Rotating Crops in High Tunnels
Planning: Crop Mix, Location (Rotation) and Scheduling
John Biernbaum and Adam Montri, Michigan State University

Many non organic farmers start by defining organic farming as growing without chemicals and pesticides. They then learn that some chemicals and pesticides are allowed, but the options are limited to non-synthetic, low solubility or low residual type chemicals such as mined minerals or biological pesticides that are on an approved list.

A next common step to understanding organic farming is learning about the importance of organic matter, the living soil and the soil food web. Organic matter and soil biology are managed by limiting deep cultivation and by managing crop residue, cover crops, green manures and compost.

Another key to maintaining soil and plant health is effective and efficient crop rotation. Crop rotation impacts all aspects of production including fertility management, soil physical properties, selection of ground cover management strategies, pest management and marketing. A basic premise of organic farming is that continued production of one crop on the same field or area can never be justified, no matter what the marketing conditions or economic limitations of industrial monoculture efficiency. A field history and crop rotation plan is an essential and required component of an Organic Systems Plan (OSP) and a monoculture will never be certified organic.

For an OSP see: http://www.attra.ncat.org/attra-pub/PDF/marketfarmplan.pdf.

One of the key reasons for not growing crops in the same place each year has to do with the development of microorganisms that help decompose plant material. At the end of a crop, there are leaves and roots that need to be decomposed. Microorganisms develop to help the process. If the same plants are decomposed in the same spot, the microorganism population may get so efficient that even healthy plants still in production will get decomposed. The best way to avoid this is to not plant the same crop in the same space time after time.

Why use rotations?

- Market Demand (Marketing Method)
  Farmer's Market, CSA, Restaurant, Wholesale
- Seasonal Opportunities
- Farm Economics
- Soil Health – Fertility
- Soil Health – Diseases
- Insect Pest Management
- Risk Management

The following information and examples can be used to schedule planting for passive solar greenhouse (PSGH) vegetables, herbs or flowers. Examples are based on personal experience and research at home and at the MSU-Student Organic Farm, as well as observing other farmers. A good description of how one commercial grower uses a similar hand drawn template is provided on pages 36 to 40 of the book *Walking to Spring: Using high tunnels to grow produce 52 weeks a year*. (Authors Paul and Alison Wiediger of Au Naturel Farm). It is important to note that they are located in Kentucky so not all the methods recommended there will work in more northern climates.

Crop Mix (What to Plant? and How Much to Plant?)

Prior to scheduling, a crop mix plan is developed based on the market being served. The crop mix will change over the season from cool season to warm season and back to cool season crops. The quantities of each crop planted are primarily influenced by the crop productivity per unit area (data available from catalogs), the market being served and the demand and profitability of the items produced.

Crop Mix Example: What crops do you intend to grow and what percent of the space do you plan to use for each? These decisions will also depend on what you want to market and when you want to market it, but crop mix is a first step. What you will grow for personal home use vs a farm stand vs CSA vs restaurant sales will be different. The crop mix allows the calculation of how much of the greenhouse space will be planted to each crop (estimates of number of square feet or beds).

Example Fall Crop Selection and Mix - Lets start with a crop mix of four categories of crops for winter harvest.

- 25% Root crops: carrots, beets, turnips, radishes, green onions
- 25% Head crops: lettuce (multiple types), Chinese (napa) cabbage, pac choi, tatsoi
- 25% Leafy greens: spinach, chard, kale, collards, komatsuna
- 25% Baby leaf salad greens (BLSG): lettuce (multiple types), spinach, mizuna, kale, beets, chard, Tokyo Bekana napa cabbage, arugula, tatsoi, pac choi, claytonia, mache, etc

Crop Location and Rotations (Where to Plant It?)

Prior to scheduling, a crop location and rotation, plan are developed based on the crop mix. Crop location in the greenhouse can be influenced by several factors (light, convenience, etc), but a key one is the need for a rotation. One of the reasons for having a crop mix is that it is not biologically sustainable to grow the same crop in the same spot over time due to the likely development of diseases or insects specific to the crop. Similar types or related species of plants can be put into groups that require similar amounts of growing area.

Example Location and Rotation: For the first year of planting, placement is not dependent on the previous crop. But in later years, the categories need to change location. The basic idea of a rotation is to not plant the same crop or closely related crops in the same place over time. For example, tomatoes, peppers and eggplants are closely related; cabbage, broccoli and cauliflower are closely related.

	Winter 1	Winter 2	Winter 3	Winter 4	
Bed 1:	root	BLSG	leaf	head	
Bed 2:	head	root	BLSG	leaf	
Bed 3:	leaf	head	root	BLSG	
Bed 4:	BLSG	leaf	head	root	

Crop Scheduling and Succession Planting (When to Plant It?)

If your goal is to maximize production and income, your goal is to keep the greenhouse space as full as possible over the season. Scheduling is developed for each individual crop, and

then for all the crops in relation to each other. Once greenhouse space is scheduled, say for lettuce, a schedule to sow and prepare transplants is also developed. Lower light and temperatures in the fall slow down growth significantly so seasonal adjustments in crop time must be made. Succession or regular planting is used to insure that crops can be harvested and space is full on a constant basis.

Example Scheduling: Learning about crop scheduling and rotations can be done by starting simple and then getting more complicated. Let's start with an example for a simple backyard greenhouse, 16' x 16'. Each quadrant of the greenhouse could be a 3.5' x 3.5' bed; for the example below, 25% is the amount of space used for each bed.

Location	Crop Type	Aug wk 1	Aug wk 2	Aug wk 3	Aug wk 4	Sept wk 1	Sept wk 2	Sept wk 3	Sept wk 4
Bed 1:	Roots:	carrots	green onion			turnips		radishes	
Bed 2:	Heads:	seed transplants				napa, pac, lettuce			
Bed 3:	Leafy:	seed transplants		chard, kale		komat	seed spinach		
Bed 4:	BLSG:					seeding through September			

Diversified vegetable rotations can be based on several factors including:

- Botanical and family relationships
- Just plant everything in chronological order – group by time of planting
- Group by time of harvest so field can be cleaned up and replanted
- Group by amounts of space used
- Group by length production times – short or long
- Group by fertility need, or moisture requirement or irrigation method
- Group by ease of cultivation or weed management – plant or row spacing
- Group by what crops do better in soil previously used to grow a certain crop.
- Group by what crops do poorly in soil previously used to grow a certain crop or cover.
- Consider insects and diseases that are common to certain crops or groups of crops

Eliot Coleman in the New Organic Grower considers several patterns from his own and the experience of others. (page 55)

- Legumes are generally beneficial preceding crops.
- The onions, lettuces, and squashes are generally beneficial preceding crops.
- Potato yields best after corn.
- For potatoes, some preceding crops (peas, oats, barley) increase the incidence of scab, whereas others (soybeans) decrease it significantly.
- Corn & beans are not greatly influenced in any detrimental way by the preceding crop.
- Liming and manuring ameliorate, but do not totally overcome, the negative effects of a preceding crop.
- Members of the chicory family (endive, radicchio, etc) are beneficial to following crops.
- Onions often are not helped when they follow a leguminous green manure.
- Carrots, beets, and cabbages are generally detrimental to subsequent crops.

He then goes on to demonstrate how given variables such as

- The number of crops to be grown
- The amount of space needed for each crop
- the number and size of spaces available to grow crops
- the desired minimum number of years before returning to a plot

can be used to develop a rotation plan. He suggests index cards with crops or group of crops that add up to similar sized fields, and then rotating the index cards on a table to develop a plan that makes sense.

Do these principles apply to high tunnel crop production where the land may be planted continuously with 3 or 4 crops per year? What are the key considerations?

Key High Tunnel Rotation Considerations

Economics: Selecting crops with market demand and income potential

Diversity: How many different crops? How much labor is available to manage the crops?
Minimizing crops to focus on producing more of a few crops for larger markets?
Focus on unusual crops?
Maximizing crops for a CSA?

Managing soil health is probably more critical when a small number of crops are being produced compared to when a large number of crops are being produced.

Soil Health: Root Pathogens: pythium, fusarium, rhizoctonia, scherotinia
Plant Health: Foliar Pathogens : powedery mildew, grey mold, blight
Plant Health: Insects (herbivores): aphids, thrips, whiteflies

- Primarily managed by not planting the same crop, species or genus (related crops)

Soil Fertility:

- Maintaining organic matter with high quality compost and effective incorporation of crop residue
- Balancing minerals – potassium, calcium, magnesium, sodium
    - Recommended Book: the intelligent gardener – growing nutrient dense food, by Steve Solomon
- pH – nutrient availability
- Anions - phosphorus, sulfur
- Cations – K, Ca, Mg, Na
    - Percent of each? (Balance)
    - 2-4%K, 60-80% Ca, 6-12% Mg
- Fertility for yield – minimum amounts
- Fertility for nutrient density – optimum to effect flavor and human health?
- Not overloading the system with nutrients, particularly nitrogen.

Planting Time

- First Planting Period - February, March
- Second Planting Period: April May
- Third Planting Period: August
- Fourth Planting Period: September, October

Residency
Short residency – single harvest: carrots, radishes, heading crops, green onions
Long residency – multiple harvests: BLSG, leafy greens, fruiting crops

First Planting Period - February, March

- Carrots (s)
- Salad Turnips (S)
- Radishes (S)
- Tatsoi, pac choi, mei qing choi (T)
- Kale (T)
- Chard (T)
- Others?

Second Planting Period: April May

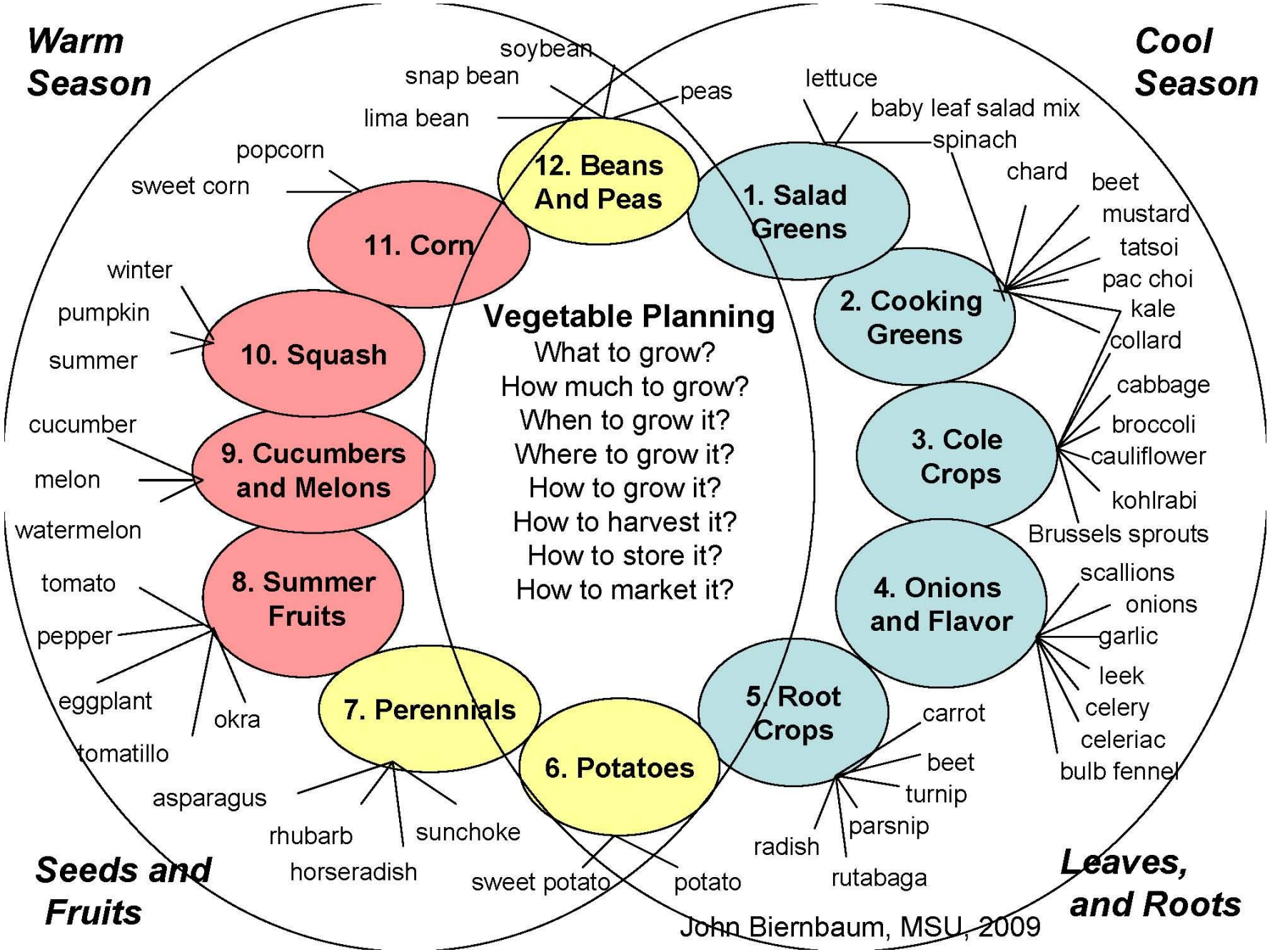
- Tomato(T)
- Pepper (T)
- Eggplant (T)
- Okra (T)
- Cucumber (T)
- Summer squash (T)
- Basil (T)
- Green beans (T)
- Sweet potato (T)
- Ginger (T)
- Others?

Third Planting Period: August

- Carrots (S)
- Green Onions (T)
- Kale (T)
- Chard (T)
- Collards (T)

Fourth Planting Period: September, October

- Baby leaf salad greens (BLSG) (S)
- Lettuce – heads (T)
- Spinach (T) or (S)
- Tatsoi, pac choi, etc as heads (T)
- Salad Turnips (S)
- Radishes (S)
- Others?


Warm Season
Cool Season
Seeds and Fruits
Leaves, and Roots
Vegetable Planning
What to grow?
How much to grow?
When to grow it?
Where to grow it?
How to grow it?
How to harvest it?
How to store it?
How to market it?
12. Beans And Peas
soybean
snap bean
lima bean
peas
1. Salad Greens
lettuce
baby leaf salad mix
spinach
2. Cooking Greens
chard
beet
mustard
tatsoi
pac choi
kale
collard
3. Cole Crops
cabbage
broccoli
cauliflower
kohlrabi
Brussels sprouts
4. Onions and Flavor
scallions
onions
garlic
leek
celery
celeriac
bulb fennel
5. Root Crops
carrot
beet
turnip
parsnip
radish
rutabaga
6. Potatoes
sweet potato
potato
7. Perennials
asparagus
rhubarb
horseradish
sunchoke
8. Summer Fruits
tomato
pepper
eggplant
okra
tomatillo
9. Cucumbers and Melons
cucumber
melon
watermelon
10. Squash
winter
pumpkin
summer
11. Corn
popcorn
sweet corn
John Biernbaum, MSU, 2009

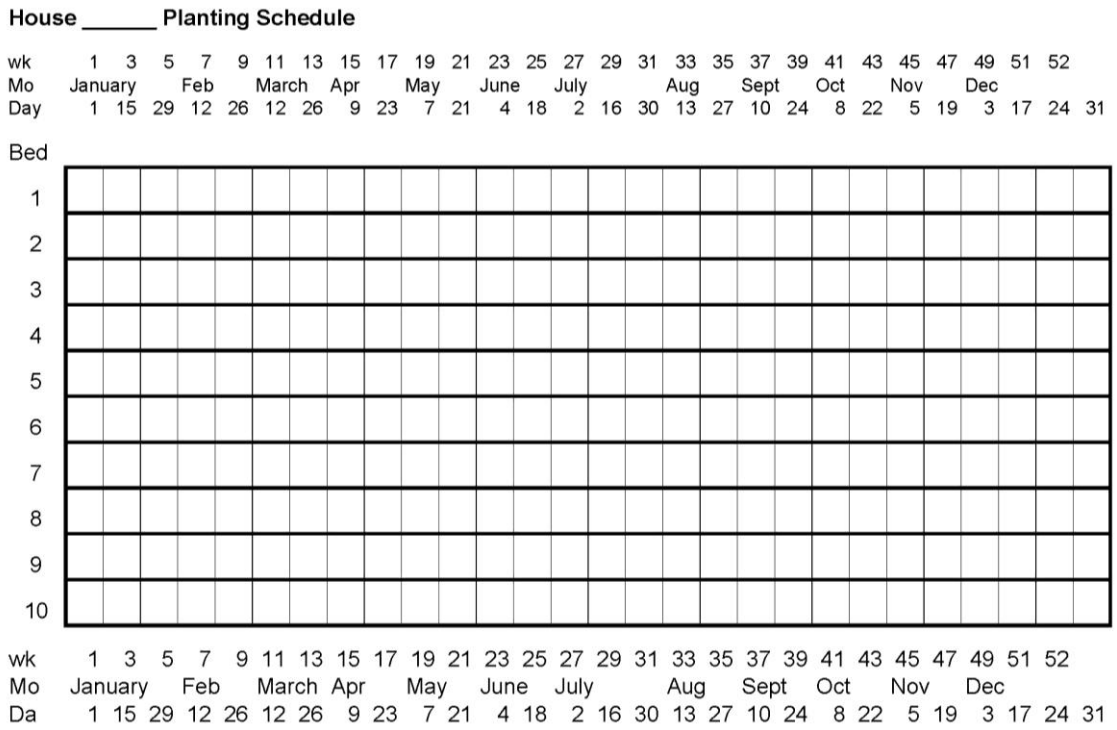
Basic High Tunnel Mixed Vegetable Rotation Examples and Options

Starting assumptions and questions:

- An organic systems plan (OSP) for a high tunnel (HT) cannot be based on continuous tomatoes and or spinach year after year.
- It is not clear whether the return of tomatoes to a site is based on the number of years (as in the field) or the number of crops planted. For example, after three years or after three other crops have been planted, which in a HT might be only one year.
- In more intensively managed year-round production space such as a HT, the routine application of compost may be able to provide an important part of the biological diversity that results from effective crop rotation. Addition of minerals based on routine soil testing can also be used to prevent nutrient depletion that can occur with inadequate crop rotation.
- HT may be used for only extending the season for warm season vegetables.
    - Tomato, basil, cucumber, pepper, eggplant, summer squash, etc
- HT may be used for protection of crops for winter harvesting.
    - Spinach, kale, baby salad leaves, lettuce, chard, collard, carrot, radish, turnip, etc
- HT schedules and rotations can be developed to allow both warm and cold season harvests.

A planting plan is based on marketing projections and available information about recommending planting dates based on regional climate factors such as light and temperature.

Start with a blank schedule, this one is made in Excel. The space identified could be beds or tunnels or fields of nearly any size.

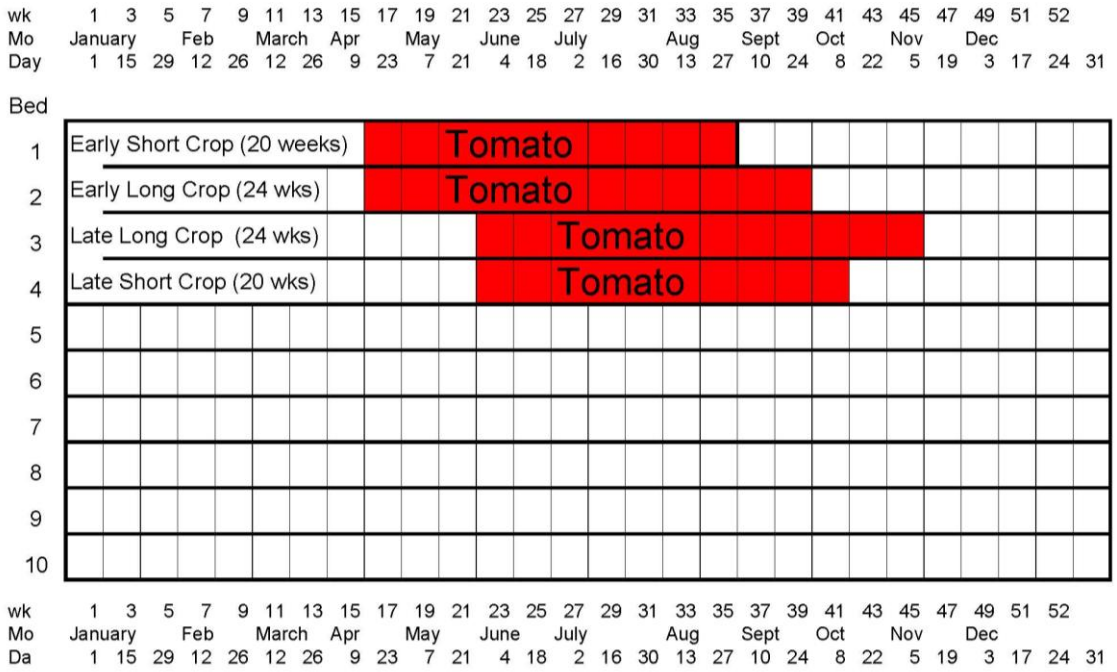


The most common HT crop is tomatoes so that is a good place to start. In the Midwest US tomatoes can be planted with four general cropping times in mind.

Early tomatoes can be planted about six weeks earlier than field planting dates assuming interior covers are used to protect the plants when needed. Earlier or later than six weeks is possible depending on the amount of intervention used.

Tomatoes can continue to be harvested from a HT as much as 4 to 6 weeks after the first field frost. However, the flavor and quality of the late fall tomatoes has not been comparable to summer tomatoes in my experience. Variety selection is likely important.

Midwest Tomato Planting Schedule Options



The temptation to plant the entire area to tomatoes is hopefully compromised by understanding the increased risk of economic failure if the tomato crop is somehow lost to weather extremes, disease (blight) or insects.

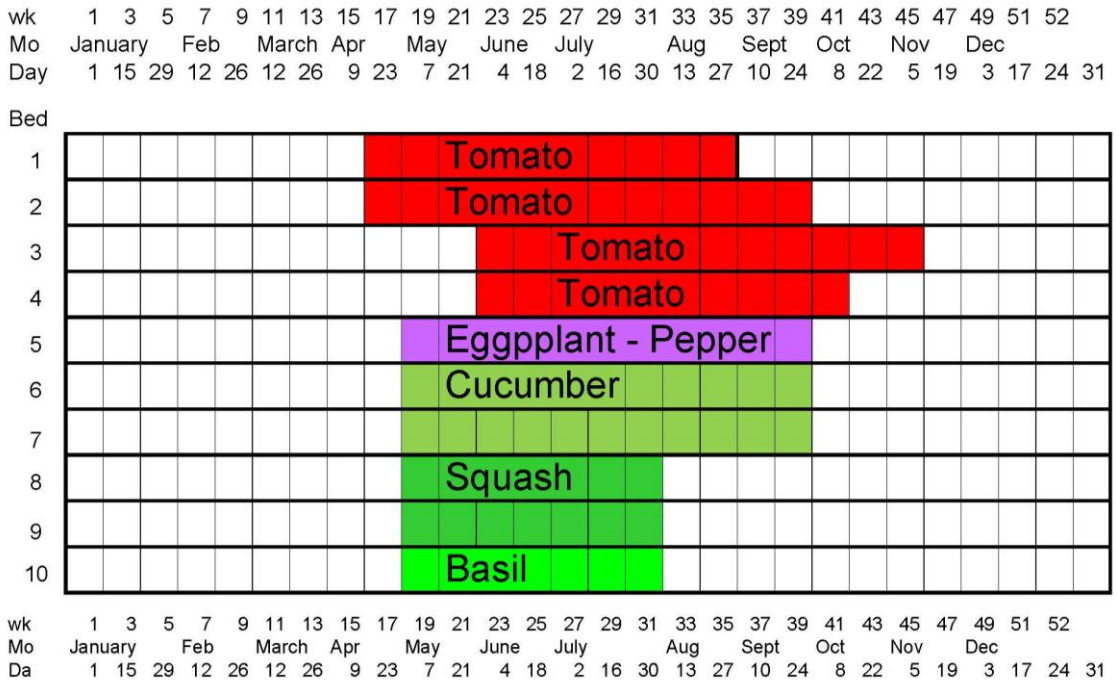
How much of the area to plant into tomatoes is partially dependent on the market potential but also dependent on how the rotation plan will be developed. Based on my current understanding and experience, it seems that 50% of the area in tomatoes would be a maximum and 25% a minimum starting point for a diversified vegetable farm.

What other crops are good warm season HT crops? Examples include basil, cucumber, pepper, eggplant, summer squash, sweet potato, ginger, etc. It is important to remember that pepper and eggplant are in the same plant family as tomato so susceptible to many of the same insect and disease problems. So perhaps the 50% should include the total of tomato, pepper and eggplant.

The early season tunnel crop may give way to field plantings so that the HT space is used for other crops. Summer squash (zucchini) is an example where productivity may be short due to powdery mildew or stem borer.

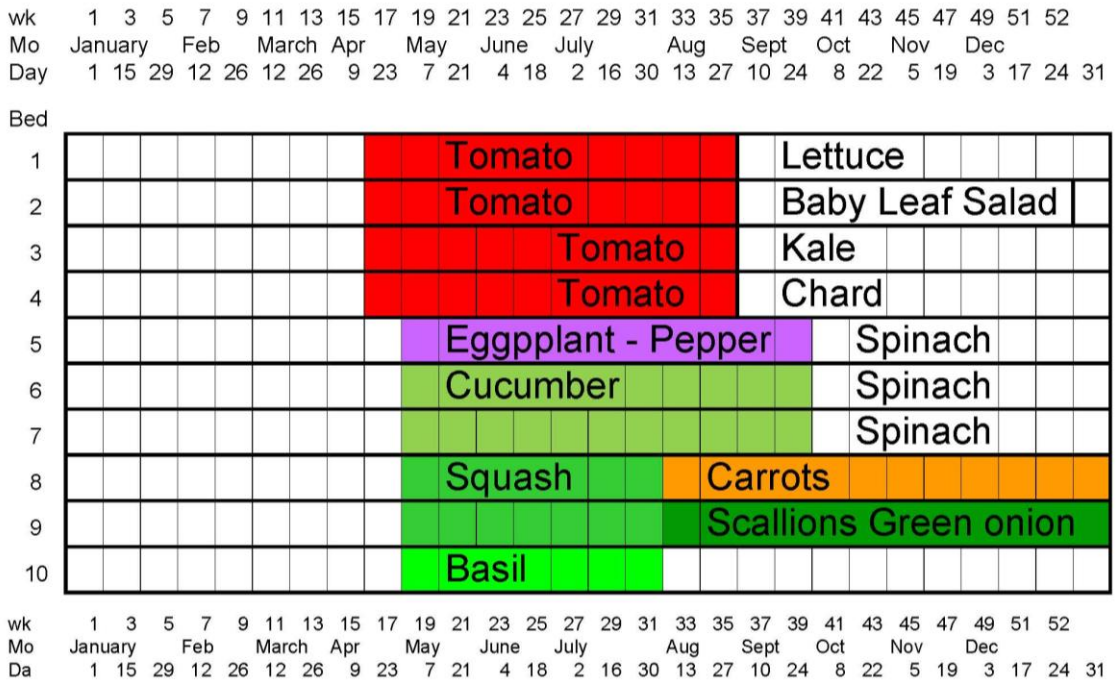
Other factors to consider are the height of the crop and the effect of shading on adjacent crops. Orientation of the rows (N-S, or E-W) will also influence crop shading.

Midwest Summer High Tunnel Planting Schedule Options



If only summer crops are produced, the decision of when to end harvest and clean up the tunnel is an easy one since it will be decided by the weather. If winter harvest is a priority, the yield of some summer crops will have to be reduced in order to plant winter crops.

Midwest Sum Fall Planting Schedule and Rotation Options

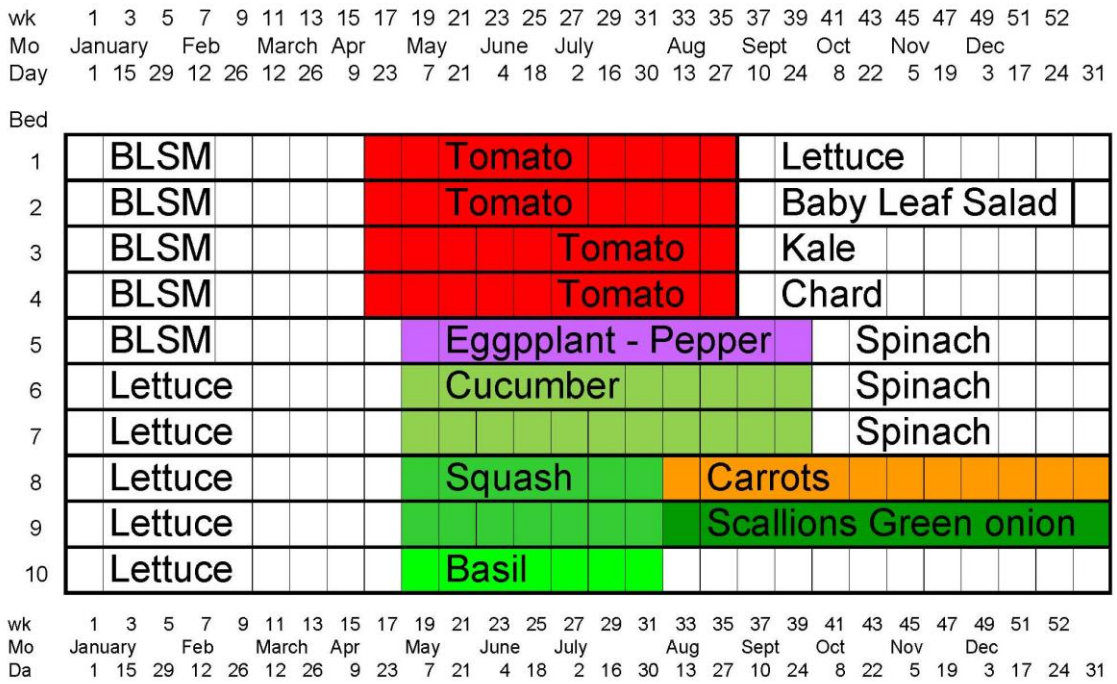


The harvest period of winter crops can also be variable. Some like spinach, kale and chard can be continued as late as March or early April. Others like head lettuce, carrots or green onions may be done as early as December or January.

Fall and winter harvest differs from spring and summer harvest of cool season crops where quality of harvest may only last for a 7 to 10 day window. In the fall and winter where the HT can serve the purpose of a refrigerator, crops can hold for weeks or months.

Decisions about spring planting will depend on when fall crops are no longer productive and when the weather conditions provide for adequate light and soil temperature for replanting.

Midwest Sum Fall Spring Planting Schedule and Rotation Options



Most all of the crops planted in the fall for winter harvest can be planted again starting in early February on average for conditions at the MSU Student Organic Farm.

The use of transplants from heated production facilities will significantly enhance the production option and the timing of replanting.

One of the tricks however is not planting crop species of the same family in the same area for an interval that includes at least three intervening crops. And so the challenge begins to develop your own HT rotation that meets you economic goals for your market and also provides adequate crop rotation to minimize disease and insect problems.

The following year rotation must then consider “flipping” the solanaceous (tom, pep, egg) crops with the curcurbit (cuke, zuke) crops. Likewise brassica (kale) family crops switched with aster (lettuce) family crops. In a separate publication the crops are further described as early and late season and short and long season that are integrated.

There are other options and ideas to consider when developing a HT schedule and rotation plan. Hopefully this provides you some starting ideas. For more information see:

www.hrt.msu.edu/john-biernbaum and www.hoophouse.msu.edu

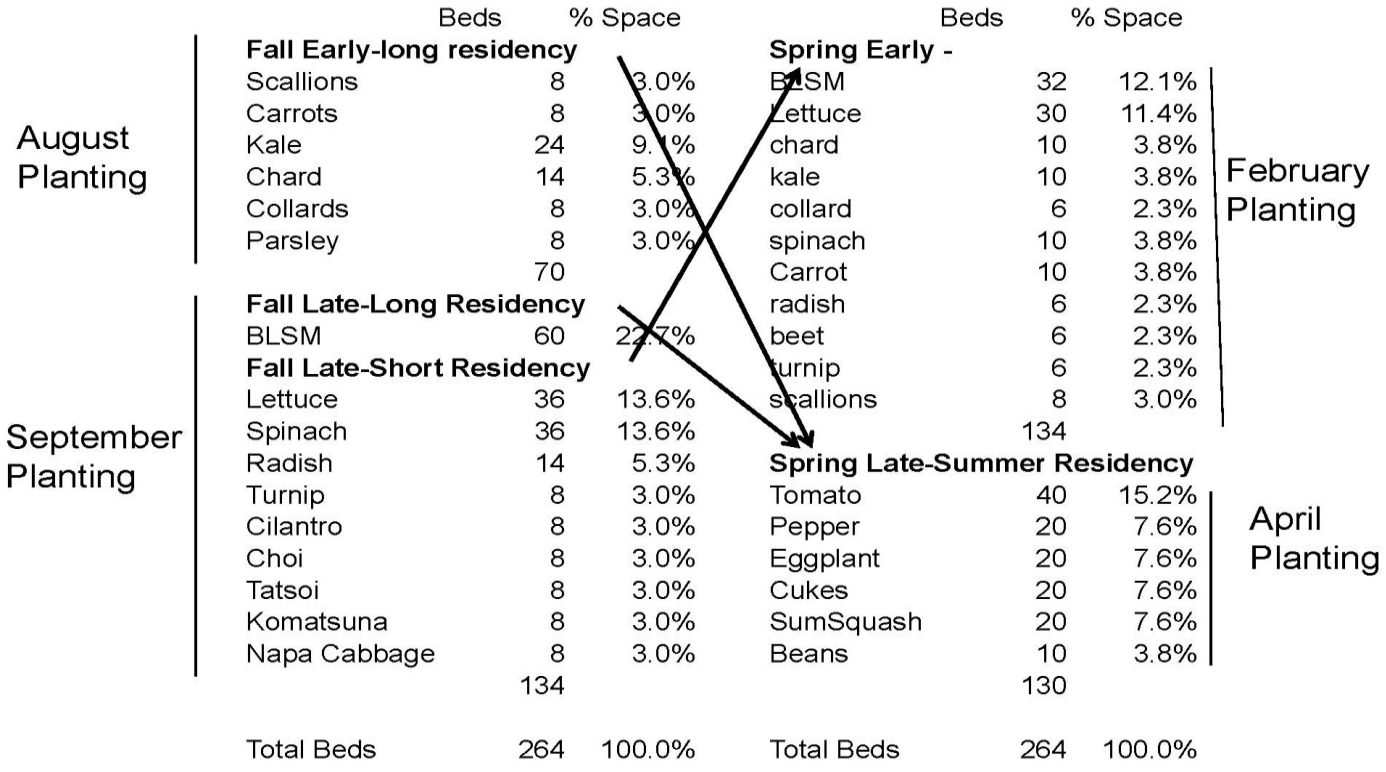
Following are some ideas from the schedule or rotation that I use at home. This is a home garden in a hoophouse, not a certified production farm. It reflects that I like tomatoes so I have two beds and usually multiple varieties. In a good year I plant one bed earlier and one bed later and pull one bed earlier and one bed later. I also really like peppers and eggplant and plant several varieties. Over the years cucumbers and zucchini go to waste so I more commonly do only one bed of those combined. Perhaps my favorite winter crop is carrots although spinach is not far behind. I have been learning to like kale.

Pear Tree Farm Home Garden Hoophouse Rotation

Bed #	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
1	Tomato 1						Arugula						Pepper - Eggplant 1						Salad & Cilantro				Carrots		
2		Work Weeds			Carrots					Salad			Tomato 1						Arugula						
3	Tomato 2						Pots of herbs							Work Weeds			Carrots								
4		Work Weeds			Carrots								Tomato 2						Pots of herbs						
5			Pepper-Eggplant 2						Worm Storage					Work Weeds			Carrots								
6			Leeks - green onions							Arugula					Pepper-Eggplant 2						Worm Storage				
7		Cuke-Squash 1			Head Lettuce									Leeks - green onions											
8	Kale, Chard, Greens				Spinach									Cuke-Squash 1			Head Lettuce								
9			Cuke-Squash 2				Pots of herbs							Kale, Chard, Gree			Spinach								
10	Pepper-Eggplant 1						Salad & Cilantro			Carrots						Cuke-Squash 2				Pots of herbs					

An example home garden hoophouse four season rotation.
Beds are 4' x 10'. Quantities produced work for 2 to 4 people with extra for freezing.
Beds are alternated from warm season to cool season production. Typically five beds for each.
There are fall planted cool crops and spring planted cool crops.
Also early season warm crops and late season warm crops.
Large pots of tender perennial herbs include figs, rosemary, oregano, lemon verbena, bulb crates, etc.
Staggered planting for pepper eggplant is accomplished by keeping transplants in pots.

MSU SOF Tunnel Rotation



		Beds	% Space
August Planting	**Fall Early-long residency**		
	Scallions	8	3.0%
	Carrots	8	3.0%
	Kale	24	9.1%
	Chard	14	5.3%
	Collards	8	3.0%
	Parsley	8	3.0%
		70	
	Fall Late-Long Residency		
	BLSM	60	22.7%
	Fall Late-Short Residency		
	Lettuce	36	13.6%
	Spinach	36	13.6%
	Radish	14	5.3%
	Turnip	8	3.0%
	Cilantro	8	3.0%
	Choi	8	3.0%
	Tatsoi	8	3.0%
	Komatsuna	8	3.0%
	Napa Cabbage	8	3.0%
		134	
	Total Beds	264	100.0%

		Beds	% Space
	Spring Early -		
	BLSM	32	12.1%
	Lettuce	30	11.4%
	chard	10	3.8%
	kale	10	3.8%
	collard	6	2.3%
	spinach	10	3.8%
	Carrot	10	3.8%
	radish	6	2.3%
	beet	6	2.3%
	turnip	6	2.3%
	scallions	8	3.0%
		134	
	Spring Late-Summer Residency		
	Tomato	40	15.2%
	Pepper	20	7.6%
	Eggplant	20	7.6%
	Cukes	20	7.6%
	SumSquash	20	7.6%
	Beans	10	3.8%
		130	
	Total Beds	264	100.0%

Example of Crop Plan and Schedule for CSA and Farm Stand Marketing. Crops are considered in categories.

- Warm Season and Cool Season
- Short Residency and Long Residency
- Fall Planting and Spring Planting

Rotation below in 3 20'x96' and 1 30'x96' houses (~10,000 sqft @ ~60% bed space).
Provides for (~Oct through Mar) for a 60 membership year-round CSA when combined with squash, potato, onion, cabbage, beet, carrot and garlic from storage and field crops outlined in the previous example for about 4 acres of field production.

Hoophouse Cultivar and Scheduling Examples **From the Michigan State University Student Organic Farm**

Crop	Cultivar*	Direct Seed (DS) or Transplant (TP)	Seed Date**	Calender Week	Scheduled Transplant Date**	Week of the Year
SPRING						
Asian Greens***	Various	TP	14-Jan	3	11-Feb	7
Baby Salad****	Various-Fast and Slow	DS	1-Feb	5	-	-
Beets	Golden, Ace	DS	1-Feb	5	-	-
Carrots	Sugarsnax, Napoli	DS	1-Feb	5	-	-
Chard	Bright Lights	TP	14-Jan	2	11-Feb	6
Cilantro	Santo	DS	1-Feb	5	-	-
Collards	Flash	TP	14-Jan	2	11-Feb	6
Cucumber	Diva	TP	27-Mar	12	1-May	17
Eggplant	Orient Express, Nadia	TP	1-Mar	9	1-May	17
Kale	Red Russian, Toscano, Winterbor	TP	14-Jan	2	11-Feb	6
Lettuces	Aruba, Ermosa, Various	TP	14-Jan	2	11-Feb	6
Pepper	Ace, Carmen	TP	21-Feb	7	15-Apr	15
Raddichio	Indigo	TP	14-Jan	2	11-Feb	6
Radish	Easter Egg, D'avignon, Cheriette	DS	1-Feb	5	-	-
Scallions	Evergreen Hardy White	DS	1-Feb	5	-	-
Spinach	Space, Tyee, Renegade	DS/TP	14-Jan	2	11-Feb	6
Summer Squash	Zephyr	TP	13-Mar	10	15-Apr	15
Tomato	Big Beef, Celebrity, Various	TP	21-Feb	7	15-Apr	15
Turnips	Hakurei, Scarlet Queen	DS	1-Feb	5	-	-
Zucchini	Sultan	TP	13-Mar	10	15-Apr	15
FALL/WINTER						
Baby Salad***	Various	DS	27-Aug to 1-Oct	34-39	-	-
Beet	Ace, Golden	DS	8-Aug to 15-Sept	31-37	-	-
Carrots	Sugar Snax, Napoli	DS	6-Aug	31	-	-
Chois	Various	TP	24-Jul to 7-Aug	29-31	20-Aug to 7-Sept	33-36
Cilantro	Santo	DS	4-Sept to 20-Sept	35-38	-	-
Collards	Flash	TP	24-Jul to 7-Aug	29-31	20-Aug to 7-Sept	33-36
Kale	Red Russian, Toscano, Winterbor	TP	24-Jul to 7-Aug	29-31	20-Aug to 7-Sept	33-36
Lettuce	Aruba, Ermosa, Winter Density	TP	13-Aug	33	18-Sep	38
Radish	Easter Egg, D'avignon, Cheriette	DS	1-Sept to 30-Sept	35-39	-	-
Scallion	Evergreen Hardy White	DS/TP	6-Aug	31	-	-
Spinach	Space, Tyee, Renegade	DS/TP	20-Aug to 15-Oct	33-41	18-Sept to 15-Oct	37-41
Swiss Chard	Bright Lights	TP	24-Jul to 7-Aug	29-31	20-Aug to 7-Sept	33-36
Turnip	Hakurei, Scarlett Queen	DS	13-Aug to 15 Sept	32-37	-	-

Additional Information available at www.hoophouse.msu.edu