Food Risk for All of Us, This Terrible Time of Day, & Suggestions for Coping

Bob Randall

If they think at all about the effect of a changing climate on food plants, most people probably imagine the big problem will be too much precipitation and flooding or too little and drought. The news media is fond of focusing on disasters when the rain stops and when it deluges. And many of us have seen what happens when plants don't get enough water or too much.

In this century, our crazy weather here in southeast Texas has accordingly featured hitherto unbelievable precipitation events, as well as historic droughts. In part because of our proximity to increasingly warm Gulf of Mexico, we have had three of the five heaviest multi-day rain events in US history. The worst was the Hurricane Harvey episode where Nederland, TX got over 5 feet of rain in 4 days. During that same rainstorm, based on calculations from more than a century of experience, the southeast part of Houston's Harris County had a rainstorm that should happen "once in 20,000 years." In this century, a third of the years have had a month with more than 12 inches of rain, and ¾ of the years have additionally had a month with 10-12 inches. Designing to keep plants alive in a foot of rain, or five feet is an ongoing serious challenge around here.

Just 12 years ago though, Texas had an historic drought. A Hill Country site had what was estimated from tree rings, the driest spring growing season for trees since the mid 1500's. Houston's backup water supply at Lake Conroe nearly dried up, and the fire threat at our largest urban park if it started was thought unstoppable . Droughts here are not becoming more frequent, but because of record heat, they are getting much more dangerous.

Here on the Texas Gulf Coast, the fall planting season for many vegetable crops is 4-8 weeks later than it was just a few decades ago. Where I am, some cool season plants like lettuce have a significantly shortened harvest season and hot weather crops like okra, longbeans, and Southern peas have much longer seasons.

Our ability to harvest many sub-tropical fruits like bananas and papayas have also increased as once reliable frost dates, if we have them, have become less common and less predictable. Our pears and apples now become mostly heat dormant in the summers and reliably bloom in the fall. Yet the winter is still cold enough to most years defoliate them and abort the tiny fruit.

As climate change heats up the Gulf and most of the planet's plants at various rates, desk bound policy crafters at all levels barely notice. This is a report on efforts to cope, a complaint about mostly climate blind agriculture, and some ideas about how to adapt to what's coming wherever you are.

The Bigger Pattern

The 15th to 19th centuries created enormous problems for our species—planet-wide colonization, ever more powerful autocracies, and huge economic inequalities such as slavery, 18-hour child labor, and mega-famine. Only weak solutions emerged to counter these. And of course, the debris from these problems is still festering.

The 20th century's unique contribution to this fester was the development of industrial and military technologies that can on a large scale destroy life by degrading vast areas for long periods. By the 1970's, the problems had multiplied: oil spills, nuclear plant disasters, rain forest destruction, ocean eutrophication and oil spills, acid rain, hazardous waste dumps, pesticides in breastmilk, forest-and-city-destroying wars, ozone depletion, acid rain, and much else.

As many have noted, greenhouse gas caused climate change had been basic physics for two centuries since Fourier and then Arrhenius said the planet was warmer because of greenhouse gas insulation in the earth's atmosphere

But starting in 1958 carbon dioxide was measured and found to be quickly rising worldwide year-by-year. And by the mid-sixties, the US government was well aware of it, and its causes.

Permaculture was in many ways a response to these disasters. In a 1981 PDC I have only heard as a recording, Bill Mollison

said that during droughts, stressed trees give off a blue haze (terpenes), and after the morning dew has evaporated, are prone to fire. This firefighter's "Terrible Time of Day" is not just early afternoon when we see haze in a drought stressed forest, but as Bill rightly saw in titling his talk, a metaphor for what we were then seeing across the planet—increasing signs of bad living conditions for most life, serious possibilities of multiple die-offs, and the cascading harm that wide-scale collapsing ecosystems will mean to the livability of our planet home.

The Mollison-Holmgren permaculture solution offered a design heuristic, ethical requirements, and a disciplined design strategy to avoid the worst while still enjoying a decent life. But humanity so far is very slow to catch on. And the broader public seems largely unaware that their food supply is in "grave danger "of as Mollison warned us back in the day, cratering.

Climate Change and Food Plants

The Intergovernmental Panel on Climate Change says, "Fruit and vegetable production, a key component of healthy diets, is also vulnerable to climate change (medium evidence, high agreement).Declines in yields and crop suitability are projected under higher temperatures, especially in tropical and semi-tropical regions. Heat stress reduces fruit set and speeds up development of annual vegetables, resulting in yield losses, impaired product quality, and increasing food loss and waste. Longer growing seasons enable a greater number of plantings to be cultivated and can contribute to greater annual yields. However, some fruits and vegetables need a period of cold accumulation to produce a viable harvest, and warmer winters may constitute a risk. {5.2.2}

Elsewhere they cite research showing the general trend, "For vegetables growing in higher baseline temperatures (>20°C/68°F), mean yield declines caused by 4°C/7°F warming was 31.5%; .... Because of such findings, there is a belief that poor, former colonial, equatorial lands will be the hardest hit.

And indeed, they may be. One study of Africa they cite found that that an overall global temperature increase of 2.6°C by 2078 would reduce the common bean growing area of the continent 30% and the banana area by 20%. An increase to 4°C by 2098 would reduce bean areas 60% and bananas 40%.

But what wealthier nations are ignoring is that these lower income economies export huge quantities of food to the wealthier ones. Yearly Africa exports about US$ 27 billion in food to wealthy nations

. The US in particular gets about 15% of its food outside its boundaries. This includes from just Latin America, about $16 billion dollars' worth of fruits and about 55% of imported vegetables. Canada also imports CA$10 billion dollars' worth of produce yearly

The IPCC also cites a 2016 review of worldwide research that found fruits and vegetable production to be highly vulnerable to climate change at their reproductive stages, and therefore at flower bud formation, fruit set, and seed and grain formations. Proteins, hormones, and enzymes destabilize at higher temperatures. There is also potential for greater disease pressure, less predictable spring frosts, and worse floods, droughts, windstorms, and hailstorms.

Rising temperatures of course increase irrigation needs because there is more soil evaporation and transpiration. And increased use of irrigation leads to higher salinity in soils and multiple problems with plant growth and water tables. Higher heat also increases low-level ozone which is damaging, and also increases windstorms, floods, and hail.

By contrast higher CO_2 may help things grow and high latitude climates may have a longer growing season. Moreover, the effects differ for different botanical families of fruits and vegetables, and food is shipped all over the planet, so it is quite difficult to make broad statements about the overall change expected for anyone's food supply.

Despite this research, when climate and food is discussed in public, if it is discussed at all, the talk is of droughts and floods, greenhouse gases created by conventional agriculture, forest to ranch conversions, and occasionally the difficulty of growing rice, wheat, corn, or livestock in the changing climate. All of these are serious threats to the food supply and need urgent attention. But rarely if ever are broccoli, apples, pintos, or hundreds of other food crops the topic. Do people really appreciate what is likely to happen to their diet in the next decades?

With some exceptions, most researchers, policy makers and horticulturists so far are acting like forest tourists in a drought. They notice the smoky luncheon haze and out of season leaf color, but they have largely ignored the effect increasing heat has on plant growth or our strategies for growing them.

But semi-tropical growers here and elsewhere are noticing problems. This is because we are quickly approaching the upper limit of temperatures where most of our North American vegetables, fruits, herbs, starchy staples, and vegetable oils easily grow, set seed, pollenate, or harvest. (See Table 1 and Appendix A).

All the hottest 18 global temperatures measured in the last 150 years have occurred since 1998, and the ten hottest have happened since 2010. All major weather stations in Southeast Texas have partially mirrored the global heat rise, with 50-100% of the hottest years in 90-140 years happening in the last 25. At my nearest weather station, the last six years have been the warmest since the station began 91 years ago.

The temperature rise on the Gulf Coast is likely happening in any tropical or subtropical areas near bodies of water, as well as anywhere snow cover is declining, and no doubt anywhere else that temperatures in the growing seasons are changing. . For information on US trends, see https://www.weather.gov/tbw/newnormals

But despite this, climate-blind agriculture, media, and government at all levels are the norm. Accordingly, farmers, agronomists, and policy makers haven't responded with plans and alerts, and the changes that are needed in farmer-gardener practices are large.

Even if in future years traditional food crops can still be grown in your location for enough months or years to get good harvests, the varieties and species that will produce good harvests, and the dates they should be planted, are now changing rapidly. When still possible, what is needed urgently in every bioregion is an accurate way to regularly update planting schedules and plant lists to reflect the unstable climate of the decades we are living in.

I have found a way to do this in my bioregion and share my ideas below hoping you can adapt them to your situation, improve on them, and hopefully provide feedback we can all use.

Temperature and Plants

People suffer from climate disasters and are often in the news. Far more insidious is what is happening to plants. As temperatures increase, evaporation is increasing, so in dry spells between the gully washers, thirsty plants are having ever increasing problems. We all know plants need water, and everyone knows what wilting in hot weather leads to. Plants use water to fix carbon, to transport minerals and sugar to their leaves and cells, and those that lack wood use water to keep themselves upright.

They also use a lot of it to cool themselves on a hot day. Plants transpire and once temperatures get into the 90's, most plants use their water to cool themselves rather than to grow. If this evaporation is needed more rapidly than the roots can get it, leaves curl then die and sometimes plants do too. Water shortage has other profound effects, but the main point is this: if the temperatures rise into the 90's, most plants if they survive will stop growing and in the 100's almost all of them will stop growing whether or not they are irrigated.

Those of us who grow plants are aware of the cold temperature tolerances of plants we grow whether they be native or exotic, for habitat, food, or other reasons. What most growers wherever they are, have been less aware of, and need to learn, is the hot temperature tolerances of plants and the likely hot temperatures in the months and years ahead where they grow.

Basically, all plants and animals have optimum temperatures in which they thrive and a wider range both colder and hotter where they don't grow. For seedlings especially, delayed growing makes them more vulnerable to pests and drought.

At even colder or hotter temperatures than optimum, even mature plants struggle and have pest and disease problems, and at still colder temperatures or hotter ones from optimum they are heavily damaged or die. These temperatures are related to the biome where they evolved and to a lesser extent to later efforts to adapt them to other places. See Figure 1.

Plants often have different optimum growing temperatures for day air, night air, soil germination, pollination, harvest quality, and for perennials, winter and summers averages, lows, highs, as well as decadienal highs and lows. Asparagus for example needs below 50°F soil temperatures for 3 months to do well; tomatoes have different nighttime and daytime temperature ranges for pollination; papayas crater at 30°F; and most apples are in trouble when winter temperatures are too warm in mid-winter or too cold during flowering. Plants also have specific tolerances for moisture—too much or too little spell trouble especially combined with unsuitable temperatures.

What to Do?

What does this mean to growers when temperatures are now increasing rapidly and somewhat unpredictably? The arctic vortex may be losing its ability to keep the subarctic jet stream regular while the oceans, large lakes, and gulfs continue to heat? The increasing potential for torrential rains, violent storms, and wild temperature swings requires a different kind of planting paradigm than the one we have been using.

It means that in addition to doing everything we can to slow and reverse climate change, we need to be good at observing our local climate to guess the future temperatures and rainfalls for plants we want to grow. We need to learn what we can about the big pattern—global warming—and as much as we can about its local patterning. We also need good information about the temperature and moisture tolerances of specific plants. And we probably need to be lucky.

A good start is knowing both what temperatures you have had in the last 15 years where you are growing your plants and what hot and cold temperatures your plants thrive in and can tolerate. If you are planting 5-month annuals like tomatoes, you need to plant them when this year's temperatures where you are will be optimum for the plant. And if the temperatures are usually not what they were in 30 years ago, you need to change your planting date and possibly your methods. You may for example need to switch to early harvesting varieties or use some additional temperature regulation for growing transplants. You may need to stop growing them unfortunately.

And if you are planting fruit trees or other perennials that you expect to live for 1-3 decades or more, they will need to tolerate longer summers, hotter temperatures, shorter winters, more drought, and flood, and possibly temperature extremes both cold and hot that are less predictable by you and them. You may or may not have fewer cold threats, but your average lows will probably continue to get higher.

You also may need if there are more deluges to use drainage methods like berms, raised beds and rain gardens; and if there are worse droughts, swales, rain tanks, ponds, drains, key line, and biological mulches to improve microbial mycelia and water retention. Depending on how hot it gets, you may need to design for more shade and trees in the vegetable garden. Trees transpire, but forests cool, and shade reduces surface evaporation.

None of this will work well unless you match your plants to your climate correctly. You need a good understanding of your likely day and night temperatures for the time your plant will be outside in soil. These days, much of this is online for a weather station near you. In the US, http://weather.gov or http://climate.gov are good places to start or ask a weather or climate specialist at a university or an NWS site. They will know where the data for your location is if it exists.

Appendix A lists the temperatures more than 140 annual food plants and herbaceous perennials need to thrive, as well as temperatures that bother or kill them. I did the best I could on this despite the poor availability of such data in the literature. In my book, there is a separate table for woody perennial fruits adapted to Southeast Texas, but they are not provided here because they are very biome specific.

If for example you are growing "45-day lettuce", you need temperatures for at least two months to be between 40°F and 75°F and ideally over 50°F at night and about 65°F during the day. You need less than two months if you grow transplants in a temperature-controlled space and will get a longer harvest if you have 3 months or 5 months mostly at the right temperatures. Lettuce can survive much colder temperatures and somewhat hotter ones of course, but the goal is yield, not survival.

Percentage That Need Temperatures Below Column Head to Grow

Type	<65	<80	<90	<100	<110	<120	<125	NA
38 Supermarket Veggies		61%	83%	92%	100%			2/38
54 Less Common Veggies	3%	44%	64%	92%	95%	100%		15/54
8 Culinary Herbs	0%	13%	50%	63%	100%			10/18
5 Grains	0%	40%	60%	60%	100%			2/7
6 Vegetable Oil Plants		17%	50%	67%		83%	100%	0/6

But given our fair share ethic, keeping this to yourself is not permaculture. If you digest temperature data for your bioregion, it is possible to create vegetable planting zones and a planting schedule for an entire bioregion, and the schedule can be used even after temperatures increase as one's zone changes.

For Southeast Texas, I have provided a planting schedule based on a locally new concept: vegetable planting zones A-G. These zones differ in seasonal low temperature averages of 2˚F (about 1.1˚C) per zone. Then there is a planting schedule based on the zone and what can be planted in that zone and season. See Figure 2 for a small portion. Cell abbreviations include T=Transplants started in correct temperatures, S=Seed outside, P=Plant outside, a=all month, e=early in the month, m=middle of the month.

Unfortunately, outside Southeast Texas, there is even more work to do. This basic effort is missing in most places even though weather is changing everywhere. And unfortunately, good high temperature tolerance data is not systematically published or verified. So, there is much to learn, and another reason to slow climate change. Δ

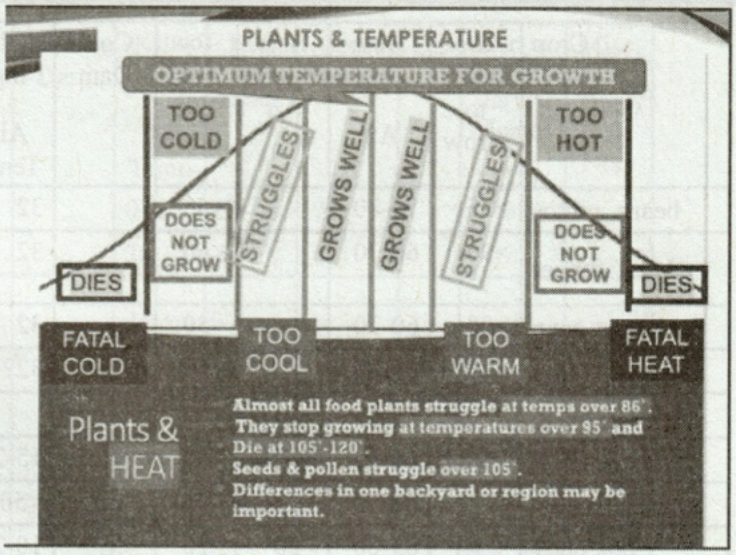

Figure 1. Plants and optimum air temperature.

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Appendix A: Temperature Needs of Vegetables (See key on p. 19)

Crop	Too Hot to Grow	Best Day Air	Best Night Air	Too Cold Grow	Cold Dam	Killing Air Temp	Best Germ. d/n	Germ Range	DL	Start to Harvest Months	Misc. Temp Note
amaranth, grain		77-85		43		32	≥70	65-75	DC	4-5	
amaranth, leaf		77-85		<68		32	≥70	65-75	IN	1-1.5	
artichoke, globe	≥75	60-65	50-60	<45	20-28	14?	80/65	60-85	IN	14	
arugula, garden	>90?	46-65		<40		5-20	57-64	>40		1-1.5	
arugula, Sylvetta	95?	60-70		<40		0-10	60	59-80		1-2	
asparagus	>75	60-64		≤59		22	75	50-95		24	A
basil	>90	68-77		<55		<37	68-75	65-85		2-3	U
beans, adzuki		60-86					86-93	>70		3-4 dry	
beans, broad	>75	60-65		<40		10-20	60-85	≥40		3	
beans, garbanzo		70-80	64-70			15				3.5-4	V
beans, hyacinth		64-86		<37		28?			DC	1.5	C, X
beans, lima	>80	60-70		<50		32	85	59-86		3	V
beans, yard-long		75-90	>64	<50			65-85	>50		1.5-3	
beans, mung	>96	80-86		<68		32	77-80	65-104	IN	3-4.5	

Crop	Too Hot to Grow	Best Day Air	Best Night Air	Too Cold Grow	Cold Dam	Kill-ing Air Temp	Best Germ. d/n	Germ Range	DL	Start to Harvest Months	Misc. Temp Note
lemongrass		68-90		31		**<20**	72			3	Hz
lemon verbena					31	14-22					
lentils	>81			<25		≤21	60-77	>40		3.5-4	
lettuce	>75	68	55-64	<40	≤26-31	5-19	60-68	40-80		1-3	E, H
luffa squash		>70		<60		32		70-95		3-4	
âche/corn salad	>79	45-65				-5/+ 5	59	50-60		2	
maca	>60	40-50				<24					
Malabar spin-ach		75-90		<70	<65	32?	77-85	59-100		2	
marjoram		86				32					
molokhia/ saluyot	>115	Av 81		<44			77-86		IN	2	
millet, proso		91-95	>50	<54			70-86	>70		3	
mint	**>90**	77	54-60	<60d		-20				2	
mitsuba					≤32	14	68-78			2	
mizuna, mibuna	>86	70-80		<50		10?	68-86	45-86		1-2	
moringa	>120	77-95		<70	33	<25				>6	
mustard	>75	60-65		<45	26-31	5-20				1-2	
mustard, seed		50-70						40-75			
Napa cabbage	>75	60-70	>53	<50		20-25	71-77	<85		2-2.5	
nasturtium		70-83	>50	<50		30	70	55-70		1.5-2	
New Zeal'nd spinach	>95	60-75		<50		22		>65		2	
oats, red	>75	70	<60	<45		5-10	68	50-77		3-4	
okra	>95	70-85		<60		33	80	59-104		3	
onion, bulb	≥85	50-60		<35	26-31	5-10	*75	40-95	IN	5	
onion, multiply-ing	≥85	55-75		<45		5-12				2 §	
orache				<40	<26			50-65			
oregano, Cuban		70-75	>62	<60	<50	40	72-75			§	
oregano, Euro.	109	65-70	55-60			-10?	70-85	>60		3 §	
oregano, Mexi-can					29	20?					
Papalo	>100?	50-60		<40		32	>70	>60		2.5-3.5	
parsley	>75	60-65		<45		0	50-85	40-90		3	
parsnip	>75	60-65		<40		0-5	50-75	35-85		4.5	

Crop	Too Hot to Grow	Best Day Air	Best Night Air	Too Cold Grow	Cold Dam	Killing Air Temp	Best Germ. d/n	Germ Range	DL	Start to Harvest Months	Misc. Temp Note
peanut	111	65-89		≤57		<28?	**75-80**	>65		4.5-5	T, V
pea, pod/shell	>80	60-65		<40		<15	*75	40-85		2-3	
pea, pigeon	>96	65-86		<41		<25-28	>77	>64		4	
pea, southern	>95	86	>60	<50		>122		65-98		3-4	
peppercorn, black	104	73-89		<60	32	22?				12-48	
pepper, sweet	>80	70-75	57-61			31-32	*85	60-95		4.5-5	J, K, V
perilla/shiso		**>64**		<45		30	68-75			2-3	
potato	>75	60-65	64-68	<40	32	<25		45		2.5-5	PP
pumpkin	>90	65-75		<50		<32	90	70-100		3.5-4.5	N
purslane		>70		<50			90	>75		2	
quinoa	>90	64-68				25?	65-75	40-60	Vv	3-4	V, Vv
radish, daikon	>75	68-77		<40		15-20	68	50-77		2	
radish, salad	>75	60-65		<40		15-20	68	50-77		1	
rhubarb??	76	60				>90		**60-70**			L
rice	>104	86	75	<60n	<66d		90	80-90		6	V
romanesco hybrid		40-75						50-60		3	Y
romanesco OP		40-75						50-60		14	M, Y
roselle	>95	70-85		<65	<40	32		75-90	DC	7	
rosemary	>105?	68-78				11	72	54-72			
rutabaga	>75	60-65		<40		20	55-75			3-3.5	
sage, culinary		80								2.5-3	
salsify /scorzo-nera	≥85	55-75		<45		0				4-4.5	
sea kale/crambe	>85	40-60			25						
sesame	>120	86-92		<70	<50?			>70		3	
shallot, French	≥85	55-75		<40		– 30			≥15	none	
shungiku/tong ho	>85	50-60		<50						1-2	
snake gourd		80-95		64			86-95	77-95		3-4	
sorghum	104	>90		<50			70	>65		3.5-5	V
sorrel	>75	60-65		<40		15				2	
spinach	>75	60-65		<37		< 0-10	59	50-68	<13	1.5	

Crop	Too Hot to Grow	Best Day Air	Best Night Air	Too Cold Grow	Cold Dam	Kill-ing Air Temp	Best Germ. d/n	Germ Range	DL	Start to Harvest Months	Misc. Temp Note
squash, bottle grd		75-85					85-95	>60		2.5-4	
squash, Sum-mer	>90	65-85		<45		33	70-95	60-100		1.5-2	N
squash, Winter	>90	65-85		<45		33	70-95	60-100		3-4	N
strawberry	100	60-78		<48	≤22-27	-10				3	K, V
sunflower seed		64-91		<50	30-31	29	>55-60	>48		3.5-4	
sweet potato	95-104	70-85		<65	<50	35	>80	>65		3-6	
sweet pot. Spin-ach	>95	70-85		<60		<28				2 §	
taro tubers		77-95		<77	≤59	20?				3-4	
tendergreens	>75	60-65		<45	26-31	20		68-77		1-2	
thyme, common		60-80			< 0						
tindora /ivy gourd		68-90		<60		<32	86-90	>65		2	P
tomatillo	**>90**	77-90		<60	<60?	<32	68-80	60-85		3.5	
tomato	>80	70-75	55-61		<50	31	85	68-80		3-4	Q
turmeric		68-95			<50	<22				9 §	
turnip	>75	40-60	>50	<40	26-31	12-20	85	60-104		1-2	R
wasabi	>70	46-64		<43	27	**25**				none	U
watercress	**≥85**	68-78		32		**<0**		46-59		2	
watermelon	>95	68-79		<55		33	70-95	60-105		3	
wheat,	>98	66-77	<88	<41		-10	68-77	38-90		4/8	V, Z
wintermelon/ wax		80-90		<60			85-95			3-4	
yacon	>104	65-77		<50		32 lf	90			7-22	
yam, tropical		86		<68		50			<12		
yam, Chinese		86		50?		10					
yuca	>95	77-90		<50	32-50	15-25	86	>70		7-9	
yu choy		60-80	≥55	<50	50-55						S

Fall Vegetables Planting Schedule

FALL ZONES: SEPTEMBER	A	B	C	D	E	F	G
Amaranth, Grain	S a	?S a	?S a				
Arugula, Sylvetta	S m	S m	S m	T a	T a	T a	T a
Bean, Pinto	?S e	?S e					
Beet	?T e T m	T m	T m				
Bitter Melon	S a						
Bok Choy	T m	T m	T m	?Tm	?Tm	?Tm	?Tm
Broccoli	T a	T a	T a	?Tm	?Tm	?Tm	

Right Table Column "The Misc. Temperature Notes"

Misc. Temp.=Upper Case Letters A-Z. These desig-nate foot-notes at the end of the table for other im-portant temperatures.
A. Asparagus needs a winter hard freeze.Asparagus needs 2-3 winter months with a soil average ≤50˚
C There are day length neutral hyacinth bean varie-ties and ones that need declining day length. There may be neutral jicama varieties, but most need declin-ing day length to develop tubers. There are day neutral pigeon peas.
D Cabbage and Cauliflower are divided into groups. The earliest are the most heat tolerant and latest the least
DC Decreasing Daylength
E Lettuce, epazote, and chervil need light to sprout
F. Chayote needs <13 hours of daylight to flower (mid-Sept.)
G To develop big bulbs, Garlic needs 1-2 months with daily mean average between 32-50˚. This can oc-cur in a refrigerator before planting. Garlic for eating should be stored in a refrigera-tor near 32˚, but for seed planting, is best stored at 50˚. It sprouts between 40-50. If temperatures get over 85˚, it will likely begin to bulb prematurely with small bulbs.
H Young lettuce plants are hardy ≥25˚ and mature ones are hardy to 5-10˚.
Hz Large lemongrass plants may survive from their roots at 20˚ without protection, but young plants may be killed by 31˚.
IN Increasing daylength.
J To pollinate, most peppers need daytime <85˚, night >55˚. Most eggplants will not pollinate ≤62˚ or ≥95˚.
K. Night temperatures as low as 51˚ permit growth in peppers and chiles. Day temperatures <65 inhibit growth. They suffer chill injury with prolonged tem-peratures <50.
L Rhubarb needs low temperatures in winter below 40˚ and summer averages <75˚.
M Open-pollinated romanesco needs either 4 weeks with lows below 40˚ to head, or to grow for 2 years.
N. For squashes and pumpkins to pollinate, they need tempera-tures before 10 am to be between 55-95˚. They need nights below 78˚
P. Perennial Tindora prefers night to day temperature differ-ences of ≤15˚ F. Soil needs to be >65˚ to be in leaf.
PP. The development of potato tubers depends both on air temperature and day length. Short days start tuber development so winters free of frost are ideal. Under long days in late spring, tuber development requires night air temperature well below 68˚F. Night air of 54˚ is ideal. For everyone degree in night air temperatures above this, the yield of potatoes drops 4%.
Q. Tomatoes pollinate best with day temperatures be-tween 65-85˚ and don't pollinate if days are ≥95. They pollinate best if night temperatures are between 55-70 and don't pollinate if the night low is ≥80. It is too cold for tomatoes to grow if day temperatures are
R. Turnips can bolt to seed if nighttime temperatures <50˚ are followed by warm weather
S. Dill goes to seed in days over 11 hours in length. To get dill seed, grow it after Feb 9. To get dill weed, grow it Nov 1 to Feb 9. Yu Choy bolts to flower at 80˚
T. Peanut soil 4 inches down should be >65˚
U. Basil has heat damage above 81˚ and cold damage below 45˚. Wasabi has heat damage >82˚.
V. Pollination temperatures: garbanzo beans 60-90; lima beans night <78, pinto beans <80, prefers nights=64; snap/green beans <85, prefers nights =64; edamame soybeans prefer <86, won't pollinate ≥95; winged beans won't pollinate >86; chayote <82˚; chile pepper night 65-80; peanut <93; quinoa <90-95; rice prefers <91, won't pollinate over 103; sorghum prefers <91; strawberry 32-80; wheat needs night <68.
Vv Quinoa grows stem and leaves with IN and grows flowers and seed with DC. Does not grow above 90˚F.
Vz Soy is killed at about 113˚.
W Young Russian kale plants are hardy ≥25˚ and mature ones are hardy to 5-10˚
X There are day length neutral hyacinth bean varieties and ones that need declining day length.
Y Cold damage: broccoli, cauliflower and roma-nesco buds are damaged between 26-31˚; the plants are hardy to at least 22˚ if they have had a period of tem-peratures below 60˚ immediately before. Jicama vine but not the root dies ≤32 but the root dete-riorates in soil temperatures ≤50; ginger leaves die <50 but the tubers survive several hours below 21˚.
Young wheat is damaged at about 15˚.
Zz Curry leaf tops die at temperatures of 32˚ or less but comes back from their roots unless temperatures drop to the teens.

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