December 28, 2011
Frank Stonaker
Specialty Crops Program
Colorado State University

Dear Frank,

I want to take this opportunity to thank you for the chance to conduct research on an alternative energy designed greenhouse and the growing of winter crops. I have thoroughly enjoyed the project at hand and hope that our research will inspire other off-the-grid farmers.

I look forward to sharing our research with other regional farmers in the coming year and publishing it for a wider audience. I hope that this is just the beginning of our work with the CSU Specialty Crops Program and I look forward to the possibility of more research opportunities.

Sincerely,

Michele Martz
2011 Specialty Crop Grower Research & Education Grant Final Report
SongHaven Farm – Michele Martz
“Bottom heated greenhouse versus high-tunnel winter salad and micro-green research”

1. Summary:

The primary project objective was to fabricate an innovative design using energy efficiency and alternative energy for a bottom heated greenhouse. The secondary objective was to compare growing winter salad greens and micro-greens under this systems approach versus that of an unheated high-tunnel and to determine the feasibility of producing crops in the winter. While we found that it is possible to grow winter salad mix in the high tunnel environment, it is impossible to get trays of micro-greens to even sprout in the late fall due to the lack of warmth and sunlight.

2. Materials and Methods:

The first step of the project involved design and construction of a bottom heated greenhouse. The main objective for the design of this greenhouse was to build a passively heated building that could also utilize beetle killed pinyon as a source of heat in a wood-fired stove to bottom heat the plant trays. As an off-the-grid farm we are not able to use heat lamps or pads to boost plant growth and nor did we think it sustainable to purchase large propane heaters to provide a frost-free growing environment for young seedlings and winter micro-greens.

One issue that is rarely discussed in farming communities when a new building is constructed is the placement of structures on the landscape. Here on our farm we believe that this decision is paramount. The factors that influenced where we put this hothouse structure were the following: proximity to living areas for ease of maintenance; ability to deliver electricity, irrigation water and chlorinated drinking water to the structure; soil depth to allow for a semi-subterranean structure; and finally, maintaining visual appeal by fitting into the landscape on the “edge” where the forest meets the grasslands.

*The beginning stages of construction.*
The hothouse was built in a semi-subterranean fashion to capture stable subsurface soil temperatures. The structure was built of concrete blocks, an easy and readily available material, with a layer of Tekfoil™ (a reflective insulation) placed between the concrete blocks and the surrounding soil. The blocks of the north wall were then filled with concrete and rebar. An earthen berm was then placed on the backside of this wall for thermal mass.

![Placing the window boxes and roof beams on the hothouse.](image)

The structure was angled to the southeast slightly to capture the early winter sun and to avoid too much summer sun. This proved beneficial, however we did have to modify the construction of the roof by adding a polycarbonate section directly above the tray rack to extend the sunlight into the hothouse during the summer months. Where possible local, reused and recycled materials were used in the construction of the hothouse. Local rough-sawn lumber was used for the roof and sidewall timbers. Knowing that the roof would be a vector for heat loss we placed a layer of Tekfoil™ underneath the galvanized tin panels and then stapled up reused grain/feed sacks from our local mill to create an 8” air space. The materials used for the south-facing wall were eight welded metal boxes that were recycled from the metal salvage yard and contain reused double-pane windows. The flue for the bottom-heated feature of the greenhouse proved to be the trickiest to design, but was made possible with the help of a local welder and materials from the salvage yard. The racks were constructed out of a recycled filters that allowed for maximum airflow from the flue up to the trays.
Tekfoil™ roof insulation with grain/seed sacks providing airspace.

One criteria for all the construction materials was that they could withstand a moist environment without rotting or molding. Not only did we expect this house to be a place where seedlings and micro-greens would grow, but also a place that could get sprayed down, if necessary, and an environment where these winter greens could be washed and processed.
3. Results:

While the hothouse was being constructed in the winter of 2010/2011 I started winter salad crops in our unheated high tunnel (14’ x 28”) to get some feedback on how crops planted directly in the soil grow in the middle of winter. On October 20th I planted one half of the high tunnel with arugula, winter hardy lettuce, kale, water cress, beets, chard and spinach. Three weeks later on Nov. 10th I planted the other side of the greenhouse with the same techniques and mix of seeds. The technique I employed with these winter greens was to water immediately upon sowing, cover with Agribon and then place hoops and a layer of plastic directly over the beds. This double layering provided enough protection in the winter months that the soil rarely froze.

Both successions of crops grew with vigor until the second week of December when they seemed to come to a standstill. The greens were only harvested for personal use and this experiment was employed to determine if and how crops would grow in the winter when directly sown into the soil. At the beginning of February I started to notice that an outbreak of aphids, signaling weak and stressed plants and I cleaned out the greenhouse in preparation of spring planting.
This past fall, November 2011, I began my research comparing the bottom-heated hothouse versus the high tunnel for winter micro-greens production. The decision to grow and compare winter micro-greens in both of these environments over winter salad greens will be discussed in the Conclusions and Discussions section of this report. Micro-greens are sprouts that are started in a soil medium placed in trays. We use Sun-Gro seedling mix in standard 1020 flats. The soil mix is tamped down flat with a homemade tamper, the seeds are spread over the soil and tamped and a cut piece of Agribon is placed over the tray before it is watered. The Agribon helps keep the seeds from drying out and is taken off the tray once the sprouts reach about 1/2”.

We tested five crops - sunflowers, kale, broccoli, arugula and kale. Of these five we had been growing sunflower micro-greens from June 1st to the middle of October for our farmers market sales and getting on average 10 ounces per tray. From June to the beginning of September it took 8-10 days to go from seed to harvest. In the September and October months it took 13-16 days from seed to harvest. In total we did four successes of tray plantings this fall/winter starting on Nov 24th and every week thereafter. A tray of each crop was started for the hothouse and for the high tunnel. A Onset HOBO U10 data logger was placed in each structure to chart the differences and fluctuations of temperature in each structure. A decision was made to place the trays in the high tunnel with no double layering (like I had used with the winter salad greens) since I wanted to mimic the growing techniques of the hothouse.
The micro-greens in the hothouse started on Nov. 24th and thereafter took 19-22 days from seed to harvest with an average of 2 ounces per tray for the brassicas and 4-6 ounces for the sunflower greens. The greens were irregular in their growth, with the sunflower greens being the most problematic in not germinating all at the same time nor growing at the same rate. The micro-greens in the high tunnel did not germinate at all, with the exception of the first sowing of sunflower micro-greens that started to germinate but then got frosted.
"Bottom heated greenhouse versus high-tunnel winter salad and micro-green research"

Micro-green trays in high-tunnel.

Kale and sunflower micro-greens in high-tunnel. Notice how the trays show signs of freeze/thaw action.
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**Data Logger Numbers -**

*High tunnel temps:*

- warmest 87.552 Nov 24 12:01pm
- coldest sustained temps below freezing: 33.411 5:01pm Dec 5 to -0.026 6:46am to 34.002 8:46am Dec 6
- approx. 15 hours of at/below freezing temps

most dramatic temperature range in a 24 hr. period:

- 15.589 12/5 6:46am
- 73.339 12/5 11:16am approx. 73 degree max/min temperature swing
- -0.026 12/6 6:46am

Avg temp 33.068
Avg Rh% 67.71

*Hot house temps:*

- warmest 84.115 Nov 29 1:12pm
- coldest sustained temps below freezing: 32.617 1:57am to 30.198 7:12am to 32.617 7:57am Dec 6
- approx. 6 hours of at/below freezing temps

most dramatic temperature range in a 24 hr. period:

- 44.560 11/29 7:27am
- 84.115 11/29 12:57pm approx. 40 degree max/min temperature swing
- 44.379 11/30 7:27am

Avg temp 51.034
Avg Rh% 66.68

*Dec 4-8th no wood-fire started in hothouse*
4. Conclusions and Discussion:

In conclusion we feel our hothouse design objective of utilizing energy efficiency with an alternative energy heat source was a success. This building provides protection from the elements and a stable temperature environment. This is necessary for our off-the-grid homestead to get an early start on the market season and we hope it will serve as an example to other off-the-grid farmers. The hothouse has enabled us to grow many of the seedlings needed for our summer vegetable market and has provided an additional source of revenue from the sale of sunflower micro-greens.

The secondary objective was to compare the growth of winter salad mix and micro-greens between the hothouse and high tunnel and also to determine if these crops could feasibly be grown during the off-season. In our research we grew winter greens directly sown in the high tunnel the first winter and micro-greens in trays the next winter. The greens sown directly into the soil in the high tunnel did well with the exception of the winter hardy lettuces which did not germinate. However, around winter solstice all growth slowed dramatically.

This winter we tested micro-greens in trays, comparing the hothouse to the high tunnel. We decided not to do winter salad mix because of the cost associated with growing in trays. Salad greens could not return a profit at $5/pound versus $16-$32/pound for the micro-greens. Our data shows that it is impossible to get micro-greens to grow in the wintertime in an unheated, unprotected environment. It also shows that even though these crops grew for us in the hot house, they took three times as long as in the summer months and provided less than half the harvest (sunflower micros) due to irregular growth.

Overall, we feel that there are serious concerns with growing any wintertime crops, namely, the lack of sunlight hours and inadequate compensation for labor hours. The micro-greens that did grow in the winter did not grow with vigor or with any consistency. The feasibility of taking a crop to market must take into account all measures, especially the harvesting and packaging of said crops. With the inconsistent growth, due to lack of sunlight, we spent twice as long harvesting these micro-greens than those harvested in the summer months. In our opinion, this is not a financially sustainable endeavor in the winter months.

5. Outreach:

So far, we have given tours and discussed our research with the Mesa Verde Organic Growers Club, the farmers and staff at Seven Meadows Farm, Confluence Farm, and numerous WWOOFERS and community members that have visited the farm. We intend to publish an article in the Small Farmers Journal this spring and provide more tours to interested groups.
6. Final Budget Sheet:

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<tr>
<th>Budget Category</th>
<th>Description</th>
<th>Funds Received from SCP ($)</th>
<th>Funds Used ($)</th>
<th>Matching Funds ($)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personnel</td>
<td>Salary of farmer doing research and labor hours of consultation, design and building of hothouse</td>
<td>3,500 received to date (1,500 remaining from grant)</td>
<td>5,000</td>
<td>2,000</td>
<td>7,000</td>
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<tr>
<td>Rental Value of Equipment</td>
<td>Tractor rental</td>
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<td></td>
<td>Concrete mixer rental</td>
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<td>Equipment Purchases</td>
<td>Misc. building supplies</td>
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<tr>
<td>Outreach Expenses</td>
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<tr>
<td>Travel Expenses</td>
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<tr>
<td>Misc</td>
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<tr>
<td>Total</td>
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<td>4,500.00 received to date (1,500 remaining from grant to be reimbursed for services rendered)</td>
<td>6,000</td>
<td>2,377.67</td>
<td>8,377.67</td>
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