒

Indicators	Value	N/A
2.1 Number of stakeholders that gained technical knowledge about producing, preparing, procuring, and/or accessing specialty crops	84,000	☐
2.2 Number of stakeholders that reported producing, preparing, procuring, and/or accessing more specialty crops	315	☐
2.3 Total number of market access points for specialty crops developed or expanded, and of those:		☒
2.3a Number of new online portals created to sell specialty crops		☒
2.3b Number with expanded seasonal availability		☒
2.3c Number of existing market access points that expanded specialty crop offerings		☒
2.3d Number of new market access points that established specialty crop offerings		☒
2.4 Number of stakeholders that gained knowledge about more efficient and effective distribution systems		☒
2.5 Number of stakeholders that adopted best practices or new technologies to improve distribution systems		☒
2.6 Total number of partnerships established between producers, distributors, and/or other relevant intermediaries related to distribution systems, and of those established:		☒

Indicators	Value	N/A
2.6a Number formalized with written agreements (i.e. MOU's, signed contracts, etc.)		☐
2.6b Number of partnerships with underserved organizations		☐
2.7 Total number of new/improved distribution systems developed, and of those, the number that:		☐
2.7a Stemmed from new partnerships		☐
2.7b Increased efficiency		☐
2.7c Reduced costs		☐
2.7d Increased specialty crop grower participation		☐
2.7e Expanded customer reach		☐
2.7f Increased online presence		☐
2.8 Number of specialty crop-related jobs:		☐
2.8a Created		☐
2.8b Maintained		☐
2.9 Total number of new individuals who went into specialty crop production as a result of marketing, and of those, the number who are:		☐
2.9a Beginning farmers or ranchers		☐
2.9b Socially disadvantaged farmers or ranchers		☐
2.10 Number of market access points that reported increased:		☐
2.10a Revenue		☐
2.10b Sales		☐
2.10c Cost-savings		☐

3. INCREASE FOOD SAFETY KNOWLEDGE AND PROCESSES

☐

4. IMPROVE PEST AND DISEASE CONTROL PROCESSES

☐

5. DEVELOP NEW SEED VARIETIES AND SPECIALTY CROPS

☐

6. EXPAND SPECIALTY CROP RESEARCH AND DEVELOPMENT

☐

7. IMPROVE ENVIRONMENTAL SUSTAINABILITY OF SPECIALTY CROPS

☒

Indicators	Value	N/A
7.1 Number of stakeholders that gained knowledge about environmental sustainability best practices, tools, or technologies	84,000	☐

Indicators	Value	N/A
7.2 Number of stakeholders reported with an intent to adopt environmental sustainability best practices, tools, or technologies	55	☐
7.3 Number of producers that adopted environmental best practices or tools		☒
7.4 Number of new tools/technologies developed or enhanced to improve sustainability/conservation or other environmental outcomes	4	☐
7.5 Number of additional acres managed with sustainable practices, tools, or technologies that focused on:		☒
7.5a Water quality/ conservation		☒
7.5b Soil health		☒
7.5c Biodiversity		☒
7.5d Reduction in energy use		☒
7.5e Other positive environmental outcomes (optional)		☒
7.6 Number of additional acres established and maintained for the mutual benefit of pollinators/specialty crops		☒

ADDITIONAL APPROVED OUTCOME (IF APPLICABLE)

☐

OUTCOME REMARKS (REQUIRED)

Please explain any quantifiable results, along with an update on their progress and data collection efforts for each of the outcomes and indicators selected in the accepted project plan. It is understood that the results may not yet be final at the time that this report is submitted; however, please provide an update on progress to date. If you do not have any data on the indicator(s) listed above, you must explain why in this section. (2,000 char.)

2.1: 84,000 is based on the number of views within the first 60days for the educational videos published on the YouTube playlist for this project. Totaling 4,800hrs of viewer watch time. Viewers were from: 54% USA, 13.5% Canada, 4%UK, 2.8% Germany, 2.3% Australia, 1.8% Sweden.

- 17 on-site tours of the project were given with a total of 53 people.
- 1 Online webinar was presented with 81 live attendees
- 2 In person conference seminars with 25-30 attendees each time.

2.2: 315 is based on my records totaling the number of questions and discussions with potential producers via email, YouTube, in-person tours & presentation. I had also planned to track the change in equivalent Hardiness zone that this system achieved. The solar high tunnel system without thermal blanket achieved a substantial improvement making my USDA hardiness zone 4b the equivalent of zone 8b (southern Georgia).

7.1: 84,000 based on total estimated number of individuals from videos, tours, webinars and seminars.

7.2: 55, It is a little hard to accurately capture numbers for how many stakeholders adopt practices, however I estimated this value based on my tracking of how many specific individuals reached out with specific questions about application as they are providing some level of feedback by asking clarifying questions on their journey of implementation.

7.4: Quite a few new technologies all play together to achieve the level of season extension achieved as part of this project.

A. Optimization of an asymmetrical high tunnel frame geometry that prioritizes direct light exposure to the growing bed, while maximizing the amount of surface area that can be covered with an opaque insulated covering.

B. Utilization of 3400# concrete blocks made from waste concrete as a thermal heat storage medium that can function without any energy inputs other than sunlight.

C. Opaque insulated PE+EPS+vinyl tarp covering to reduce heat loss.

D. Unique reduced cost climate battery.

NARRATIVE

ACCOMPLISHMENTS (REQUIRED)

If this is an annual report, list your accomplishments for this reporting period. If this is a final report, your accomplishments should be cumulative and include all accomplishments previously reported on and updated to include activities conducted this past reporting period. Indicate how these accomplishments associated with each of your project's objective(s), outcome(s), and/or indicator(s). This listing should identify your project's partners and their contributions. Additional accomplishments can be added as needed.

+	#	Accomplishment (1,200 char.)	Related to (Objective/ Outcome)
-	1	High tunnel hoop geometry calculations to maximize solar heat collection while minimizing heat loss for our South Dakota latitude. (Year 1)	2.1, 2.2, 2.8, 7.1, 7.2, 7.4
-	2	Structural calculations to ensure system can withstand potential snow loads (utilized North Dakota agricultural building snow loads). (Year 1)	2.1, 2.2, 2.8, 7.1, 7.2, 7.4
-	3	CAD models and drawings created, worked with fabricator to optimize design for fabrication and shipping. Built all parts and assembled the frame. (Year 1)	2.1, 2.2, 2.8, 7.1, 7.2, 7.4
-	4	Evaluation of film materials, light transmission & heat loss calculations and measurements. Measured heat loss of non-inflated film vent and now collecting data on inflated film vents. (Year 1)	2.1, 2.2, 2.8, 7.1, 7.2, 7.4
-	5	Selection of portable concrete thermal mass wall material for passive heat storage and data collection of emissivity, heat absorption & release for fall/winter 2023. Will be comparing the impact of painting the block black to understand if that is worth the effort. (Year 1)	2.1, 2.2, 2.8, 7.1, 7.2, 7.4
-	6	Several configurations for opaque insulative covering for the north wall & roof were analyzed and tried, with eventual selection of a method that works and meets the high tunnel objectives of a temporary covering. Heat loss data and thermal imaging showing the impact was collected. (Year 1)	2.1, 2.2, 2.8, 7.1, 7.2, 7.4
-	7	Local high-tunnel benchmarking: A local standard high tunnel at a neighboring producer was instrumented and data collected for key parameters, air temperatures at three locations, fan airflow rates, fan electrical consumption. (Year 1)	2.1, 2.2, 2.8, 7.1, 7.2, 7.4
-	8	Excavation and below grade assembly of climate battery heat storage components. (Year 1)	2.1, 2.2, 2.8, 7.1, 7.2, 7.4
-	9	Assembly of selected glazing film. Assembly of several types of opaque coverings & insulation methods for the non-transparent portion of the high tunnel. (Some failure and success. Thermal imaging of heat loss between the different materials.) (Year 2)	1,2,4
-	10	Data collection and performance characterization of a concrete block thermal mass for solar heat storage. Comparison of natural white and stained black concrete performance at heat storage and emission. (Year 2)	2
-	11	Updating high tunnel frame design drawings/model with things learned from the assembly and performance so far. Changing things that didn't work well. (Year 2)	1,2,4
-	12	Completed thermal imaging, temperature measurements, data collection for the inflated roll up vent thermal performance. Collected cooling performance utilizing only a single south facing roll up vent for the summer. (Year 2)	1,2,4
-	13	Started temperature and humidity measurements of the solar high tunnel ambient conditions to compare to several standard high tunnels in the area. (Year 2)	1, 2
-	14	Provided 12+ tours to local producers, educators & students interested in the research. (Year 2)	5
-	15	Local high-tunnel benchmarking: Added an additional local high tunnel with different construction and management procedures to compare to. (Year 2)	1,2

-	16	Designed and assembled fan system to move air through the climate battery (in-ground heat storage system), required custom fan-tube adapters to get air tight seal, several fan types are installed to compare the effect of multiple air flow rates. Measured resulting airflow rate of all 80+ heat exchanger tubes. Next year will be varying fan speeds to understand heat storage performance & utilizing that data to compare potential manifold layouts. (Year 2)	1
-	17	Carried out data collection on studies regarding the influence of air flow rates through climate battery heat exchanger on heat storage and extraction rates. Used to provide education and guidelines for producers or builders of climate batteries. (Year 3)	1,2,3,4
-	18	Performed measurement and logging of light levels throughout the year in order to calculate the Daily Light Integral and provide educational materials on potential seasonal growing length without supplemental light in this type of growing system. (Year 3)	3
-	19	Data processing, cleaning, analysis and interpretation for all the prior stages of the project. (concrete block performance, climate battery performance studies, Light Studies, etc) (Year 3)	1,2,3,4
-	20	Educational video creation: Planning, storyboarding & scriptwriting, creation of visuals (lighting study videos, etc), Recording, Editing, Publishing, Promotion, Check & adjust for next videos. Reply to questions, comments & email inquiries. (Year 3)	4,5

CHALLENGES AND DEVELOPMENTS (REQUIRED)

Provide any challenges to the completion of your project or any positive developments outside of the project's original intent that you experienced during this reporting period. Also, provide the corrective actions you took to address these issues. If you did not attain an approved objective, outcome(s), and/or indicator(s), provide an explanation in the Corrective Actions column. For developments, you may put "N/A" under Corrective Actions. Additional challenges/developments may be added as needed.

+	#	Challenge or Development (1,200 char.)	Corrective Action
-	1	Materials cost changes due to unanticipated inflation. Original supplies budget was based on cost estimates made before the rampant inflation started. (Year 1)	Postpone or potentially remove objective #3: retractable insulating blanket to stay under budget. Reduce costs of sensor systems by finding used alternatives.
-	2	Unplanned labor/employee relocation. Chris moved to western SD at the end of Sept. and is only available for remote work activities. (Year 1)	I had to find alternative assistance for work requiring on-site labor or make time to do more of it myself when possible.
-	3	Technical Challenges: Original insulation covering concept wasn't viable. Low cost tarp material was discovered to have very poor sunlight resistance, had to utilize more expensive materials. (Year 1)	Found alternative materials with good performance specifications and got it in time to collect good data this winter season.
-	4	Technical Challenges: Original blanket insulation concept for north wall and roof wasn't viable due to mineral wool slumping between the tarps. Substantial design changes and delays would have resulted to stay on the same path. (Year 1)	Converted the plans to utilize foamboard materials instead. R-values end up being a bit lower than planned for.
-	5	Technical Challenge: A low cost automated inflated passive roof vent system that can reliably open/close in our freezing winter conditions is more complex than expected. (Year 1)	For this winter eliminated the upper exhaust vent and focused on learning about methods to make the lower vent work. Enabled successful data collection this winter/spring season.
-	6	Drilling anchors into the concrete blocks was much harder than expected due to the fact that they utilize surplus cement from many different applications (some contain quartzite aggregate that is undrillable) (Year 1)	Invested more labor, drill bits and effort into anchoring the hoops into the blocks. Valuable learning, design should be revised to utilize ground stands instead of blocks.
-	7	Technical Challenges: Original insulation covering concept wasn't viable. Low cost tarp material was discovered to have very poor sunlight resistance, had to utilize more expensive materials. (Year 2)	Found alternative materials with good performance specifications and got it in time to collect good data this winter season.

-	8	Technical Challenge: A low cost automated inflated passive roof vent system that can reliably open/close in our freezing winter conditions is more complex than expected. (Year 2)	Decided to test with only the lower vent for a season, with really good success. Growers may not need to add cost of an upper vent.
-	9	Technical Challenge: The thawing of frost in the spring caused the ground to shift under the concrete block wall causing a substantial structural risk (which was good to learn in an experimental situation like this). (Year 2)	Consulting with civil engineer to understand the root cause, identify a way to buttress the wall to stabilize it and identify methods to avoid it for others.
-	10	The originally planned 120mm to 4inch duct fan adapters for the 80+ fans would not fit well enough to work and their cost increased a lot from the original budget due to inflation. (Year 2)	Designed my own 3D model that fit the application as intended and 3D printed all the adapters myself.
-	11	The temperature & humidity loggers for the exhaust end of the ductwork have been unreliable, likely due to the amount of moisture that condenses and runs down that wall in their vicinity. This reduced the quality of my climate battery data collection this summer. (Year 2)	Planned to try to repair those sensors and/or replace them with a different style that is water proof, but I would have had to sacrifice measurement of outlet humidity, which I was using to calculate latent heat transfer.
-	12	Fall-Winter 2023-2024 weather forecast suggests we might have a warmer winter than normal. The warmer fall reduced the amount of severe cold that I was hoping for in order to do the climate battery performance tests. (Year 2)	I planned to postpone the airflow rate studies to January-February when more severe cold would be more reliable.
-	13	The objective of designing and testing a full scale retractable roll up blanket(#3) was going to cost substantially more for materials due to inflation affecting affordability of the materials. Also if it were to fail it would prevent the ability to perform the experiments necessary for objective 1. (Year 2)	In order to still make some progress towards this goal, I planned to test smaller segments of potential blanket materials and characterize their insulation level (as well as watch for other problems with them)
-	14	Data collation took quite a bit of extra time because there were some sensors with intermittent data collection due to moisture damage/humidity fluctuations. The sampling times ended up getting of so more cleaning of the data was needed than I like. (Year 3)	It took a few months extra to work through this, but I was able to work on other aspects of the training videos while Avram worked on the data.

UPCOMING ACTIVITIES (REQUIRED FOR ANNUAL REPORTS)

Provide a description of the activities that you are planning to complete during the next reporting period. Additional activities can be added as needed. Please note, if this is a final report there should be no upcoming activities associated with the project, and this section should be left blank.

+	#	Activity (600 char.)	Anticipated Completion
-		All Activities are completed	

LESSON LEARNED (REQUIRED FOR FINAL REPORTS)

The recipient or subrecipient is required to provide recommendations or advice that others may use to improve their performance in implementing similar projects. If this is an annual report, please skip this section. (1200 char.)

Recommendations for others planning similar projects:

1. Consider the impact of inflation and wage growth that may occur within the time period between submitting proposals and project completion. Due to the volatility following the effects of the COVID pandemic this may have been more apparent than normal, but it is something I hadn't included in my original plans.

2. Make sure to include the impact of potential labor burden costs in the planned labor rates such as Worker Comp, or other professional insurance requirements.

CONTINUATION AND DISSEMINATION OF RESULTS (REQUIRED FOR FINAL REPORTS)

Describe your plans for continuing the project (sustainability; capacity building) and/or disseminating the project results. If this is an annual report, please skip this section. (1200 char.)

All of the planned objectives and information have been disseminated as planned. Due to the nature of YouTube videos being continuously available to a large potential audience, I have some ongoing efforts following up on comments/questions and email inquiries (approximately 1-2 per week). I have been very surprised by the world-wide viewership of the educational materials and the amount of positive feedback regarding the highly technical nature of this project and the depth of information.

Some of the questions I received touched on topics outside the scope of this project, but they've provided excellent inspiration for future educational videos and projects. I've compiled a list of potential topics to cover—many of which require little or no additional materials—so I plan to continue publishing additional educational content throughout the winter.

The full series of videos are available via this YouTube playlist called Maximum Season High Tunnels:

https://youtube.com/playlist?list=PLbVsXzG_yXEy9zAHLvtHaws5o1F_Lqxo&si=TPREfP_swBHxdmFo

PROJECT BENEFICIARIES (REQUIRED FOR FINAL REPORTS)

Provide the number of project beneficiaries. If this is an annual report, please skip this section. (12 char.)

50,000

FEDERAL PROJECT EXPENDITURE

EXPENDITURE (REQUIRED)

You must respond to at least one cost category. Please note, the subtotal and total rows include formulas to auto-calculate totals. The approved budget should come from the accepted project plan or any approved budget amendments.

Cost Category	Amount Approved in Budget	Actual Federal Expenditures (Federal Funds Only)
Personnel	\$47,520.00	\$32,271.30
Fringe Benefits	\$0.00	\$0.00
Travel	\$0.00	\$0.00
Equipment	\$0.00	\$0.00
Supplies	\$25,734.00	\$26,495.93
Contractual	\$0.00	\$0.00
Other	\$0.00	\$0.00
Direct Costs Sub-Total	\$73,254.00	\$58,767.23
Indirect Costs	\$0.00	\$0.00
Project Expenditure Total Federal Costs	\$73,254.00	\$58,767.23

DISCUSSION OF EXPENDITURES (REQUIRED)

For 1st Annual Reports, if total project expenditures is less than 30 percent, and for 2nd Annual Reports, if total project expenditures is less than 60 percent, include a statement explaining how the grant funds will be expended and project activities completed as planned by the end date on the grant agreement. Any state approved budget amendments should be included here; include the line item that the funds are coming from and going to, as well as the date that the state approved the budget amendment. (1,200 char.)

The total project expenditures were about 20% below budget. The supplies category was slightly over (3%) so it was below the threshold of needing an amendment.

The supplies budget is over slightly and was challenging to keep within the target due to inflationary effects since the original budget creation to project completion schedule. In hindsight a % increase should be planned in for that.

The labor estimate ended up below budget due to several reasons:

1. The revised objective for tracking Daylight Integral and analyzing day length limitations on the growing season vs. the original of developing and building a retractable thermal blanket was much less labor intense as well as it kept the supply costs close to budget.
2. I over estimated the labor in the original budget because I wanted to be safe. If I had more time I would use that labor budget to cover additional educational topics for this project that came up through producers questions. I have tracked these and have a list of future educational topics.

PROGRAM INCOME (IF APPLICABLE)

If program income was earned on the project, grant recipients are required to report on the source, amount, and how funds were expended. Program income is gross income --earned by a recipient or subrecipient under a grant --directly generated by the grant-supported activity or earned only because of the grant agreement during the grant period of performance. Program income includes, but is not limited to, income from fees for services performed; the sale of commodities or items fabricated under an award (this includes items sold at cost if the cost of producing the item was funded in whole or partially with grant funds); registration fees for conferences, etc.

+	Source/Nature of Program Income (100 char.)	Amount Approved in Budget	Actual Amount Earned
-		\$0.00	\$0.00

USE OF PROGRAM INCOME (IF APPLICABLE)

Describe how the earned program income was used to further the objectives of this project during the performance period. Any income generated must be reinvested back into the project and not set aside or reserved for future expenses after the grant ends. (1,200 char.)

PPR ATTACHMENTS DESCRIPTION (IF APPLICABLE)

Grantors will rely on the data that is submitted in this form when they report to congress. However, if you think additional documents are necessary to support PPR, please attach then and provide a document name and description of document below.

+	Document Name	Document Description
-		