2019 Organic Vegetable Production Conference

Greenhouse Management

	Mike Bollinger River Root Farm	Chris McGuire Two Onion Farm	Harriet Behar Sweet Springs Farm
Location	Decorah, IA	Belmont, WI	Gays Mills, WI
Acres in Vegetables	2.5	4	4
How these tasks are done in the Greenhouse			
make soil mix	I do not do this task	with a machine	I do not do this task
fill seeding flats with soil	by hand with hand-scale equipment	I do not do this task	by hand with hand-scale equipment
seed flats	with a machine	with a machine	by hand with hand-scale equipment
water flats	by hand with hand-scale equipment	with a machine	by hand with hand-scale equipment
move flats within the greenhouse	by hand with hand-scale equipment	by hand with hand-scale equipment	by hand with hand-scale equipment
move flats out of the greenhouse	by hand with hand-scale equipment	by hand with hand-scale equipment	by hand with hand-scale equipment
sanitize seeding flats	by hand with hand-scale equipment	I do not do this task	I do not do this task
farming style	certified organic	certified organic	certified organic

Greenhouse Design

History	Our greenhouse production space has grown over time with our need for space. We have always purchased a greenhouse "kit," rather than sourcing materials ourselves. We started with a 22x48, then moved to a 30x48, then added to that building to make it 30x96, and lastly have added a second 30x96.	From 2005-2009 we raised all seedlings in 5 wooden A-frame style cold frames (8'x16') covered with poly and with electric heating cable buried in the ground for heat. In 2010 and 2012 we added small quonset greenhouses (2 12x20 and 1 12x44) and also went on using older cold frames. During this period our seeding, potting, and germination chambers were in separate sheds. We built a new greenhouse from scratch in 2015-2016. We designed it over the winter of 2014-2015. In spring 2015, we hired someone to level the site for us and we set the ground pipes in concrete and laid buried electric and water lines to the site. In August to early December we poured concrete, assembled frame, covered with plastic, and laid buried hot water heat. In February-March 2016 we installed electricity and watering systems, built germination chambers and got greenhouse ready for use.	I have been growing bedding plants for over 35 years. I have used a variety of homemade greenhouses and saved up my pennies to build my dream greenhouse. I referred to a variety of books including *Solviva* by Anna Eddy and *Solar Greenhouses Underground* by Daniel Geery as well as visiting many greenhouses to get ideas. *The Northland Winter Greenhouse Manual* by Carol Ford and Chuck Waibel is also good. We built our earth-bermed solar greenhouse in 2001 and it has lived up to expectations. I over-winter many perennial plants in it for sale the next year as 2-3 year old herbs and flowering plants as well as "mother" plants for taking cuttings. I grow several crops in ground for family consumption and sell some to a small local coop and neighbors. I do not need to heat it until it goes below zero outside, then a small woodfire will keep it from freezing.

	River Root Farm	Two Onion Farm	Sweet Springs Farm
Key Functions and Considerations	The driving force behind our greenhouse expansion was the phased process of taking over an existing wholesale plant sale market. We have hundreds of flats going out the door on a weekly basis so we saw a few things as essential and other items we could add later to improve efficiency. Essential items: efficient gas heaters to keep the air temps at 60 degrees minimum during the coldest production period in February, adequate germination chamber space to start the number of seeds each week, a seeder that could plant flats effectively and quickly, a trolley and plant racks to move flats around the greenhouses, and area to be able to house multiple totes of potting soil and fill trays. Efficiency items: radiant bench top heating, soil flat filler, additional water hydrant and hose trolley, and concrete floors.	We wanted to fit an existing building site about 34' x 72'. Wanted ample room for potting/seeding/soil mixing activities within greenhouse. Wanted bottom heat for seedlings and automatic watering.	I wanted a greenhouse that would need minimal oversight for heating and cooling, and wanted to move flats directly into attached coldframes. The only fan takes hot air from the peak and drives it into the rock bed and soil heat sink below. Since it is earth-bermed, and oriented to receive the maximum sun from November to April (not mid-summer), it does not overheat. I have automatic opening vents at the top, and when the cold frames are open at the bottom, I get natural convention that cools it well enough for my dog to seek it out in the heat of summer! There is a small "germination" room at one end, which has in-floor heating using an electric hot water heater (run on solar panels) and food grade anti-freeze in the tubes. I can keep that room warm to germinate plants and keep them in there until they are big enough to go into the greenhouse, which can get down to 55 at night in the spring.
Important/Favorite Features	The most important items are the ones we have invested in and are listed above. In addition, we feel a 30'W greenhouse with sidewalls	Bottom heat for seedlings, automatic watering, hot water for soil mixing, watering, and hand washing early in the spring. Overhead door for moving pallets of materials in and out.	For a 20 x 60 foot greenhouse, I use only about 1 pickup load of firewood per year. I need to heat the germination room for about 6-8 weeks, mid-Feb to early April, and if a sunny day, the thermostatically controlled heat may not turn on until 10 PM. Very little energy used to cool the greenhouse, just enough to open and close the vents. I like that it has use year-round. Since my racks are hanging and are easily removed, I can grow in-ground in the winter. I fit 140 flats in my germination room, 480 flats in my greenhouse, 112 flats in my cold frames, and 180 flats on my outside racks. I also have a 30 x 60 high tunnel that I can use for late spring hardening off. This greenhouse is large enough, but not too large for a one-person operation.

	River Root Farm	Two Onion Farm	Sweet Springs Farm
Desired Changes	move gas tank and heaters to the east end of the greenhouses - move germination chambers to the east end of the GH1 - concrete floors instead of gravel - radiant bench top heating in GH1 - automated sidewall and roof peak ventilation	I would remove ridge vent. It was very time consuming to construct and will make changing plastic more difficult in the future. Instead I would use fans in the endwall.	If I could figure out a way to insulate the windows at night, I could probably keep my tomato plants going through the winter. The method would need to not take up much room when not being used. There are some ideas that have been intriguing such as bubbles and styrofoam peanuts, but neither seemed practical or doable. I have put in an overhead micro sprinkler watering system, but I usually use it only to water cover crops in-ground in the summer and when I am planting my winter crops in the fall. I have too many layers of racks to use this effectively for my bedding plants. It does take some time to hand water all of the plants in late spring when it is full.
Other Notes on Design	No	Very simple and primitive designs can suffice in the early years of your farm.	This type of greenhouse can be built on the south side of a building to gain some of the benefits, but it would not have quite as much of the cooling effect that an earth-bermed building has. The structure is made of black locust wood, which has held up quite well, no treated wood in the building.

Equipment & Supplies

Lived Without for Too Long	germination chamber - we spent too much time working with heat mats for germination. The heat mat provides adequate warmth for germination, but it is a dry heat. We would water our trays frequently to provide enough moisture to germinate seeds, but the dry heat of the mats worked out moisture very quickly. So we would water again, at which point we would end up seeing some dampening off. This only increased as we tried to scale up germination with the use of heat mats.	Automatic watering - this saves a huge amount of time in the spring and for us has done a more consistent, better job of watering than hand watering. The components are cheap (a few hundred dollars). I would recommend it at almost any scale.	none

	River Root Farm	Two Onion Farm	Sweet Springs Farm
Indispensable Equipment	Items on the equipment spreadsheet	Germination chambers are key for even, reliable germination. I would have at least one chamber as soon as possible. Having a cool germ chamber for summer lettuce is also really important for year round lettuce production. You can get away with very primitive, poorly heated growing conditions IF you first get the seedlings to germinate evenly in a chamber. Heating of some kind is key for early spring seedling production. Our system of bottom hot water heat combined with nighttime covers is more expensive and time consuming to install but it grows excellent plants at minimal operating cost. Vacuum seeder speeds up seeding trays and I find it much easier on my body and more fun to use compared to prolonged hand seeding. It was expensive and so it's possible to get along without it for a long time until your volume of production or physical discomfort justifies it. I can seed about 18 trays of 1.5" blocks per hour, including making blocks, covering, and putting away, using vacuum seeder, but only 12 seeding by hand.	My little 2 shelf cart, which can hold 10 flats. Purchased at tractor supply 15 years ago. The automatic opening vent, which is programmable, opening at a higher temperature in the winter, than in the spring.
Seedling Flats	LSF Open Seeding flats for microgreens - 392 cell trays for seed germinating - L Series 1204 for 4 pack sales - 50 cell peat pots for wholesale account - 50/72/128 cell trays for on farm use - 4 in. round pots for herb sales (15 per flat) - 4 in. square pots for tomatoes/peppers/eggplant (32 per flat)	Homemade trays made from 1/2" untreated fir CDX plywood. Do not use pine - it will fall apart when wet. Fir will last for 10+ years of use. Trays are just flat pieces without sides. We have two sizes : 8.75"x12.75" which will hold 6 4" blocks, and 7.875"x18.75" which will hold three punches from the standup 1.5" or 2" or 3" blockmakers.	1020 flats with inserts, since I sell most of my plants. Web flat underneath and inserts. If I am using 1020 solid flats, such as for onions or for nursery flats, I like the heavy duty ones so I can reuse them more readily. If flats are broken, I tape them and then use them for retail customer to take home plants.
Flat Labels	Hand written wooden craft sticks for some - thermal label printer for others - wholesale account provides plastic tags for others	Popsicle sticks. $15.68 for a box of 1000 from Amazon: Perfect Stix 114ST Wooden Craft Sticks	I print out my own plant tags using a plant tag printer, photos in my ppt.
Soil Mix	I buy it in	I make my own	I buy it in

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Making Soil Mix		We mix in electric powered cement mixer. Steps are: 1.Measure each of the following ingredients immediately before you add them to the mixer. Do not measure in advance except for peat. 2.Add water (5.5 gallons). (2 bucket-fulls of 2.75 gallons each). 3.Add peat moss – no clods (2x3 gallons) 4.Turn mixer on 5.Add micronutrients, slowly. Both can be measured into one large yogurt cup and not stirred together prior to adding: soymeal (2x6 oz) and kelp meal (1x6 oz) 6.Add compost – no clods (2x3 gallons) 7.Add vermiculite (1x4 gallons) 8.Allow mixer to run until mix looks mixed. If it sticks to back of mixer then squirt more water in. Dump mix on floor when done Time to make a batch: 6 minutes. One batch will make about 720 1.5" blocks, 432 2" blocks, 144 3" blocks, or 42 4" blocks.	
Bought in Soil Mix	Cowsmo Compost Totes - Double Green	We used to use Johnny's 512 mix and have also used Vermont Compost. They worked fine. Soil blocks require a lot of mix over a season and for cost savings we switched to making our own soil.	Cowsmoo, Cochrane WI. I buy it in 750 pound totes, and we move those around with our Kubota tractor front forks.
Soil Mix Storage	Overwinter totes in GH2 until we need that space and then outdoors.	We try to use within 7-10 days of mixing. We store it on the floor in the greenhouse, on concrete, in the area where we make soil blocks.	Totes are stored outside, except for a few that are brought into the greenhouse for early starting. I have a very large wooden door at one end that we open for bringing in the totes in the fall.

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Benches		No benches. We place trays on the ground under wickets made from steel pipe. At night we pull row cover over the wickets for insulation.	My greenhouse benches are "modular" . They hang from a 2 x 2 wooden cross piece that is suspended on a door track. Four pieces of conduit about 4 feet long have a variety of small holes where I put tractor pins that support 2 x 2 cross pieces. An 8 foot sheet of steel siding x 30" (like for pole sheds) is put across the 2 by 2s. I can have two layers or the upper layer can have a half sheet 8 foot by 15 inches. These can hold 16 flats each for the full sheet and 8 for the half sheet. These are easily adjustable and installable/removable. The corrugation of the steel helps with drainage of the flats.
Irrigation		Automatic watering saves a huge amount of time and does a better job than hand watering for us. The components are cheap (a few hundred dollars). The watering system is controlled from the "room" described in "Heat Source." There is a timer to control length of watering. Valves allow us to turn water on/off for individual beds. Plumbing setup allows us to use hot water or a mix of hot/cold from our water heater (valuable in spring). From control room, 1/2" orchard tubing water lines go underground (buried in sand) and come above ground at end of growing beds. In the growing beds the lines hang from metal wickets, about 27" above ground. One line down the center of a 5.5' wide bed covers the entire width. Sprinklers are set 3' apart down the length. We use yellow flat spreader and orange nozzle from Nolts. Sprinklers are punched directly into orchard tubing. Don't use the anti-drip fittings because they suck. The sprinklers drip constantly while in use regardless, so we are careful to not place trays directly under the sprinklers.	I have an overhead micro-sprinkler system, but mostly use the hand held wand for watering flats in plants.

Seeding

	River Root Farm	Two Onion Farm	Sweet Springs Farm
Seedling Flow	Production starts in GH1 and then overflows into GH2. Beginning early Feb. we drop a curtain on the west 1/3 of GH1 with old greenhouse plastic in order to heat a smaller space during the coldest part of the season when we are just getting started. As we require more space we move the curtain back until we drop it completely. All plants are established in GH1 and as we require more space we move the oldest plants to GH2. More mature flats are loaded onto multi-shelf racks and moved with a tractor to the pallets in GH2. The pallets in GH2 are set so that we can drive the tractor in with the rack to where we need to unload it. There are a couple of weeks when we need to add more pallets to GH2. When that happens we set the wheeled racks down on the east end of GH2 and roll them to the area where they are unloaded.	Trays are seeded in work area. Seeded trays go in germ chambers, then to greenhouse seedling beds, and then outside to cold frame for hardening off. For certain crops or at certain times of year, we may skip the germ chambers and/or greenhouse seedlings beds.	Trays are seeded in the greenhouse and moved to the germination room, either on tables (some have heating pads, some do not), or under lights. Once they are big enough, the flats move into the greenhouse. I transplant from nursery flats into 2 inch or 4 inch pots for bedding plant sales. I may use 128s, 72s, or 50s for my own use or for sale to other growers. Once the weather is acceptable, usually around April 1-10, I open up the cold frames to the greenhouse and move frost hardy plants out into the cold frames. From there they move onto my outside racks for sale, once they are big enough and the weather has settled somewhat. I am in a valley and I needed the rack to prevent the heavy dew from falling on my plants and then when the sun hits them, they can get scalded.
Seed Storage	Cool dark room in our basement.	In winter we keep them in a cooler above freezing. During summer we store them in an unheated shed except lettuce seed that we are not actively using week to week - those we keep in a cooler to prevent heat-induced dormancy.	I keep my seeds in rubber maid tubs in small cardboard boxes organized by the time of year that I seed them. They are in a cool place through the winter.
Filling Flats	Soil is held in a macro bin - 2' x 4' piece of plywood across half of the macro bin - trays are placed on the plywood - a 10" x 18" piece of twin wall polycarbonate is used to scoop soil and dump on trays - the polycarbonate is then used to scrap the surface flat - excess soil gets pushed back into the macro bin	We do not use flats	Hand fill flats, I cover all seeds with vermiculite to prevent damping off. My compost based mix is fairly wet, and watering in of the seeds is all I need to do. I have a wooden tamper that I press into the soil to compact it and make furrows if necessary for the seeds.

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Making Soil Blocks	potting soil mixed with water to correct consistency by eye in an open tub	We use standup blockmakers to make 1.5", 2" or 3" blocks. Mix is wetted during mixing process and then dumped from mixer on the concrete floor. We like to mix at least one day in advance of making blocks. Immediately before making blocks we re-wet mix as needed. We lay trays on floor, make blocks and eject them onto trays and then set trays on table.	
Cells vs. Soil Blocks	Soil blocks produce an excellent plant, however we have found efficiency in cell trays in conjunction with the vacuum seeder. We do still use mini blocks for germinating limited need transplants due to their ease of moving to larger cell trays.	We have never used cells. We have always been pleased with quality of seedlings in soil blocks. We are careful to transplant at a small size to avoid roots growing from one block into the next one.	
Seeding Flats	Full and half flats are seeded using a vacuum seeder - limited need seedings are done into miniblocks using a hand dial seeder. In most cases we do not use a topping mix - when we do for larger seeds we use coarse vermiculite.	2" or 3" blocks and all unpelleted, non-brassica seeds are seeded by hand, usually by scraping seeds off an index card with a nail file. 1.5" blocks with pelleted seed or brassicas are seeded with EZ-Seeder vacuum seeder, custom made to fit our trays of soil blocks. Topping mix is fine vermiculite, about 1-1.5 cups per tray. We do not water trays unless they are going directly to cold frame and we are afraid of wind blowing the vermiculite away in which case we will lightly mist trays.	I seed flats with the vibro hand seeder, I may count out seeds and then use a measuring spoon to seed flats if I am doing many of the same type, such as onions. I push a furrowing board into the soil and seed the flats with vibro hand seeder and then cover everything with vermiculite (medium or coarse), not sure if there is any difference, I use both, and then press the vermiculite flat with a solid wood board tamper.
Labeling Flats	Crop, variety, seeding date. (Broccoli, Gypsy, 3/1) for full flats, the label goes in the second cell in from the left on the short side of the flat. for flats with multiple varieties, the first label goes in the first cell on the short side of the flat and the next label goes in the first cell where that variety was sown.	Variety abbreviation on one side (e.g., GYP for Gypsy) and sowing date (e.g., 4/15) on back side. Stake goes at 45 degree angle, between last two rows of blocks. We try not to mix varieties on a tray.	I write on a plant tag what is on the flat, I may write the date if needed, but I keep a very detailed log of what I plant when, so if I need to know the planting date, I can usually look it up in my log.
Other notes on Seeding	No		I overseed to make sure I have enough high quality plants. I try not to crowd seedlings in the flat, so I have a cushion in case I can't up pot them at the optimum time.

Germination

	River Root Farm	Two Onion Farm	Sweet Springs Farm
Germination Chamber Design	Our two germination chambers are purchased units - one is 48 flat from the company Phytotronics, the other is a 96 flat from Seed EZ Seeder. Each is a self-contained unit with internal metal shelves, heating element and digital thermostat.	Three chambers. Wooden frames made from cedar, wrapped with 2" thick rigid foam insulation and covered with polyethylene. The chambers rest on landscape fabric in the greenhouse. The "doors" are large pieces of foam insulation. The poly that goes over the doors can be opened via zipwall construction zippers. Eight shelves per chamber. Each shelf can hold 8 trays of 1.5"/2"/3" blocks. One chamber is larger and each shelf can hold 12 trays. So total capacity of each chamber is 64 or 96 trays. Dimensions overall are about 78" high, 24" deep and about 6' wide (or 9' for the larger one.)	It is a large room included in my greenhouse, with the same solar exposure and 8 foot concrete wall to the north. The floor is concrete with a drain, goes to a grey water drain field. The concrete has radiant floor heat tubes. This room has its own outside door.
Germination Chamber Heat	Internal hot water basin with heating element attached to a digital thermostat - the thermostat runs on 3 degree variation - both chambers require daily filling with a hose by hand	Continental 7 Quart Stainless Slow Cookers connected to a thermostat. 2 cookers in each of the smaller chambers and 3 in the larger chamber We add water each morning to the cookers while doing chores. This provides moist heat and we do not need to bag or water the trays. DO not let cookers run dry or they will be ruined. To distribute the heat we have a circulating fan near the bottom between the two cookers - J&D 14" fan for extreme environments, Global Industrial item T9F968708 In summer for lettuce germination, we use one germ chamber which has an AC mounted to it for cooling. This dries the air and we enclose the individual trays in plastic bags (16x28 2 mil poly bags Uline S-3107)	In floor heat from an electric water heater, anti-freeze in the pipes. We have solar panels producing our electricity for the whole farm and house, so even though electricity is not the most efficient way for heating liquid, it is the most energy efficient for us, since we are making the power.
Germinating without a Chamber			I may also use my four -4 foot- heat pads to start very early flats with domes above the flats to hold in the heat, before I turn on the whole germination room.

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Germination Temperature	80 degrees	68-85, varies by crop	65-75 degrees
Moving out of the Chamber	Flats in the germination chamber are checked daily and removed upon necking. Newly germinated flats are moved into full sun in the greenhouse.	Aim to remove right before seedlings emerge. For lettuce and most brassicas, this is 48 hours after sowing. For most other crops, we check daily and take out when seeds have sprouted but not emerged. All trays are set on beds on floor of greenhouse after coming out of germ chamber.	After the true leaves come out, a little later for peppers. I have lights on some of my racks, or else they get light from the greenhouse windows. My germination space is not in the dark.
Other Notes on Germination		At one time we used a walkin cooler as germ chamber in spring when we were not harvesting. We set up heat inside and had temporary shelving. This worked quite well and was an inexpensive solution but the location of the cooler (inside the packing shed) was inconvenient. We have even used a walkin for summer lettuce germination by setting cooler temp up to 68 if we knew there was a time when the cooler would not be needed for produce storage for two days.	

Greenhouse Operations

Why Up Pot	Because we need full flats for our transplant sales we start almost all seeds in small cells and then pot up according to account requirements.	Tomato, pepper, and eggplant, to save valuable heated space in the germ chamber and greenhouse. We also want to make sure we do not waste soil mix in 4" blocks - these require an enormous amount of mix!	I transplant most of my plants into larger individual pots, I sell about 80% of the bedding plants I grow, the rest I use for myself.
One Plant per Pot?	Hand thinning if necessary	By planting one seed per block.	I do some thinning.
Greenhouse Irrigation	Water by hand with a watering wand as necessary - observe visually.	Automatic overhead sprinklers on timers. We run these anywhere from 15-20 minutes to an hour, once per day (skipping overcast days in early spring). Aim to water between 10 AM and 1 PM to allow foliage to dry. It is very frustrating to water soil blocks by hand because excess water runs off the top of the blocks so you need to water repeatedly at a very gentle rate. The automatic sprinklers give a gentle spray which the blocks can mostly soak up.	I water when needed, usually every other day until end of April or May when it may be every day. I use a hand wand.

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Moving Flats in the Greenhouse	All flats are started in GH1. Once that greenhouse is full we move more mature plants to GH2 to free up space. These plants are loaded onto racks that hold 50 flats and are moved with the tractor.	One tray at a time, by hand, within greenhouse. For moving from greenhouse to cold frame we use a wooden garden cart (Carts Vermont style) with a homemade plywood shelf inside that allows us to move 16 trays at once.	I have a small metal two shelf 4 wheeled cart that I move around, both inside and outside the greenhouse.
Daytime Greenhouse Temps	75-80 degrees.	75-80	I try to keep it less than 82 or so on a sunny day, I don't like my plants to get overheated. This is usually easy to do with the opening vents.
Nighttime Greenhouse Temps	60-65 degrees	60-65 in the growing beds, but it will get a bit cooler on very cold nights. The air within the greenhouse itself can freeze on cold nights - we are only heating the enclosed area where the seedlings grow.	55-60
Heat Source (continued on next page)	Forced air heaters and circulation fans mounted to greenhouse trusses.	Electric hot water heater, together with circulating pump to move water through 1/2" pex tubing which is buried in sand underneath growing beds. There are four beds each 30'x5.5'. To make growing beds, we laid a thin layer of gravel down and smoothed it out, then layered 2" foamular 250 insulation on top of that. Then laid wire mesh (concrete reinforcing wire) and fastened loops of 1/2" pex tubing to that using zip ties. Tubing is laid on 8" centers. We laid two loops per growing bed, with a total length about 130' per loop (very long loops do not work well). Covered with 4" sand (really limestone fines) and landscape fabric over that. At the edges of the bed we buried vertical 2" foamboard to keep heat from escaping into walkways. We are careful to wet sand thoroughly at the beginning of every season so it conducts heat well. (continued on next page)	Hot air from the peak of the building goes into a rock bed and soil in the ground, releasing slowly during the night hours. I have done some tracking of this and the active heat storage will raise the temp of my soil 15 degrees whereas without it, the soil temp goes up 2-3 degrees. All of that heat is gone overnight, keeping the greenhouse at a moderate temp. If it goes below zero at night, I make a wood fire in my trusty Kickapoo woodstove. Usually, I make a fire around dusk, to maintain the heat from the day and then stuff it with firewood around 8:30 PM, which will hold the greenhouse warm through the night, even on the coldest nights. The greenhouse temp will be around 36 in the morning. It was about 55 at 8:30 PM. This is in January and February. In March-April, I usually do not need to make a fire more than a few times during those months, the temp stays around 55 with no extra heat other than what the sun provided and I stored in the soil.

	River Root Farm	Two Onion Farm	Sweet Springs Farm
Heat Source (continued from previous page)	**<u>Chris McGuire Two Onion Farm</u>**: (continued from previous page) "Wickets" made from bent 1.315" chain link fence toprail are set over each bed. At night we cover entire bed with three layers of Dupont 5131 row cover. This cover is attached at two long edges to a length of 1.315" steel pipe to facilitate rolling and unrolling the cover morning and night. During the day we move the covers, wound up on their steel pipes, to shelves at the sides of the greenhouse to be out of the way. Two people can uncover or cover the 4 beds in about 5 minutes if they are serious, even if one of them is nine years old. One person can do it alone in about 10-15 minutes with some more walking back and forth to handle long pieces of pipe. The hot water heater, pump and all associated plumbing are contained in a very primitive "room" inside the greenhouse - a wooden frame with a tarp covering the top and sides. This tarp protects components from UV and also allows us to heat the room on very cold nights using a space heater to keep plumbing from freezing. Circulating pump is turned on/off by a thermostat. Thermostat is on flexible electric cable which can be hung from the trusses and easily moved to any of the four beds. Shutoff valves near the pump allow the heat to be turned on/off in individual beds. Between the room and growing beds, pex is enclosed in insulating foam and buried in sand. There are some safety considerations. We have expansion tank and pressure relief plumbed into system. Also we have a sink with hot water and we make sure to open the hot water in the sink every day to let out sulfur gas which can build up in the heating system and make your farm explode.		
Ventilation	Manual roll up sides and manual endwall peak vents.	Ridge vent and sides with manual rollups. Ridge vent is first option in early spring; don't use sides much before mid April. We do have four circulating fans hanging from trusses above seedlings beds.	I have a 12 inch by 60 foot vent that automatically opens according to a programmable thermostat. I can set it up to open at 82 in the winter and 50 in the summer. This works great. The software and controller is what they use to control the fabric sides on confinement animal operations, an example of using technology developed for a problematic type of production for a good type of production!
Supplemental Fertility	We keep a general purpose fertilizer on hand and only use if we notice a visual issue with plants. Otherwise, the objective is to have fertility available through the potting media. Biolink all purpose fertilizer 3-3-3 - apply as needed if necessary.	No. There is fertility in potting mix and we transplant most seedlings at small size. E.g., in summer, we transplant brassicas and lettuce 14-16 days after sowing.	Very rarely, maybe a little bit of fish/kelp on tomatoes. I use a siphon mixer on my hose to my hand wand.
Diseases		Really none. Have almost never had significant damping off - its hard to overwater soil blocks because there is nothing to hold the excess water.	No disease problems

	River Root Farm	Two Onion Farm	Sweet Springs Farm
Insects	Occasional aphid and fungus gnat identification - monitor watering, improve air circulation and apply Safer Soap when needed	In rare cases we have had thrips on peppers and have used safer soap sprayed from backpack sprayer.	Once in a while I get some aphids on my peppers, I don't add extra N to my potting mix. Also, I spray safer soap on the overwintered swiss chard and celery, which tend to be nursery plants for the aphids, before I start my bedding plants, this has worked well for the past few years.
Greenhouse Cleaning	Annual winter greenhouse cleaning - we use a bleach water mixture based on product specifications and run it through a power washer to clean surfaces.	Wash concrete floor with hose and water occasionally (there is a floor drain). Rest of greenhouse has landscape fabric. We sweep once per year if we feel ambitious.	I plant cover crops in the summer, every 3-4 years I add compost to the soil.
Flat Cleaning	We use a bleach water mixture based on product specifications - submerge flats for ten minutes in a large garbage can - rinse with water and allow to air dry.	Scrape any leftover mix off trays immediately after transplanting. Spread trays out to dry on shelves in greenhouse (so wood will not rot) and then stack.	I empty any leftover flats into our tractor loader, then dump that into a pile. After a year, we spread that around our fruit trees as a mulch. I do not clean my flats, I have very little disease problems.
Operating Exposes, excluding labor		Roughly $300-$400 for electricity per year - this is for heat (water heater is electric), fans, germ chambers.	Fuel ($100 for firewood, we cut it), electricity ($400 max, estimate), we make all of our own electricity through solar panels. I buy potting mix, about $800

Hardening Off

Hardening Off	In Greenhouse: Circulation fans and open sidewall ventilation Outside Greenhouse: None	Cold frame - about 9' wide and 26' long, built on gravel base. Wooden chalet style frame attached to steel pipes driven into the ground. Side walls about 10" high; peak about 8' high. Covered with greenhouse poly. The two sides can be rolled up to peak and are rolled up most of the time except during cold nights and storms. On very cold nights wooden frames with row cover fabric are set inside the cold frame above the seedlings. Cold frame has similar auto sprinkler system to greenhouse. At peak time of year, when hardening off peppers and tomatoes and eggplant we have used additional temporary areas for hardening off (haywagons driven into shed at night, metal hoops set in ground and covered with row cover at night, etc)	In Greenhouse: My plants get wind from natural convention, I move them out into an adjoining cold frame system which gets some heat from the greenhouse. Outside Greenhouse: I have racks with a clear corrugated plastic top for hardening off outside.

	River Root Farm	Two Onion Farm	Sweet Springs Farm
Hardening Off System	None	At least 1 week before transplanting set plants in cold frame. In summer we do not use greenhouse at all for growing but put seedlings immediately into cold frame.	I move them out to the racks once they have been in the cold frames for about a week.
Achieving Stout, Healthy Plants	Quality potting media - proper temperature management - time to grow the crop to adequate size for transplanting - last several days before setting out we have plants in GH2 at lower temperature and with less water.	We space tomato trays out widely in cold frames for last 10-14 days before transplanting.	Transplant at least 3 weeks before you want to sell or transplant.

Marketing

Markets	A little on farm - racks outside our local food co-op and wholesale through a distributor for their onsite sales and mail order		orders from other growers or home gardeners
Transport to Market	Wholesale distributor picks up their plants - for the transplants to our local food coop we have an enclosed trailer with racks.	shelves in cargo van. Seedlings go into cardboard beer flats (uline S-13340)	In my car, I have built a rack, I can carry about 25 flats, or in my truck, I have built racks and can carry 60 flats
CSA		customers pre-order and we deliver to CSA drop sites on special seedlings delivery day in late May. Our price is $4 for 4" block (tomato, pepper, cuke etc) and $2.50 for 2" block (herbs)	
Farmers Market	No farmers market		
On-Site Farm Stand	no onsite farm stand		I give customers a plant list and they fill it out, I have their order ready when they come to pick it up. Prices: $. 75 per 2 inch pot $1.50 for 4 inch pot. I will probably raise my prices this year.
Direct to Grocery	4-pack (1.35) - 4" round pot (1.75) - 3" square pot (1.35)		$.50 for a 2 inch pot, .90 for a 4 inch pot
Wholesale to Distributor	4-pack (1.35) - 4" round pot (1.75) - 3" square pot (1.35) - Peat Pot Herbs (37.50/flat) - Peat Pot Tomato/Pepper/Eggplant (25/flat)		
Other Notes on Marketing			I like having an order form for people to use, I have my longer term customers trained to use it, and it works well for both of us.

River Root Farm - Equipment

Name	Make/Model	Size	Supplier	Used for	Cost	Notes
Vacuum Seeder	Speedy Seeder	Standard 1020 size	Carolina Greenhouses	Seeding	$500 (used)	Seeding Efficiency
Germination Chamber	96 Flat	66 1/2″ high, 24″ wi	Seed EZ Seeder	Germination	$400 (used)	Quick & Uniform Germination
Germination Chamber	48 Flat	4 1/2' W x 6 1/2' H x	Phytotronics	Germination	$1,800	Quick & Uniform Germination
Greenhouse Flat Trolley	Unknown	Holds 15 flats - Com	Four Season Tools	Moving Flats	$1,200	Material Management
Macro Bin	Unknown	48"x44"x30.75	Unknown	Holds potting soil	Free	Soil transfered to this from bulk totes
Heat Mats	Hydrofarm	60" x 21"	Johnnys Seeds	Post germination warmth	$90 each	Use 4 - provides additional warmth after necking in germination chamber
Heater - GH1	ThermaGro Plus	220,000 BTU	Used	Heat	$500 (used)	
Heater - GH2	Effinity 93	215,000 BTU	Nolts Midwest Produce Supplies	Heat	$3,000	
Hand Seeder	Dial		Johnnys Seeds	Hand Seeder	$4.00	
Hand Held 20 Soil Blocker		Mini	Johnnys Seeds	3/4 Soil Blocks for germination	$27	Used for varieties we are planting that don't require a full flat - easy to move to larger cells
Water Breaker	Dramm & Foggit	Yellow Dramm - 2gpm Foggit	Nolts Midwest Produce Supplies	Watering	$10 & $8	
Plug Popper	392 Flat Popper		Seed EZ Seeder	Pushing up young seedlings	$295	
Tables - GH1	Handmade	4x10	Handmade	Tables	Unknown	Made from untreated pine 2x4 - galvanized wire surface with 2x4 holes
Tables - GH2	Pallets	Standard	Used	Tables	Free	Untreated

Sweet Springs Farm - Equipment

Name	Make/Model	Size	Supplier	Used for	Cost	Notes
wood stove	Kickapoo		out of business	heat	$200 18 yrs ago	Still going strong!
soil totes	Cowsmoo	700 lbs	Cowsmoo	potting mix	$110 per tote	
vibro hand seeder			Johnnys		70	
flat soil tamper	homemade		my husband Aaron	tamping soil in flats	I made him a pie	They have lasted me over 20 years. Two types in photo
hand wand	Dramm		Jungs	watering flats	15	I have a small hole head for young plants and one with larger holes to provide quicker watering on larger plants.

Two Onion Farm - Equipment

Name	Make/Model	Size	Supplier	Used for	Cost	Notes
Vacuum seeder	E-Z Seeder	Standard 1020	E-Z Seeder	Seeding	1004	plates with size #16 #7 and #3 holes custom drilled for 60 block trays
Soil blockmaking area		2'x8'		Making soil blocks	250	L-shaped sided wooden frame wall lined with 1/2" rigid plastic to contain potting mix while making soil blocks
Germ chambers	homemade	(2) 6.5'x2'x6' and (1) 6.5'x2'x9'	Materials from Menards	germination	2000	cost includes all materials and crockpots
Cement mixer	Imer Minuteman II	5 cubic ft	Toolfetch.com	mixing soil mix	600	save time and work mixing. We purchased this as soon as we decided to make our own mix (in 2015) - this saved us about $4000 per year in materials compared to buying mix
Pallet Bins for storing compost for potting mix	homemade	(8) 4'x4'x2.5'	white oak from local sawmill	holding compost for potting mix	430	We buy compost in bulk but need a contained way to store it in greenhouse
Heating system	homemade		Menards	heating growing beds	1800	Includes 1/2" pex and fittings, 30 gallon 4500 watt electric water heater, NIBCO® 1/25 HP Bronze Hydronic Pump, 2 gallon expansion tank
Watering system	homemade		Menards, Nolts, Zoro, etc		~$250	1/2" orchard tubing, fittings, controller (Nolts DG5006), sprinklers (butterfly, bridge, orange nozzle and yellow flat spreader)
Growing beds					1400	Includes insulation, row cover, but not pipe for wickets and rolling up cover (we re-used old pipe - it would have been about $550 new). Sand to cover 48'x34' was probably another $225. Landscape fabric to cover 48' x 34' (with fabric left over) was additional $225.
Soil blockmakers		4 x4", 1x3", 2x1.5", and 1x2"	Johnnys and Peaceful Valley	Making soil blocks	710	plus different dibblers
Hand pallet jack	Crown PTH Heavy-Duty Pallet Jack 27x48 5000 lb		Crown	moving soil mix ingredients in bins or on pallets	475	goes along with pallet bins above; a necessary investment once we decided to make our own mix

River Root Farm - Crop Specifics

Crop	Seeding Cell Size	Germ Temp	Germ Days	Up Pot Cell Size	Days in Greenhouse	Days in Hardening Off
Beets	72	60	4-5	depends on	3-4 wks	5-7
Broccoli	392	80	2	final	3-4 wks	5-7
Brussels Sprouts	392	80	2	destination	3-4 wks	5-7
Cabbage	392	80	2		3-4 wks	5-7
Cauliflower	392	80	2		3-4 wks	5-7
Celery	392	80	10		4-6 wks	5-7
Collards	392	80	2		3-4 wks	5-7
Cucumber	72	60	4-5		2-3 wks	5-7
Eggplant	392	80	4-5		4-6 wks	5-7
Kale	392	80	2		3-4 wks	5-7
Kohlrabi	392	80	2		3-4 wks	5-7
Lettuce	72	80	2		3-4 wks	5-7
Melon	50	60	4-5		2-3 wks	5-7
Onions	128	80	4-5		2-3 wks	5-7
Peppers	392	80	4-5		4-6 wks	5-7
Squash - Summer	50	60	4-5		2-3 wks	5-7
Squash - Winter	50	60	4-5		2-3 wks	5-7
Tomatoes	392	80	4-5		4-6 wks	5-7

Sweet Springs Farm - Crop Specifics

Crop	Seeding Cell Size	Germ Temp	Germ Days	Up Pot Cell Size	Days in Greenhouse	Days in Hardening Off
Broccoli	nursery flats	60-70	4	36	4 wks	7-10 days
Brussels Sprouts	nursery flats	60-70	4	36	4 wks	7-10 days
Cabbage	nursery flats	60-70	4	36	4 wks	7-10 days
Cauliflower	nursery flats	60-70	4	36	4 wks	7-10 days
Celery	nursery flats	60-70	8	36	6 wks	7-10 days
Collards	nursery flats	60-70	4	36	4 wks	7-10 days
Cucumber	18 or 36	70-75	4		2 wks	2 days
Eggplant	nursery flats	70-75	4	18 or 36	6 wks	7-10 days
Kale	nursery flats	60-70	4	36	4 wks	7-10 days
Kohlrabi	nursery flats	60-70	4	36	4 wks	7-10 days
Lettuce	4 pack 2"	60-70	4		2-4 wks	2 days
Melon	nursery flats		4	18 or 36	2 wks	2 days
Onions	nursery flats		8		8-10 weeks	7-10 days
Peppers	nursery flats	70	4	18 or 36	6 wks	7-10 days
Squash - Summer	18 or 36	70	4		2 wks	2 days
Squash - Winter	18 or 36	70	4		2 wks	2 days
Tomatoes	nursery flats	70-75	4	18 or 36	6 wks	7-10 days

Sweet Springs Notes:

I succession plant so I have large early bedding plants, and nice ones for gardeners who plant late.

Cucumbers: Plants get wind and cooler air at night after around May 1-5, so I don't need to harden off if planted May 1, which is when I do cucurbits.

Onions: 400 to 450 plants/flat

Two Onion Farm - Crop Specifics

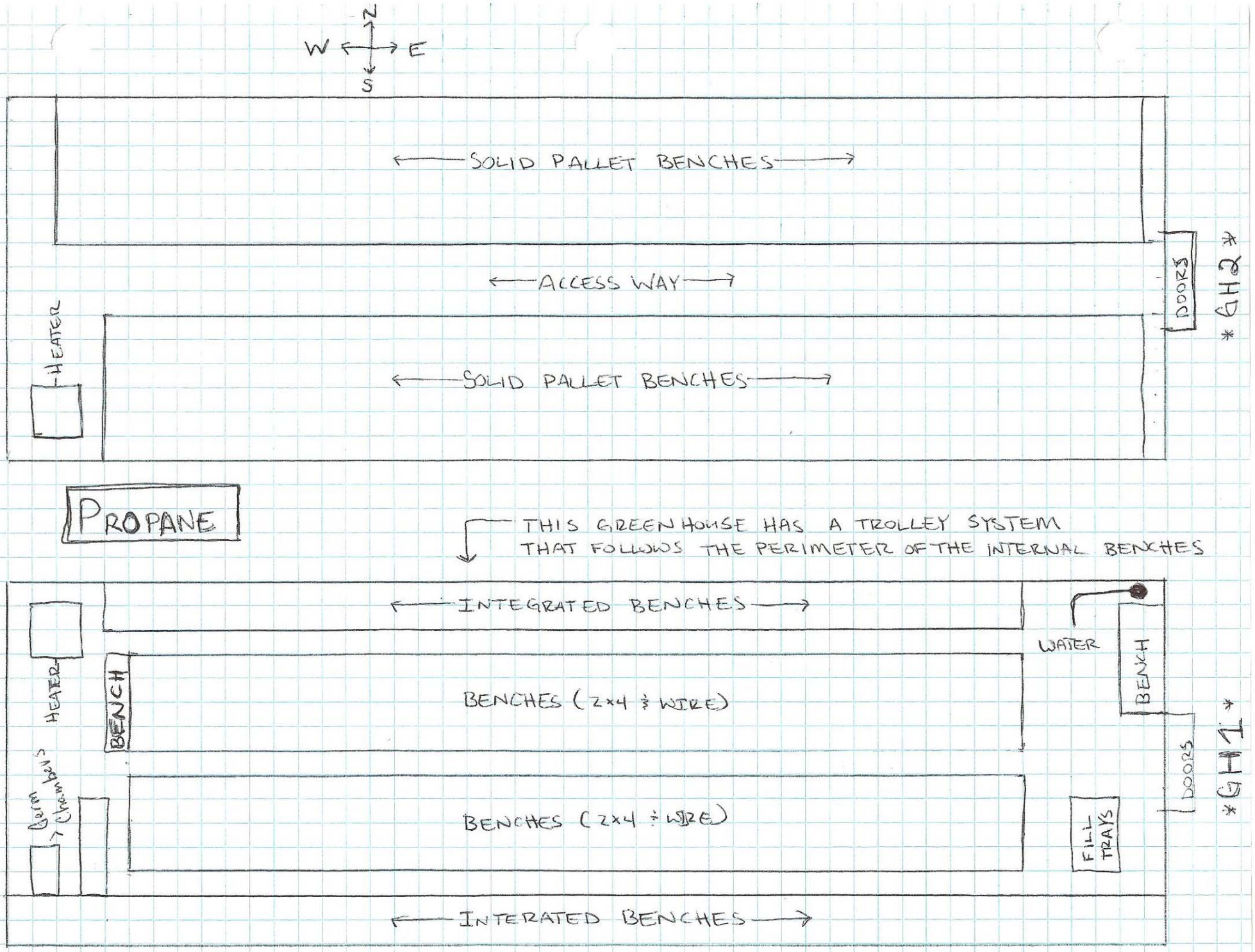
Crop	Seeding Cell Size	Germ Temp	Germ Days	Up Pot Cell Size	Days in Greenhouse	Days in Hardening Off
Broccoli	1.5	75	2		10-17 in spring	~7
Brussels Sprouts	1.5	75	2		10-17 in spring	~7
Cabbage	1.5	75	2		10-17 in spring	~7
Cauliflower	1.5	75	2		10-17 in spring	~7
Celery	2	none	none			~7
Cucumber	3	85	1		~5	~7
Eggplant	2	85	2-4	4	~35	~7
Kale	1.5	75	2		10-17 in spring	~7
Kohlrabi	1.5	75	2		10-17 in spring	~7
Lettuce	1.5	68-70	2		10-15 in spring	~7
Onions	1.5	70	4-5		15-30	~7
Peppers	2	85	2-4	4	~35	~7
Squash - Summer	3	85	2		~5	~5
Squash - Winter	3	85	2		~5	~5
Tomatoes	2	85	2-3	4	~30	~7

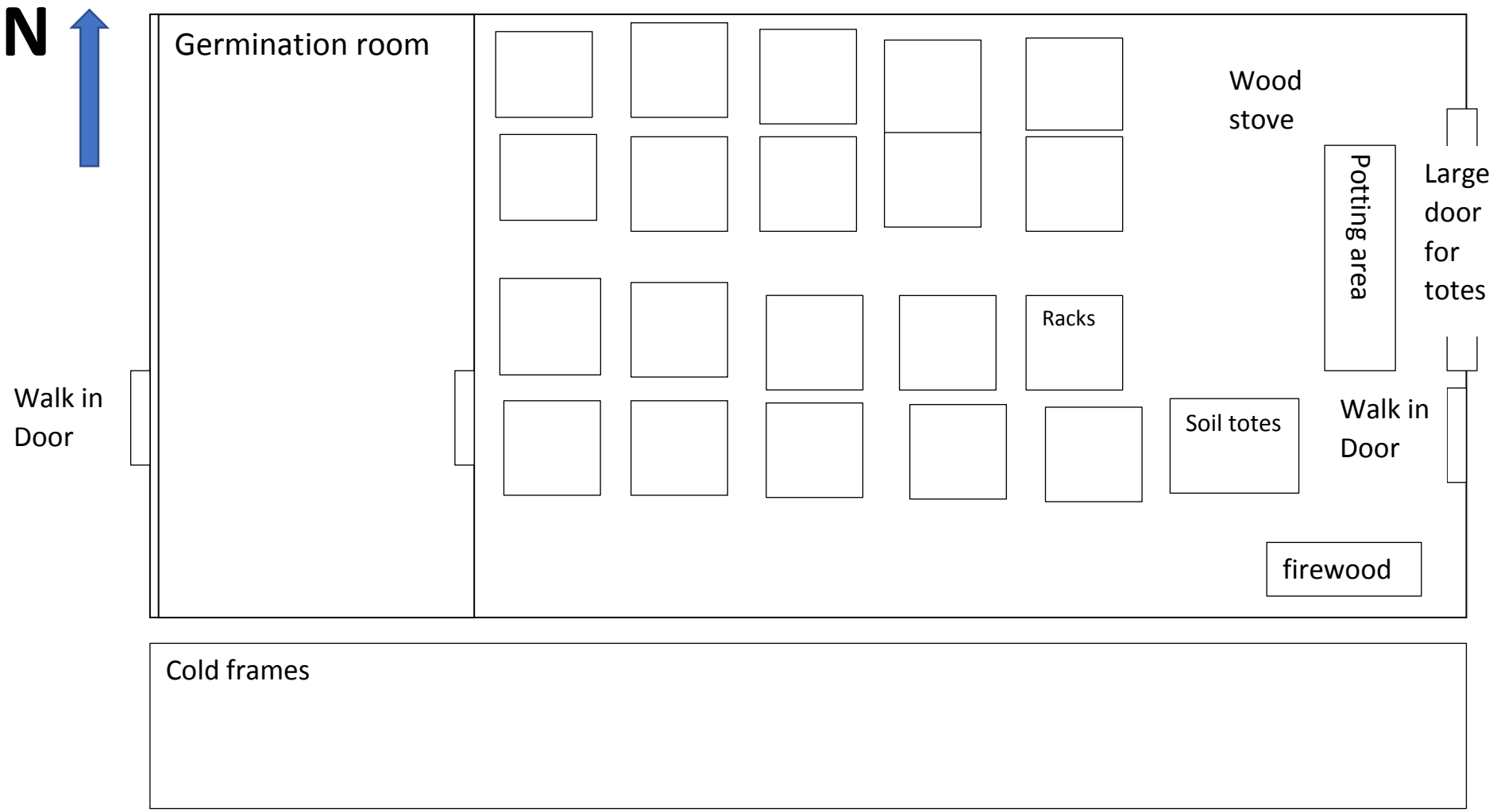
Two Onion Notes:

Summer changes for Brassicas: skip germ chamber and greenhouse; transplant after 14 days in cold frame

Celery: Skip germ chamber, put directly into greenhouse growing beds. Heat bed only during day

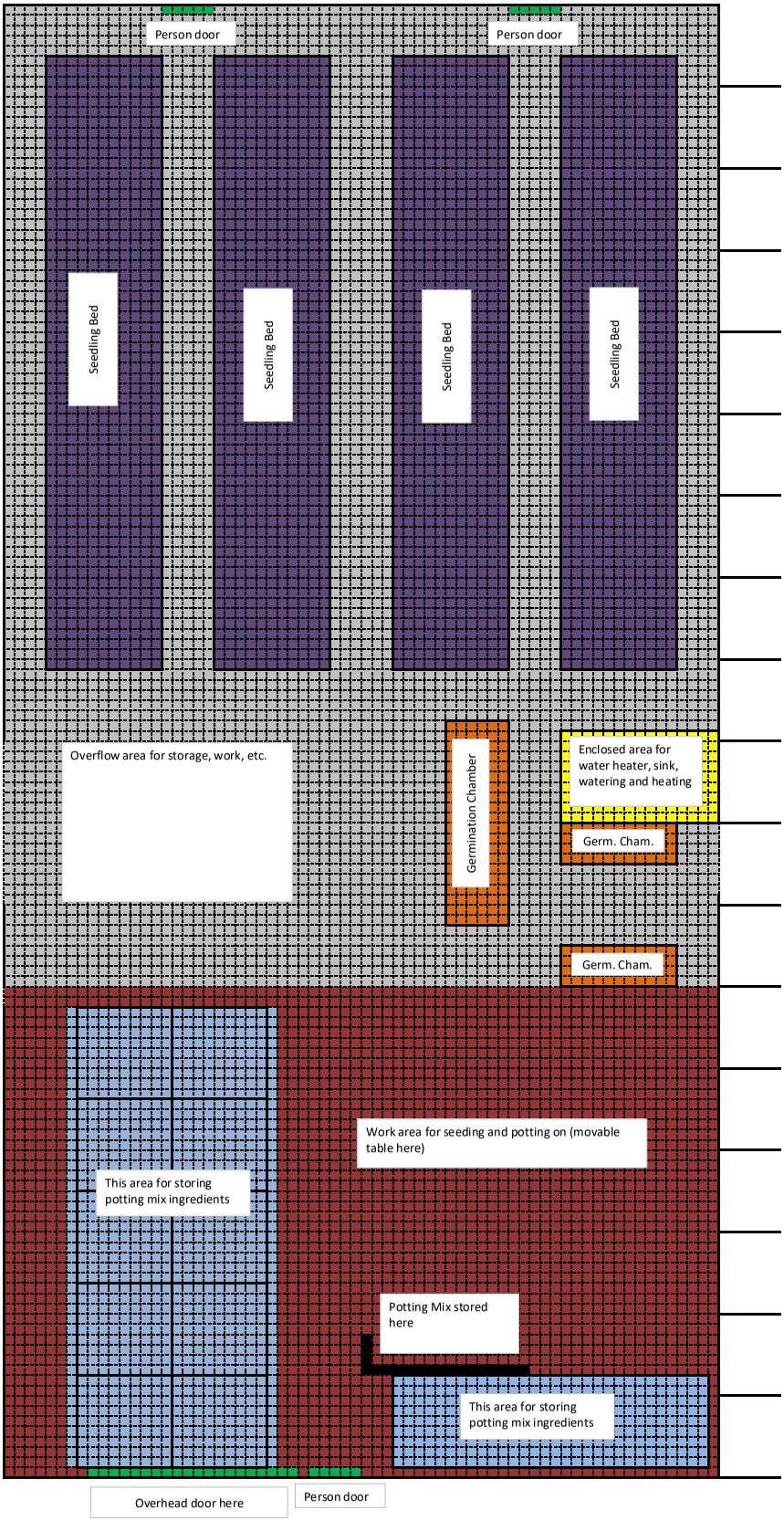
Lettuce: skip greenhouse in summer; 2 days in germ chamber, 14 days in cold frame, then transplant


N
W
E
S
SOLID PALLET BENCHES
ACCESS WAY
SOLID PALLET BENCHES
DOORS
* GH2 *
HEATER
PROPANE
THIS GREENHOUSE HAS A TROLLEY SYSTEM
THAT FOLLOWS THE PERIMETER OF THE INTERNAL BENCHES
INTEGRATED BENCHES
WATER
BENCH
HEATER
BENCH
BENCHES (2x4 + WIRE)
Germ Chambers
BENCHES (2x4 + WIRE)
FILL TRAYS
DOORS
* GH1 *
INTERATED BENCHES



Sweet Springs Farm Earth-Bermed Greenhouse map

North wall is 8 feet of concrete, buried into the ground, earth-bermed. Side walls step down from 8 feet to 0 feet of above grade concrete to the south. 4 foot frost wall on sides and front (south side)



Cold frame for hardening off