Croptime

online vegetable scheduling

http://smallfarms.oregonstate.edu/croptime

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Endotherms

Metabolic heat maintains high body temperature

Ectotherms

Body temperature is close to environmental temperature

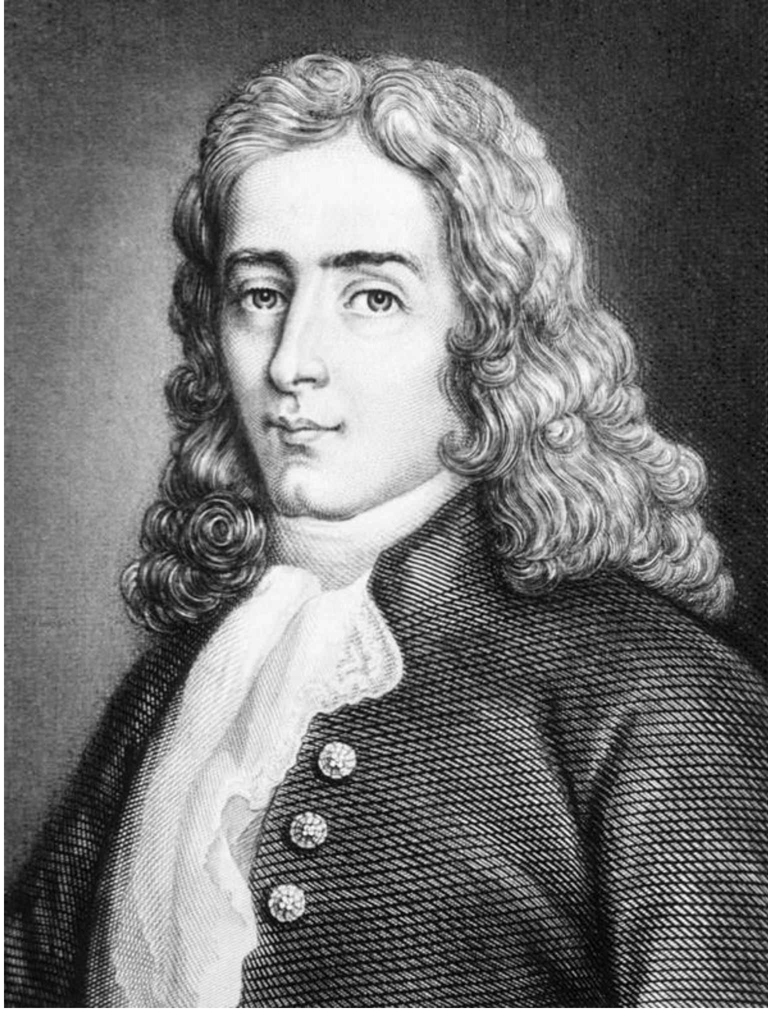
Red eared slider

Plants are primarily ectothermic

- Metabolism and rate of development is strongly influenced by temperature
- Temperature & time (degree-days) are useful for predicting development
- Some plants can generate some heat from metabolism

René A. F. de Réaumur (1683-1757)

- Used daily mean temperatures to predict plant development in mid 18th Century
- The importance of threshold temperatures was recognized by mid-20th Century (i.e. Arnold, 1959)
- Threshold temperatures are low or high temperatures that limit development and growth



$$\frac{Tmax + Tmin}{2} - Tbase = degree\ days$$

Area under sine curve & between thresholds = degree-days

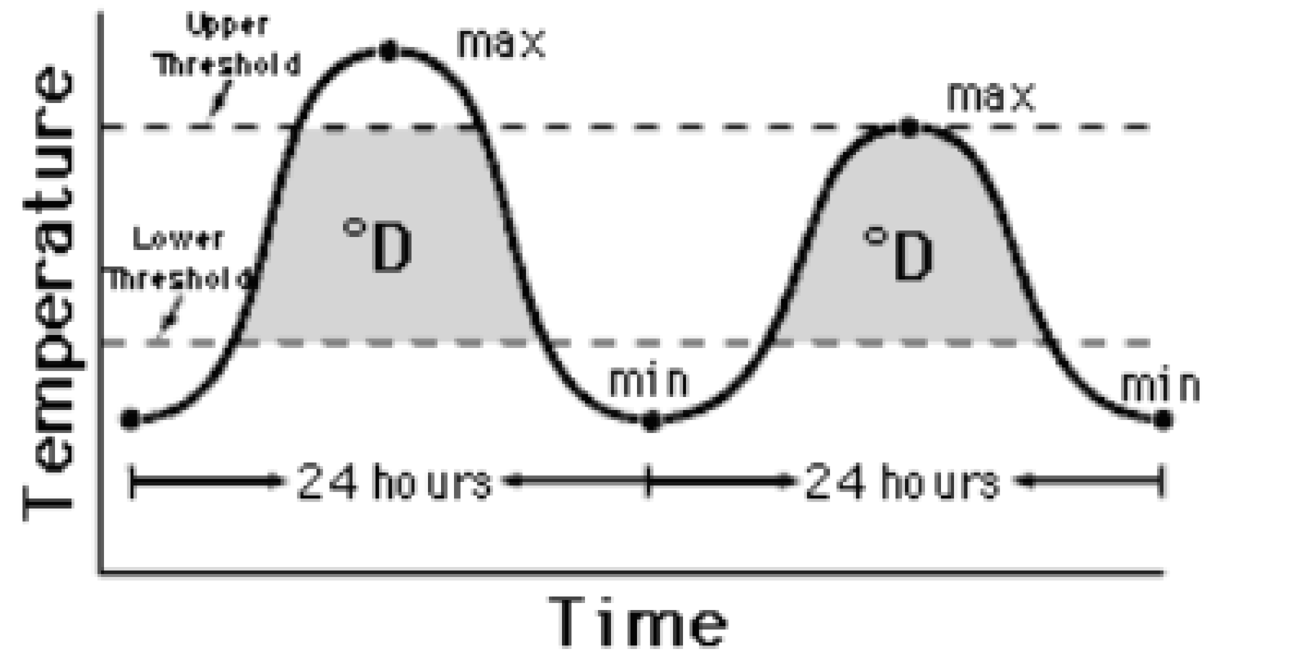
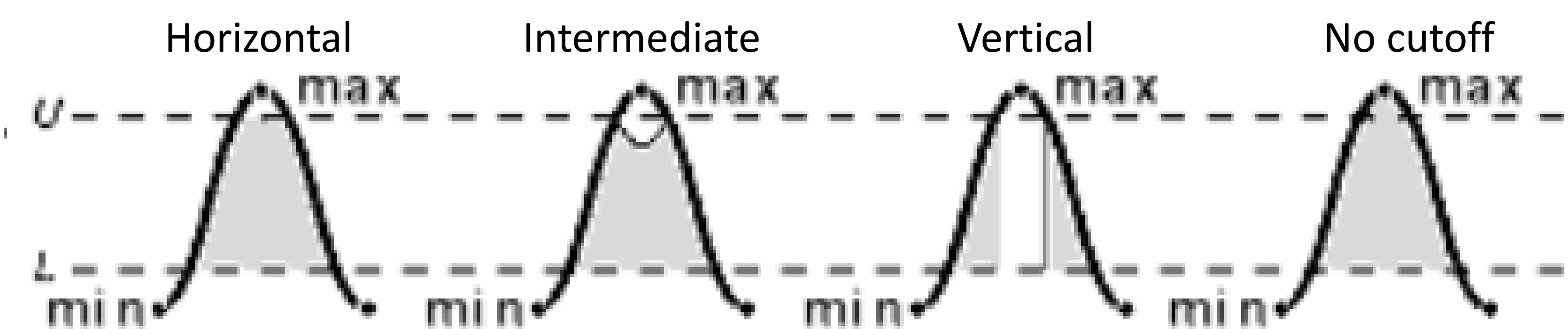


Figure 1. Thresholds and accumulated degree-days

Cutoff methods



Using degree-days
David Brown, Mustard Seed Farm

"I have used degree days for over 20 years to schedule successive plantings of vegetables.

I have made some educated guesses… (but) having more information, based on some research, would be helpful in refining my schedules and maybe even using the information for more crops."

Frank Morton, Wild Garden Seed

Photo by Shawn Linehan

"The 'days to maturity' varietal information available in most seed catalogs is not useful to farmers, except in a vague relative sense.

If seed breeders and catalogs could provide degree-day information for their vegetable varieties, farmers would be able to more accurately model their crop delivery schedules in years of unusual weather patterns or extremes."

Growers helped us prioritize crops

Fruiting Crops

(number of varieties)

- Snap beans (3)
- Tomato (5)
- Summer squash (5)
- Cucumber (4)
- Sweet pepper (7)
- Winter squash (4)
- Sweet corn (6)




Root Crops

(number of varieties)

- Carrot (3)
- Parsnip (4)

Brassicas (number of varieties)

- Broccoli (4)
- Cabbage (6)
- Cauliflower (3)
- Kale (2)

Leafy Crops

(number of varieties)

- Lettuce (4)
- Spinach (3)

Collecting field data

Growth stages and descriptions

Monitoring

- Once per week
  - 2013
  - 2014
  - 2015
- Record growth stage
- Ask us if your not sure

Growth Stage
Direct Seed
Germination
Transplant
Number of true leaves
Cupping
Head initiation
Head development
First harvest
Ongoing harvest
End of harvest period

Growth Stage Guide

Contents

Broccoli

BRASSICACEAE

Broccoli and Cauliflower

Growth Stage	BBCH #	Description
Direct Seed	000	Note the seeding date if direct seeded in the field.
Germination	001 - 009	001 = seed can imbibe water due to soil moisture, irrigation or priming (this may be the same as direct seed date), 009 = cotyledons emerge from the soil, estimate percent of crop emerged.
Transplant	102-104	Record the transplanting date and the number of true leaves at transplanting if appropriate.
Number of true leaves	100-114	Count number of fully unfolded true leaves. 100 = cotyledons completely unfolded, 101 = first true leaf unfolded, 110 = 10 true leaves unfolded.
Cupping	150	The innermost heart leaves curve around the growing tip where the head will initiate. The innermost heart leaves, which are still growing in an upright fashion, are concealed by the larger, older leaves surrounding them. Approximately 12-16 leaves.
Head initiation	400	The harvestable head is visibly initiating on median plant. Head can be felt without destroying leaves (1/2" diameter). Head initiation can be detected destructively at a smaller diameter by cutting away leaves. Head initiation normally occurs at about 14-18 true leaves and earlier in broccoli than cauliflower.
Head development	401-409	Measure the diameter across the main head on each plant you examine. Use the average diameter from two measurements at a 90° angle to each other, for example: Record median head diameter. 402 = 2" diameter, 406 = 6" diameter.
First harvest	424-428	Record date and head diameter at first harvest. First harvest varies by variety. 424 = first harvest with 4" median head diameter, 428 = first harvest with 8" head diameter.
Ongoing harvest	460	Harvest continues after first harvest and head diameter is no longer measured.
End of harvest period	501-590	Beginning of flower emergence, development pattern varies by variety. Heads become unmarketable. 501 = branches of inflorescence begin to elongate, 550 = 50% flowering 590 = 90% flowering

BRASSICACEAE

Broccoli

100: Cotyledons completely unfolded

103: 4 true leaves unfolded

107: 7 true leaves

401: Cupping

402: Head initiation

500: Head development

500: Harvest

500: Early flowering

Growth stages - Broccoli

Transplant

Growth stages - Broccoli

Transplant

Cupping

Growth stages - Broccoli

Transplant

Cupping

Head Initiation

Growth stages - Broccoli

Transplant

Cupping

Head Initiation

Mature

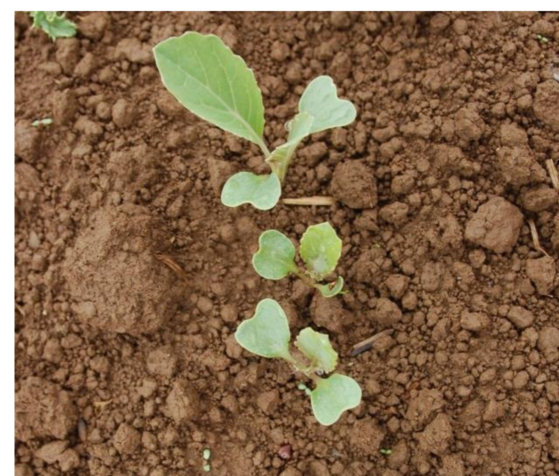
Growth stages - Broccoli

- Transplant
- Cupping
- Head Initiation
- Mature
- Early Flowering

Diversity in Horticultural Systems

Bare ground | Direct seed

Plastic mulch | Transplant



Vegetable models

Priority crops ID'd by growers (number of varieties)

Fruiting Crops (34)

- Snap beans (3)
- Tomato (5)
- Summer squash (5)
- Cucumber (4)
- Sweet pepper (7)
- Winter squash (4)
- Sweet corn (6)

Root Crops (7)

- Carrot (3)
- Parsnip (4)

Brassicas (15)

- Broccoli (4)
- Cabbage (6)
- Cauliflower (3)
- Kale (2)

Leafy crops (7)

- Spinach (4)
- Lettuce (3)

- 20 crop models by June 2016
- 50 crop models by Mar 2017

Data collection & model development

Data sets: 1 data set = crop development observations paired with daily max/min temperature records:

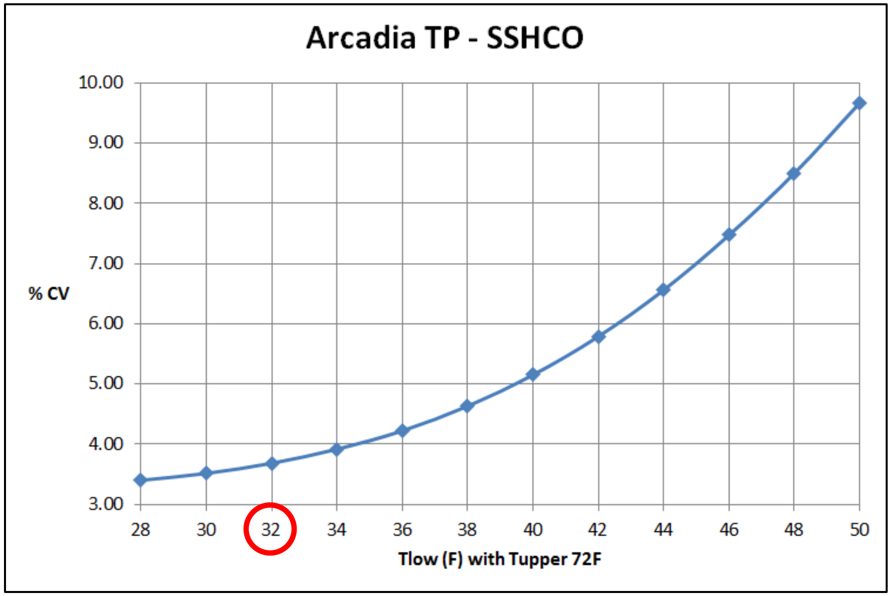
- 8-10 data sets to verify thresholds for a crop
- 4-6 data sets to verify thermal time to maturity for a variety

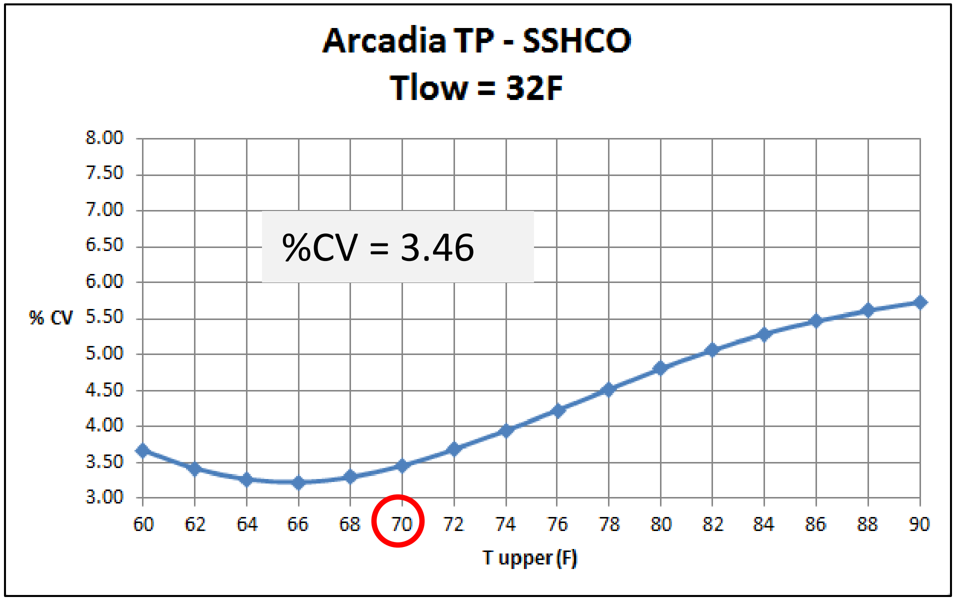
Crop modeling: lowest %CV

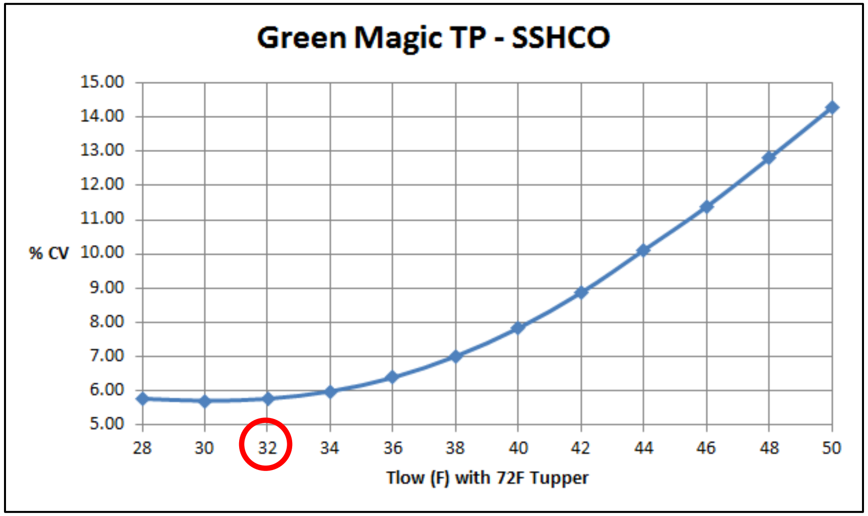
Template for lowest CV analysis of Tlow					
Variety:	ARCADIA Transplant				
start GS:	Transplant				
End GS:	Early flower				
Year	**Farm**	**Date begin**	**True leaves**	**Date end**	**Days**
2014	NWREC	7/28/2014	3 tl	10/12/2014	76
2014	MSF	5/3/2014	2 tl	8/1/2014	90
2014	Thistledown	7/2/2014	4tl	9/24/2014	84
2014	OSU Veg Farm	7/22/2014	2 tl	10/15/2014	85
2014	Thistledown (a)	7/25/2014	3 tl	10/19/2014	86
2013	47th Ave Luscher	5/14/2013	2 tl	8/13/2013	91
2015	NWREC	6/12/2015	3tl	9/1/2015	81
2015	OSU Veg Farm	8/6/2015	4tl	11/5/2015	91

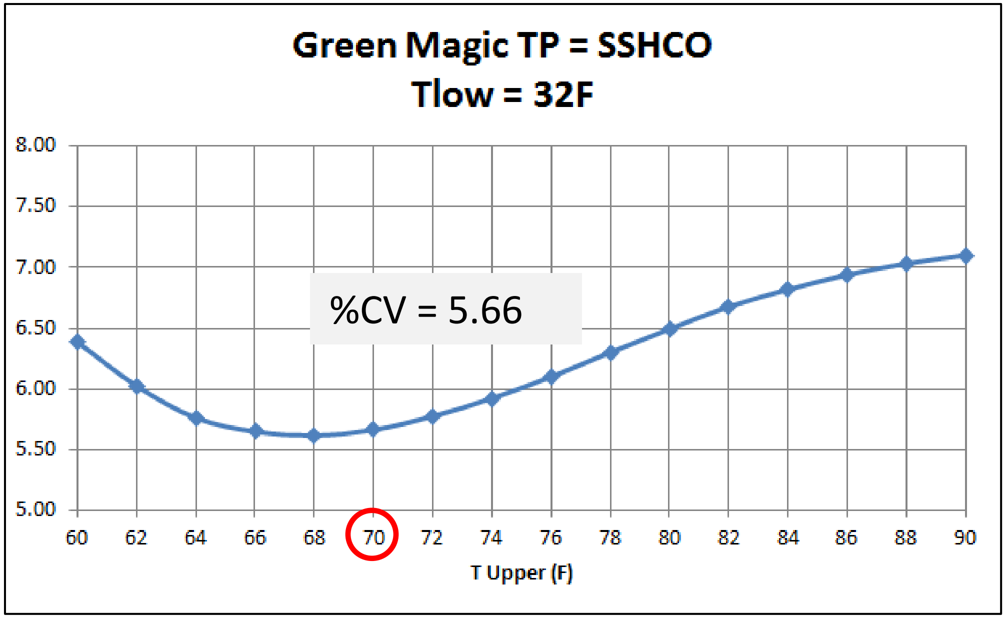
	LOWER Threshold with Tupp = 72. Calculation method single sine, horizontal cutoff											
	28	**30**	**32**	**34**	**36**	**38**	**40**	**42**	**44**	**46**	**48**	**50**
	2872	2718	2564	2410	2256	2102	1948	1794	1640	1486	1334	1184
	3136	2954	2772	2590	2408	2226	2044	1862	1681	1500	1322	1150
	3172	3002	2832	2662	2492	2322	2152	1982	1813	1643	1476	1310
	3100	2928	2756	2584	2412	2240	2068	1896	1724	1555	1389	1226
	3112	2938	2764	2590	2416	2242	2068	1894	1722	1551	1383	1220
	3086	2902	2718	2534	2350	2166	1982	1798	1616	1435	1258	1087
	3169	3005	2841	2677	2513	2349	2185	2021	1857	1693	1529	1366
	2968	2784	2600	2416	2233	2049	1866	1685	1507	1333	1167	1007
Mean	3076.9	2903.9	2730.9	2557.9	2385.0	2212.0	2039.1	1866.5	1695.0	1524.5	1357.3	1193.8
SD	104.68	102.15	100.65	100.25	100.73	102.49	105.05	108.07	111.19	113.91	115.33	115.38
% CV	3.40	3.52	3.69	3.92	4.22	4.63	5.15	5.79	6.56	7.47	8.50	9.67
CV Diff	0.12	0.17	0.23	0.30	0.41	0.52	0.64	0.77	0.91	1.02	1.17	

Supports broccoli thresholds 32/70F









Thermal time to maturity

Transplanted broccoli 32/70F, SSHCO	50% head initiation	First harvest	Early flowering	Accuracy (± days)
Arcadia (TP)	1674	2281	2672	2.5
Green Magic (TP)	1458	2103	2456	4.1
Emerald Pride (TP)	1565	2151	2518	6.4
Imperial (TP)	1753	2383	2688	4.6

~10 days diff. between varieties

± 3-6 days with DDs

± 15 days in catalogs for Arcadia

Thermal time to maturity

Cucumber 50/90F, SSHCO	Type	2 true leaves	Early flowering	First harvest	Accuracy (± days)
Cobra (DS)	Slicing	339	665	964	2.5
Marketmore-76 (DS)	Slicing	364	784	1211	1.1
Marketmore-76 (TP)	Slicing	-	344	805	1.9
Dasher II (DS)	Slicing	365	731	1060	1.8
Zapata (DS)	Pickling	380	688	984	2.7
Extreme (DS)	Pickling	366	692	946	1.2
Supremo (DS)	Pickling	366	677	981	0.8

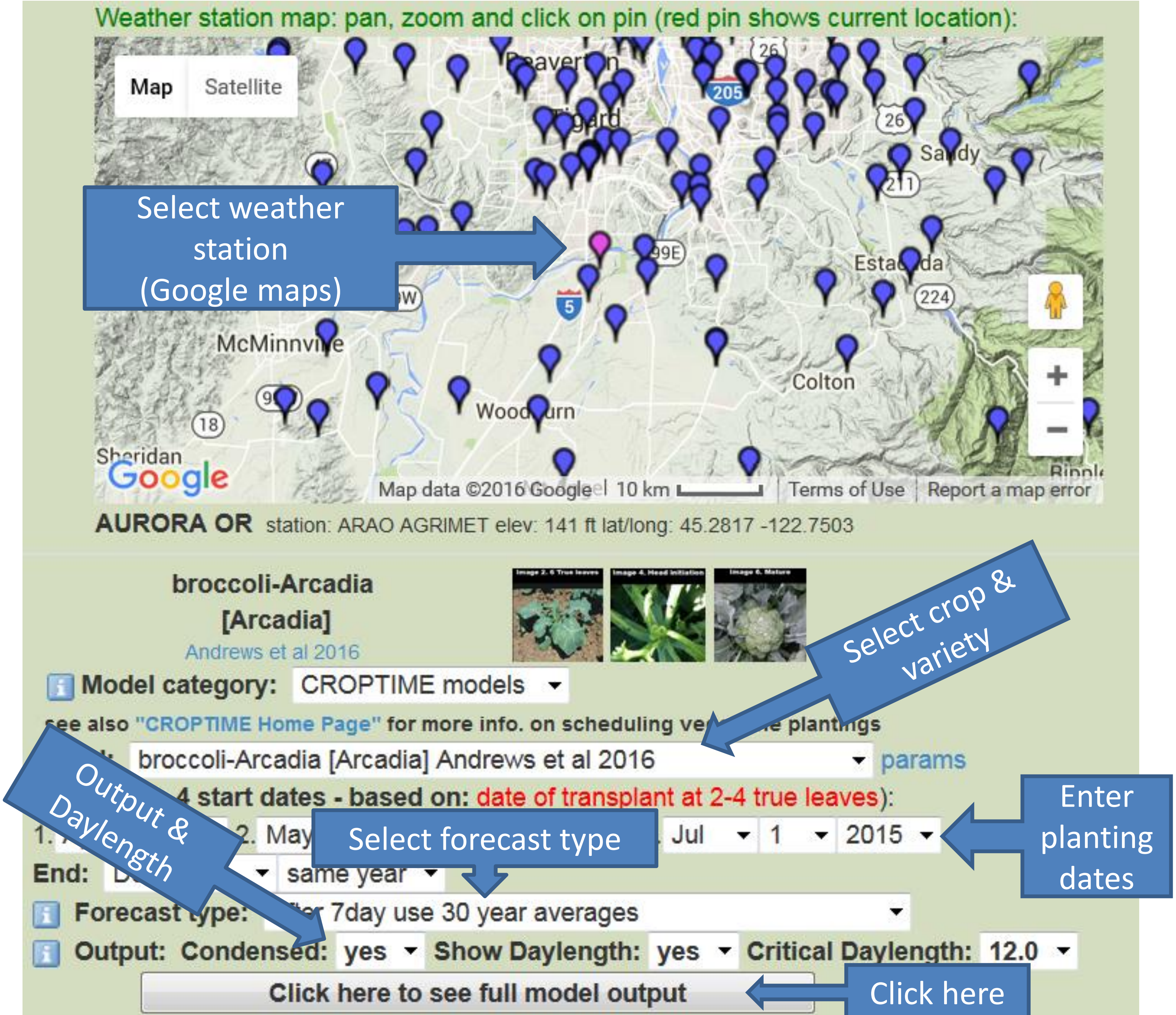
~12 days diff. between varieties

± 1-3 days accuracy

Using Croptime

Using Croptime

1. Search for Croptime
   http://smallfarms.oregonstate.edu/croptime



Weather station map: pan, zoom and click on pin (red pin shows current location):
Map
Satellite
Select weather station (Google maps)
Beaverton
Tigard
Sandy
McMinnville
Woodburn
Colton
Estacada
Sheridan
Map data ©2016 Google
10 km
Terms of Use
Report a map error
AURORA OR station: ARAO AGRIMET elev: 141 ft lat/long: 45.2817 -122.7503
broccoli-Arcadia [Arcadia]
Andrews et al 2016
Image 2. 6 True leaves
Image 4. Head initiation
Image 6. Mature
Select crop & variety
Model category: CROPTIME models
"CROPTIME Home Page" for more info. on scheduling
broccoli-Arcadia [Arcadia] Andrews et al 2016
params
4 start dates - based on: date of transplant at 2-4 true leaves):
Jul 1 2015
Enter planting dates
Select forecast type
Output & Daylength
End:
same year
Forecast type:
7day use 30 year averages
Output: Condensed: yes
Show Daylength: yes
Critical Daylength: 12.0
Click here to see full model output
Click here

MODEL INPUTS

Model species/general links	broccoli-Arcadia [Arcadia]
Type	crop
Model source/other links	Andrews etal 2015
Calculation method	
Lower threshold	32 degrees Fahrenheit
Upper threshold	72 degrees Fahrenheit
Directions for starting/BIOFIX	date of transplant at 2-4 true leaves
Starting date(s)	4-1,5-1,6-1,7-1 2015
Ending date	12-1
Model validation status	new model-not yet validated
Region of known use	W. Oregon
Short day critical day length (hr)	12.0
Day length < critical value indicator:	**

EVENTS TABLE

DDs after transplant:	Model Event
5	transplanted - 2-4 leaves
1762	50% head initiation
2344	first harvest
2734	early flowering

Date | Temp/Precip | DD | Day length | Cum DD | Crop events

Month	Day	Max	Min	Precip	DDs Today	Day length (hr)	QA + Notes	Starting 4-1	
								Cumu. DDs	Model Events
4	1	53.0	40.1	0.10	14.6	13.1		15	transplanted - 2-4 leaves
5	1	73.8	45.6	0.00	27.5	14.6		612	
6	1	62.5	53.9	0.21	26.2	15.8		1458	
6	11	81.4	49.9	0.00	31.4	16.0		1780	50% head initiation
6	28	83.6	66.3	0.00	38.6	16.0		2351	first harvest
7	1	95.4	57.9	0.00	36.2	16.0		2461	
7	9	85.2	59.8	0.00	36.2	15.9		2751	early flowering
7	14	83.4	57.6	0.00	35.1	15.8		2930	
7	22	72.1	53.1	0.00	30.6	15.5		3205	
7	26	72.7	55.6	0.03	32.1				
8	8	79.7	56.2	0.00	34.0				
8	19	97.6	59.7	0.00	36.9				
8	20	81.1	58.4	0.00	35.2	14.3		4214	
9	7	74.5	52.2	0.00	31.0	13.3		4787	
9	20	77.7	52.6	0.00	32.0	12.7		5190	

Scroll right for other planting dates

2nd planting — 3rd planting — 4th planting

Month	Day	Starting 5-1		Starting 6-1		Starting 7-1	
		Cumu. DDs	Model Events	Cumu. DDs	Model Events	Cumu. DDs	Model Events
4	1						
5	1	28	transplanted - 2-4 leaves				
6	1	873		26	transplanted - 2-4 leaves		
6	11	1195		348			
6	28	1766	50% head initiation	919			
7	1	1877		1030		36	transplanted - 2-4 leaves
7	9	2166		1319		326	
7	14	2346	first harvest	1499		505	
7	22	2621		1774	50% head initiation	781	
7	26	2753	early flowering	1906		913	
8	8	3204		2357	first harvest	1363	
8	19	3594		2747	early flowering	1754	
8	20	3630		2783		1789	50% head initiation
9	7	4202		3355		2362	first harvest
9	20	4606		3758		2765	early flowering

2nd planting

3rd planting

4th planting

Month	Day	Starting 5-1		Starting 6-1		Starting 7-1	
		Cumu. DDs	Model Events	Cumu. DDs	Model Events	Cumu. DDs	Model Events
			transplanted - 2-4 leaves				
			...itiation	919			
7	1	1877		1030			
7	9	2166		1319			
			...vest	1499			
				1774			
7	26	2753	early flowering	1906			
				2357			
				2747			
				2783			
				3355		2362	first harvest
				3758		2765	early flowering

TP dates

Apr 1 = 88 DTM

May 1 = 74 DTM

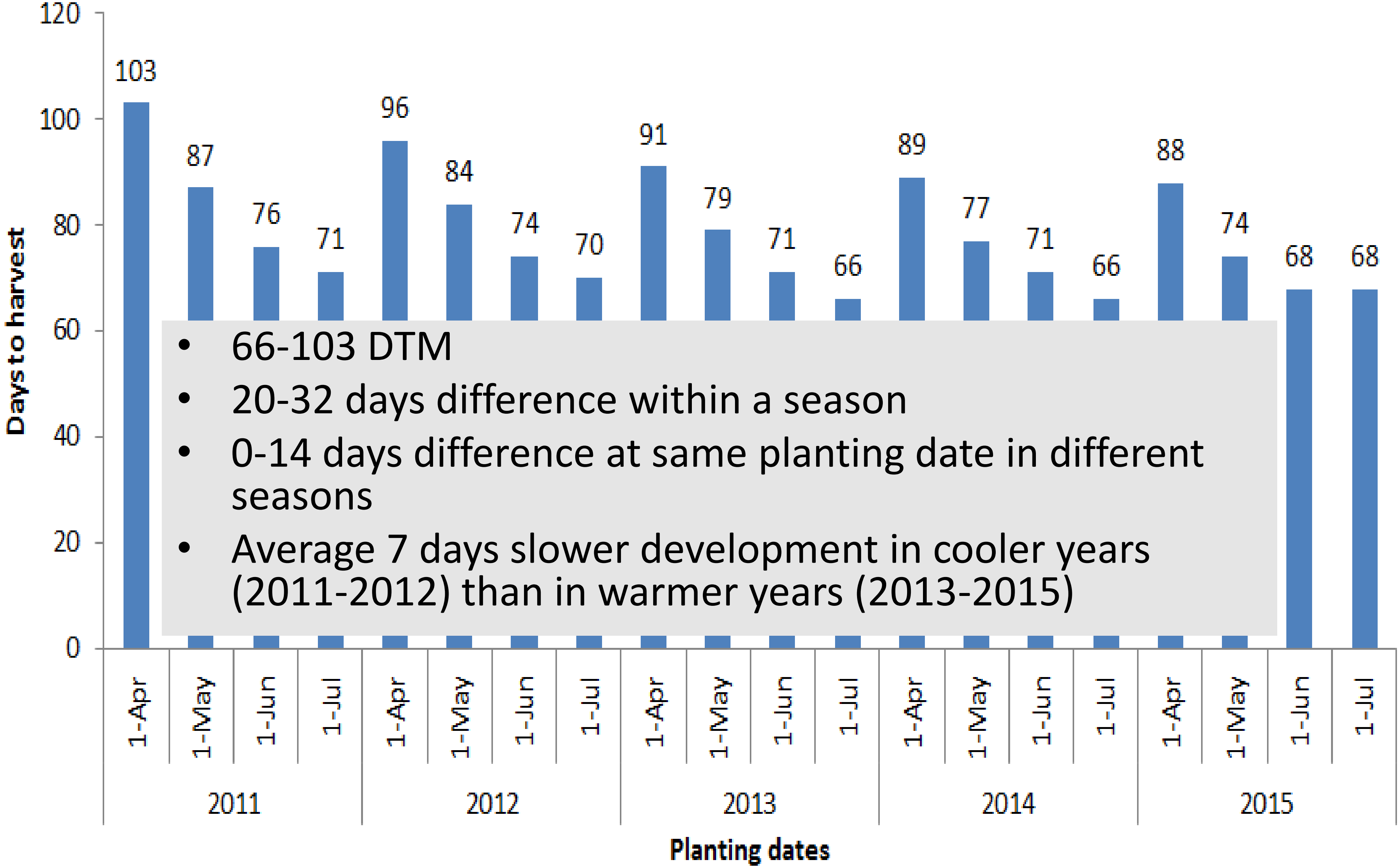
Jun 1 = 68 DTM

Jul 1 = 68 DTM

Seed catalogs estimate 63-94 DTM
In W OR we saw 66-103 DTM

Degree-day models use local temperature data, forecasts or historical averages to predict harvest within a few days

Transplanted Arcadia brocolli
Aurora, OR, 2011-2015



- 66-103 DTM
- 20-32 days difference within a season
- 0-14 days difference at same planting date in different seasons
- Average 7 days slower development in cooler years (2011-2012) than in warmer years (2013-2015)

Weed models (Heinrich & Peachey)

Croptime weed models

Weed models can help farmers answer the following questions:

- **When can I stop cultivating?**
- **Do I need to send in a crew to hand weed before harvest to prevent seed set?**
- **Should I remove weeds from field?**
- **Can the crew just focus on specific weeds?**



Farmer's choice

Lambsquarter

Hairy nightshade

Crabgrass

Pigweed

Croptime weed models reduce uncertainty

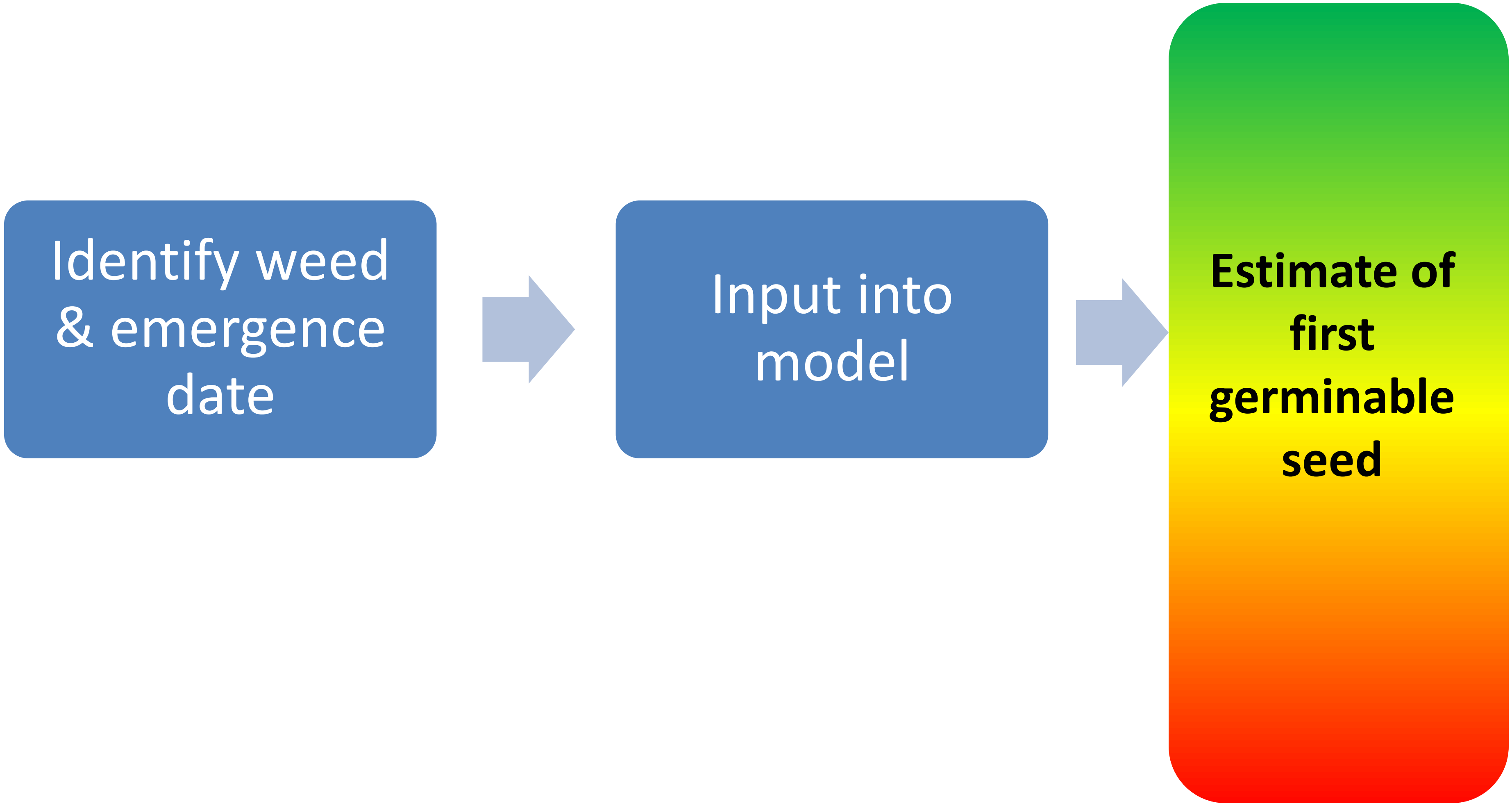
Do you think the seeds in this flower head are viable?

Grower #1 - **35-50%**

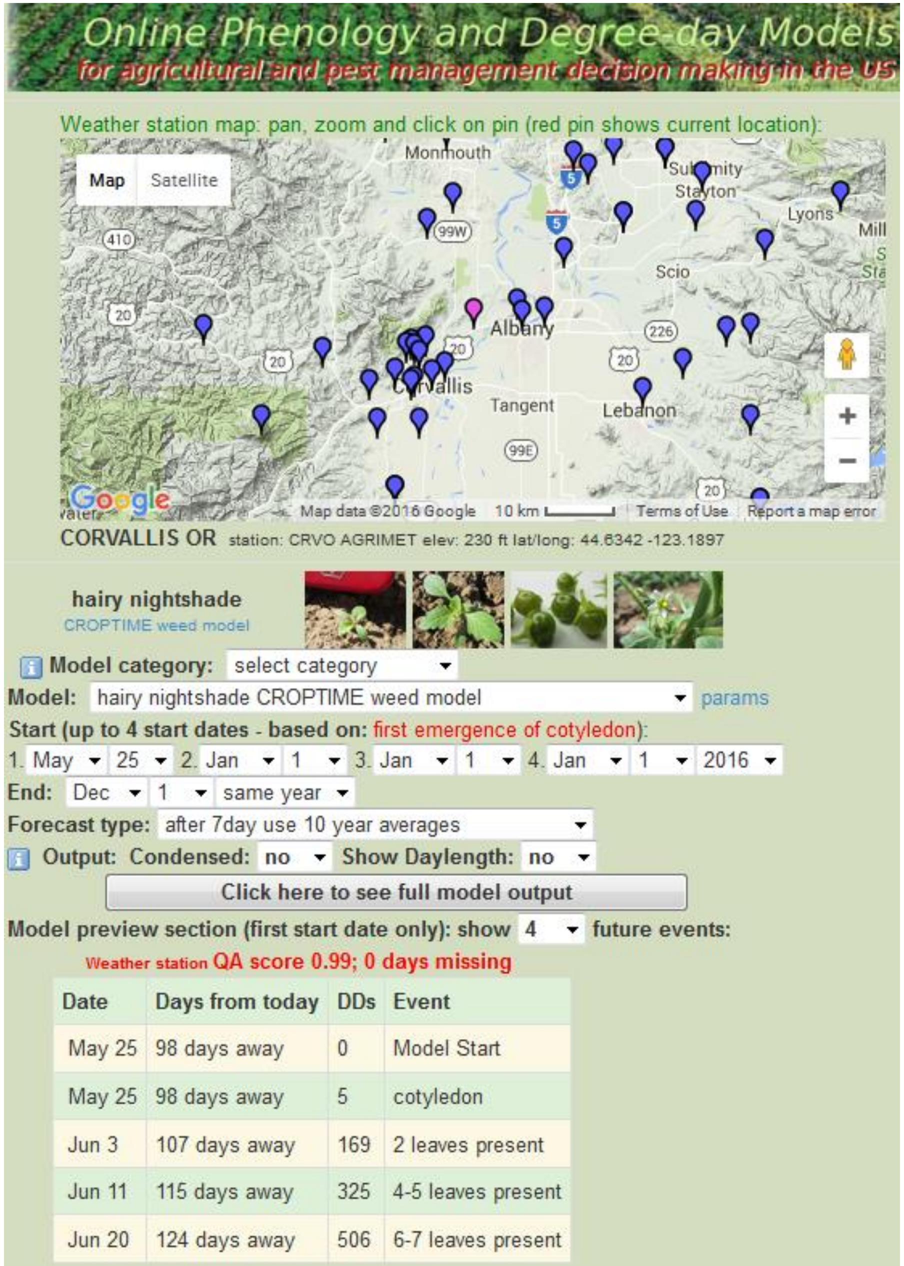
Grower #2 - **None**

Lab results – **~50% viable**

How to use weed models



The model



- Model most appropriate for late April through early July plantings
  - Influence of photoperiod on growth not considered
- Start date = cotyledon
  - Hard to identify some weeds at cotyledon stage
  - Use first flush of weeds after cultivation as start date?
- Combine with in-field observations

Output

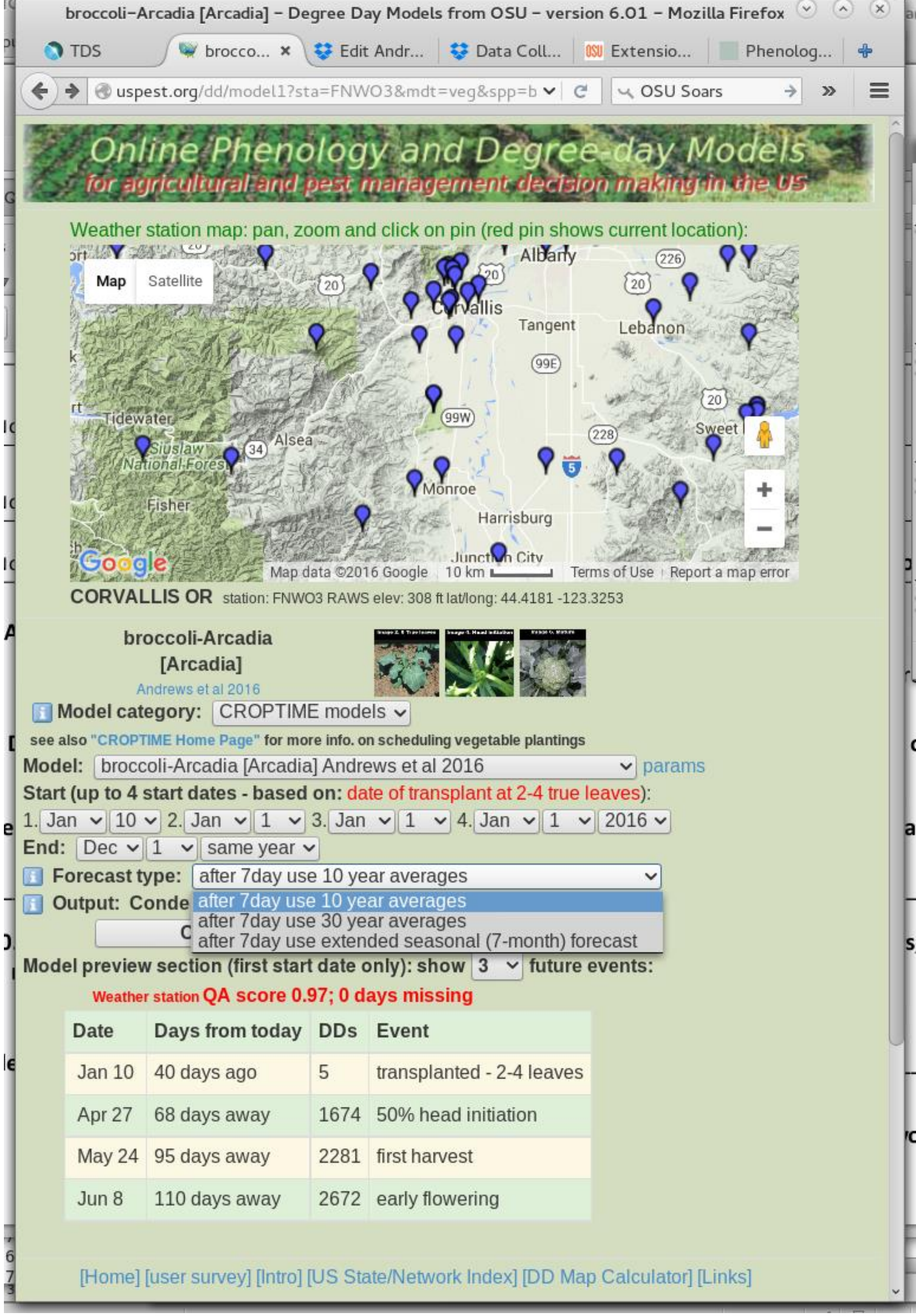
Month	Day	Starting 6-1 Model Events	
6	1	cotyledon present	
6	7	2 leaves present	
6	13	4-5 leaves present	
6	20	6-7 leaves present	
6	28	first flowering	
7	26	lower 95% CI first viable seed	Low risk
7	31	average first viable seed	Moderate risk
8	4	upper 95% CI first viable seed	High risk

Avoid this! Reduce future weed pressure by using weed models in conjunction with crop models to minimize the risk of seed set occurring before harvest

7-month climate forecasts (Coop)

Forecast Options

- Uses recorded temps up to the day before a model is run
- Uses 7-day forecasts
- Long-term forecast options:
  - NEW 7-month seasonal climate forecast
  - 10-year average
  - 30-year average
  - Same as last year
  - Same as the year before



broccoli-Arcadia [Arcadia]
crop model of Andrews et al 2016

Output from uspest.org/wea insect degree-day/phenology model program:
Heat Units and predictions of key events from daily weather data

MODEL INPUTS

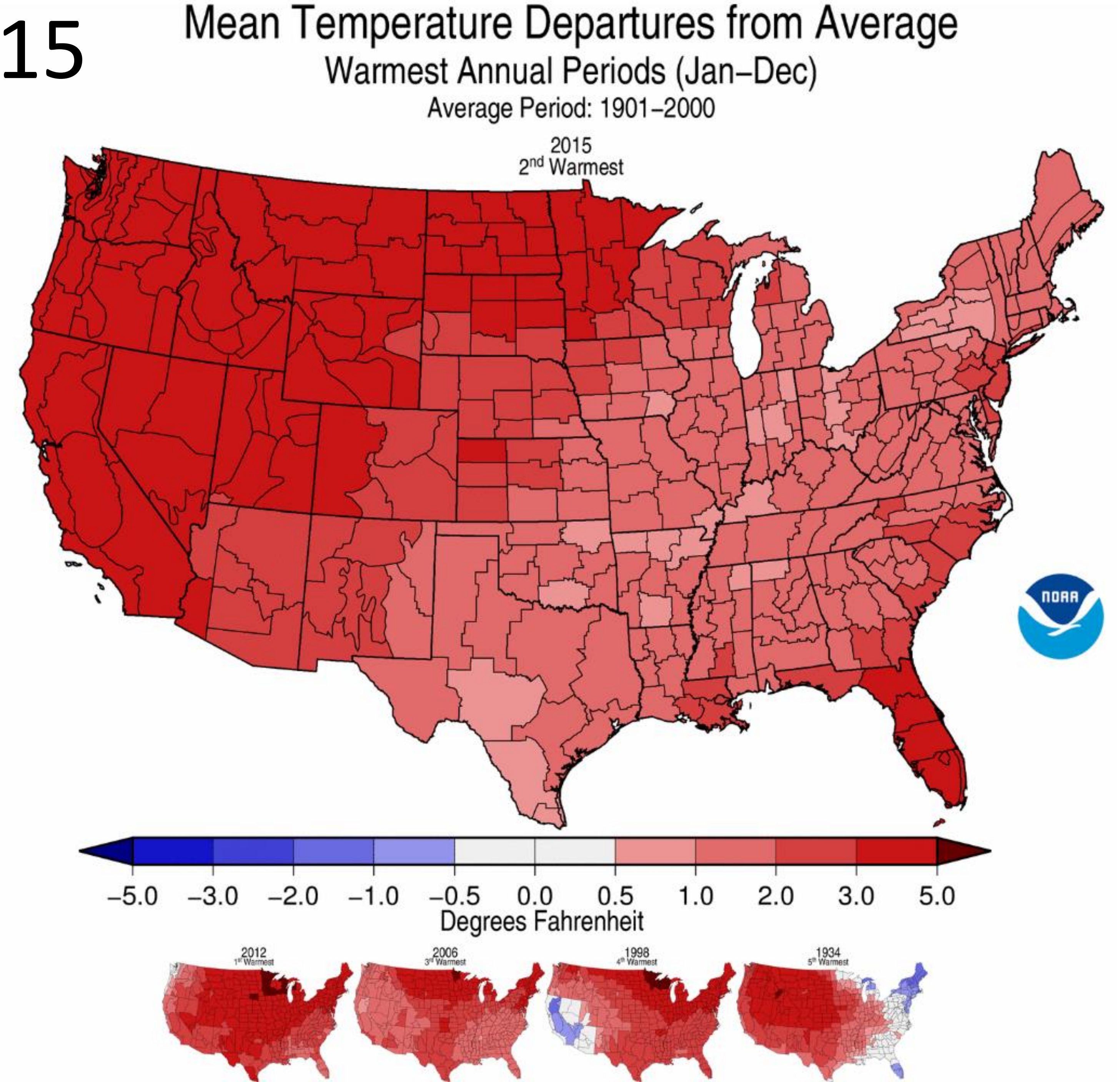
Model species/general links	broccoli-Arcadia [Arcadia]
Type	crop
Model source/other links	Andrews et al 2016
Calculation method	single sine curve
Lower threshold	32 degrees Fahrenheit
Upper threshold	70 degrees Fahrenheit
Directions for starting/BIOFIX	date of transplant at 2-4 true leaves
Starting date(s)	1-10 2016
Ending date	12-1
Model validation status	new model-not yet fully validated
Region of known use	W. Oregon
Extended forecast type	After 7 days, use 7-month NMME based seasonal climate forecast

MODEL OUTPUT w/ NMME:

Month	Day	Max	Min	Precip	DDs Today	QA + Notes	Cumu. DDs
					13.0		500
					21.0		521
					23.5		544
					18.5		563
2	17	63.0	46.0	0.04	22.5		585
2	18	51.0	43.0	0.39	15.0		600
2	19	49.7	43.3	0.246	14.5	Fx Fn forecast	615
2	20	53.9	34.5	0.042	12.2	Fx Fn	627
2	21	49.7	31.8	0.095	8.8	Fx Fn	636
2	22	52.1	31.7	0.006	9.9	Fx Fn	646
2	23	62.7	33.2	0.00	15.9	Fx Fn	662
2	24	55.4	38.6	0.165	15.0	NMME	677
2	25	55.6	38.7	0.163	15.2	NMME	692
2	26	55.8	38.8	0.162	15.3	NMME	707
2	27	56.0	38.9	0.16	15.4	NMME	723
2	28	56.2	39.0	0.158	15.6	NMME	738
2	29	56.2	39.1	0.158	15.7	NMME	754

2015

Is recent climate well-predicted by 30-year Normals?



Many studies linking sea surface temperatures to future climate

Concurrent NIFA funded research† used NOAA ensemble extended weather/climate forecasts (NMME)

Current & Forecast El Nino is a major part of the forecast

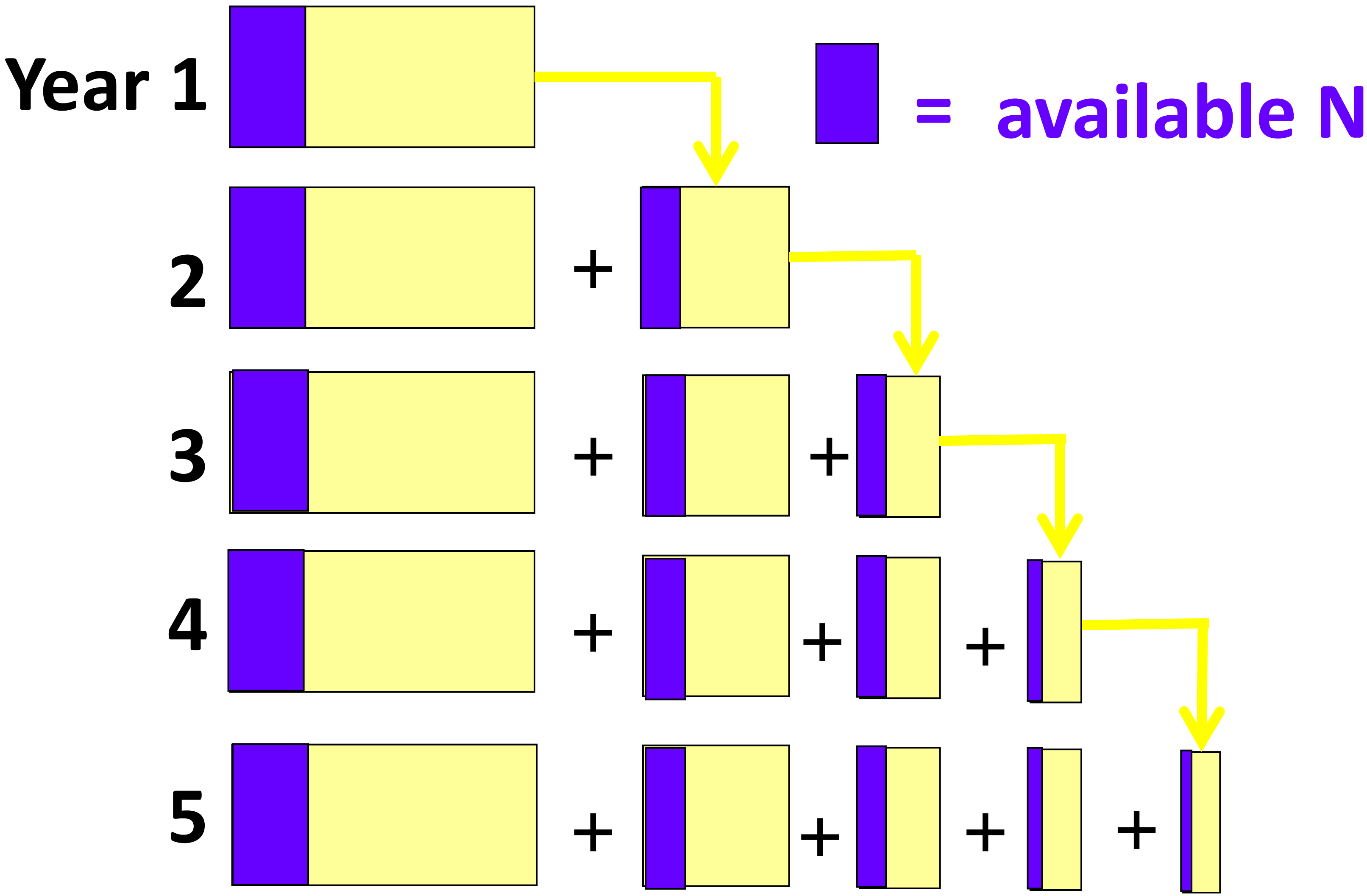
† USDA NIFA CPPM ARDP funded project

2016 HARVEST FORECAST COMPARISONS

June 1, 2016 transplant			Aug 1, 2016 transplant		
NMME	8/12/16	72 days	NMME	10/16/16	76 days
2015	8/11/16	71 days	2015	10/17/16	77 days
2014	8/13/16	73 days	2014	10/12/16	72 days
10-yr ave	8/15/16	75 days	10-yr ave	10/20/16	80 days
30-yr ave	8/15/16	75 days	30-yr ave	10/20/16	80 days

Thermal time & nitrogen release (Sullivan)

Plant-available Nitrogen Released from Soil Organic Matter



Substrates (pools of N mineralization)

1. **Very rapid N mineralization** from uncomposted high N organic inputs (most manures, legume cover crops, and specialty products)
2. **Baseline N mineralization** from relatively stable soil organic matter.
3. **Enhanced N mineralization from "active" soil organic matter** (residue of organic inputs for last 3-10 yr).

Specialty organic fertilizers and legume cover crops

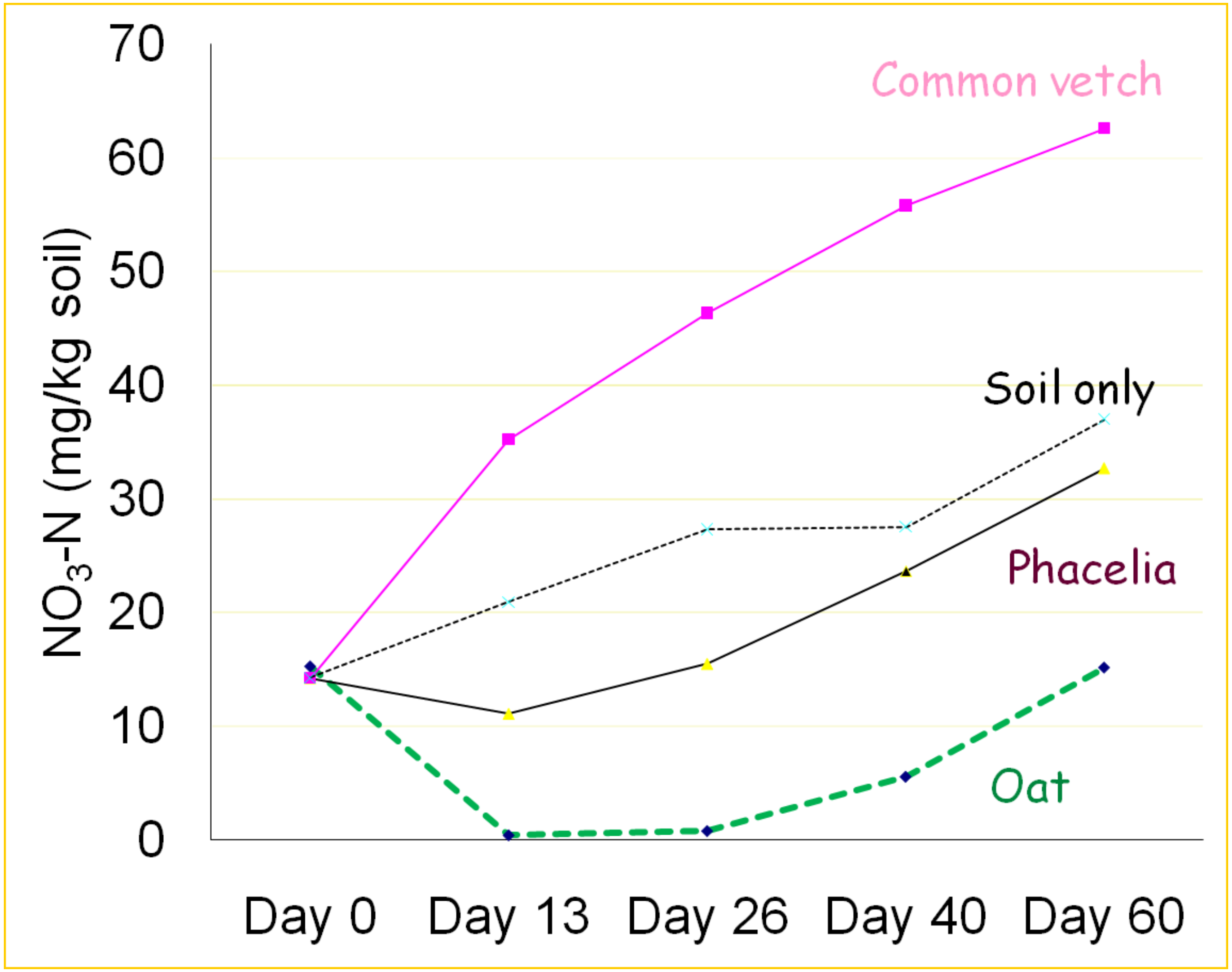
- High N concentration (>3% N in dry matter)
- Rapidly release plant-available N in the first 4 weeks after application
- Supply plant-available N even when soil temperatures are cool in spring or fall

PAN accumulation

Baseline (soil only) vs. soil with cover crop residue

Lab incubation in moist silt loam soil (72 °F)

A. Garrett thesis, 2009



"Organic Fertilizer Calculator" Estimates of plant-available N (PAN)

Fresh Amendment total N	Example	**Fresh** Amendment C:N	PAN 28 days	PAN full season
% dry wt.		Approx.	% of total N	% of total N
1	Solid manure w/bedding	35	< 0	0
2	Dairy solids	18	0	15
4	Broiler litter	9	30	45
6+	Specialty products	less than 6	60	75

Substrates (pools of N mineralization)

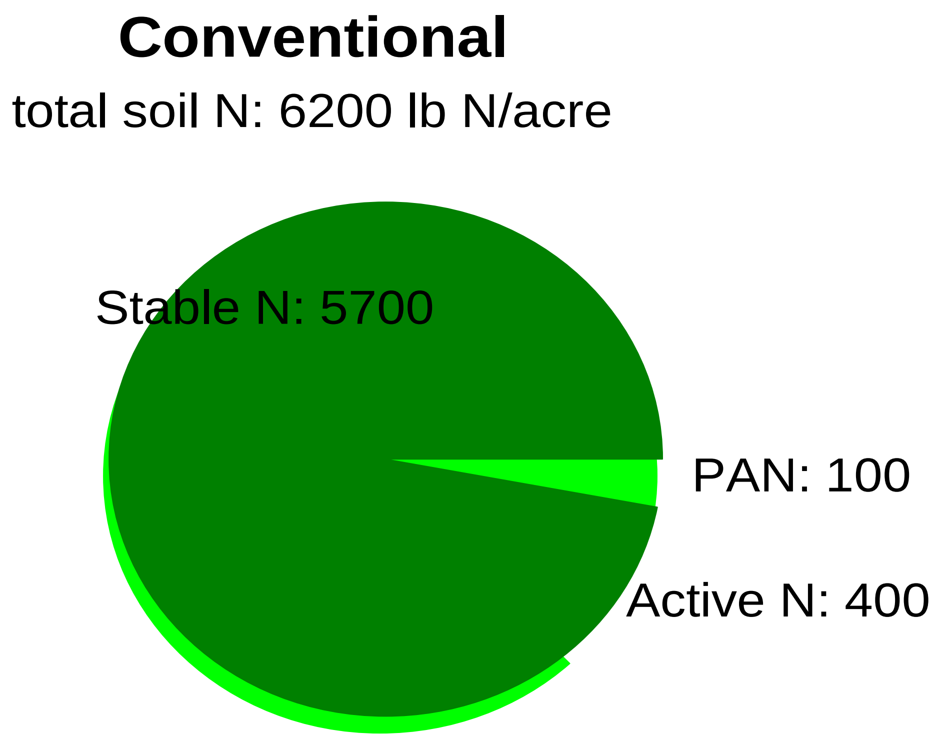
1. **Very rapid N mineralization** from uncomposted high N organic inputs (most manures, legume cover crops, and specialty products)
2. **Baseline N mineralization** from relatively stable soil organic matter.
3. **Enhanced N mineralization from "active" soil organic matter** (residue of organic inputs for last 3-10 yr).

Typical Willamette Valley soil

3% organic matter (0-12 inches)

Contains a large amount of total N

But only a small fraction is mineralized each year



Mineralization measurements
conventional sweet corn

Willamette Valley, OR 2011-13.

sandy loam, silt loam, silty clay loam soils

	Crop N uptake	
Zero N fertilizer	lb/acre	88*

	Soil	
Total N	%	0.15
Organic matter	%	2.9
Total N (0-30 cm)	lb/acre	5220

	Soil N mineralized/crop	
Soil Nmin estimate	% of soil N	1.7

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CropTime Project (Andrews et al., in progress)

Testing equation for predicting temperature-adjusted net N mineralization from soil organic matter decomposition* =

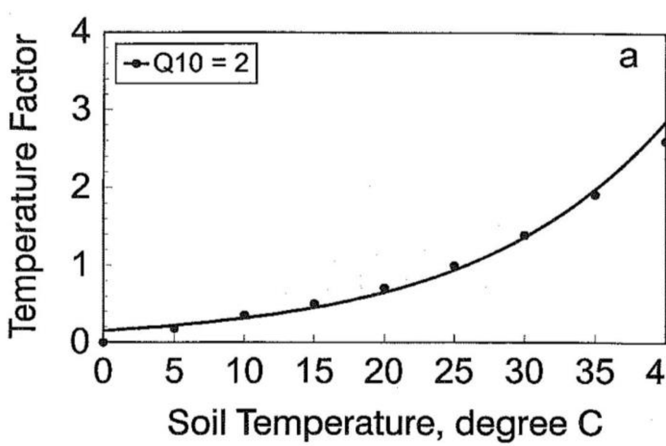
N min = Soil N x [1-exp((-k)(TF))]

Where:

Nmin = PAN produced from soil organic matter (lb/acre/day)

Soil N = soil N (lb/acre, 0-12 inches)

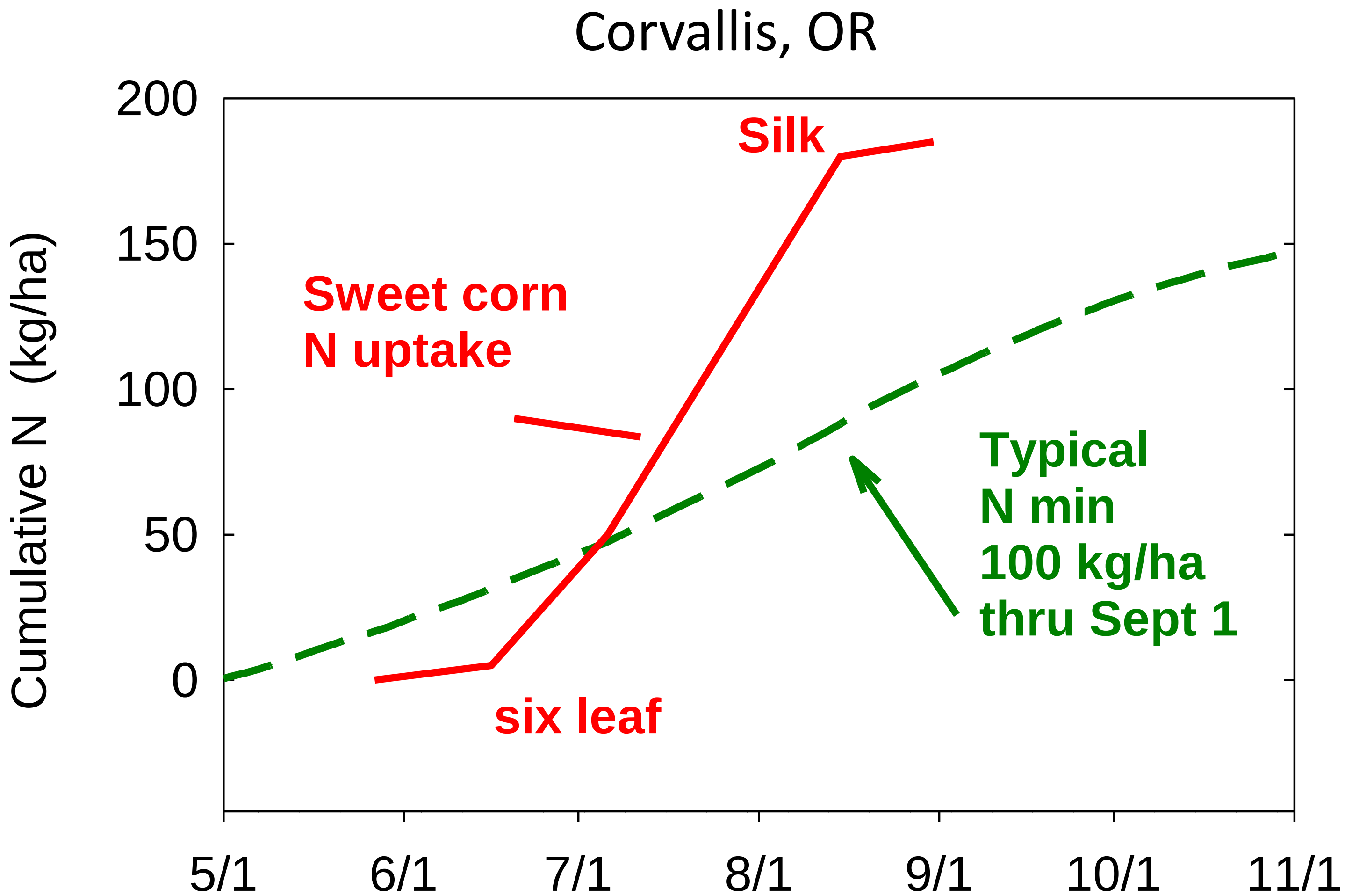
K = daily OM decomposition rate, 0.0002 per day at 77 °F



on Q_{10}, equal to 1.0 at 77 °F

* Based on Gilmour, 2009. Soil Sci. Soc. Am. J. 73:328-330

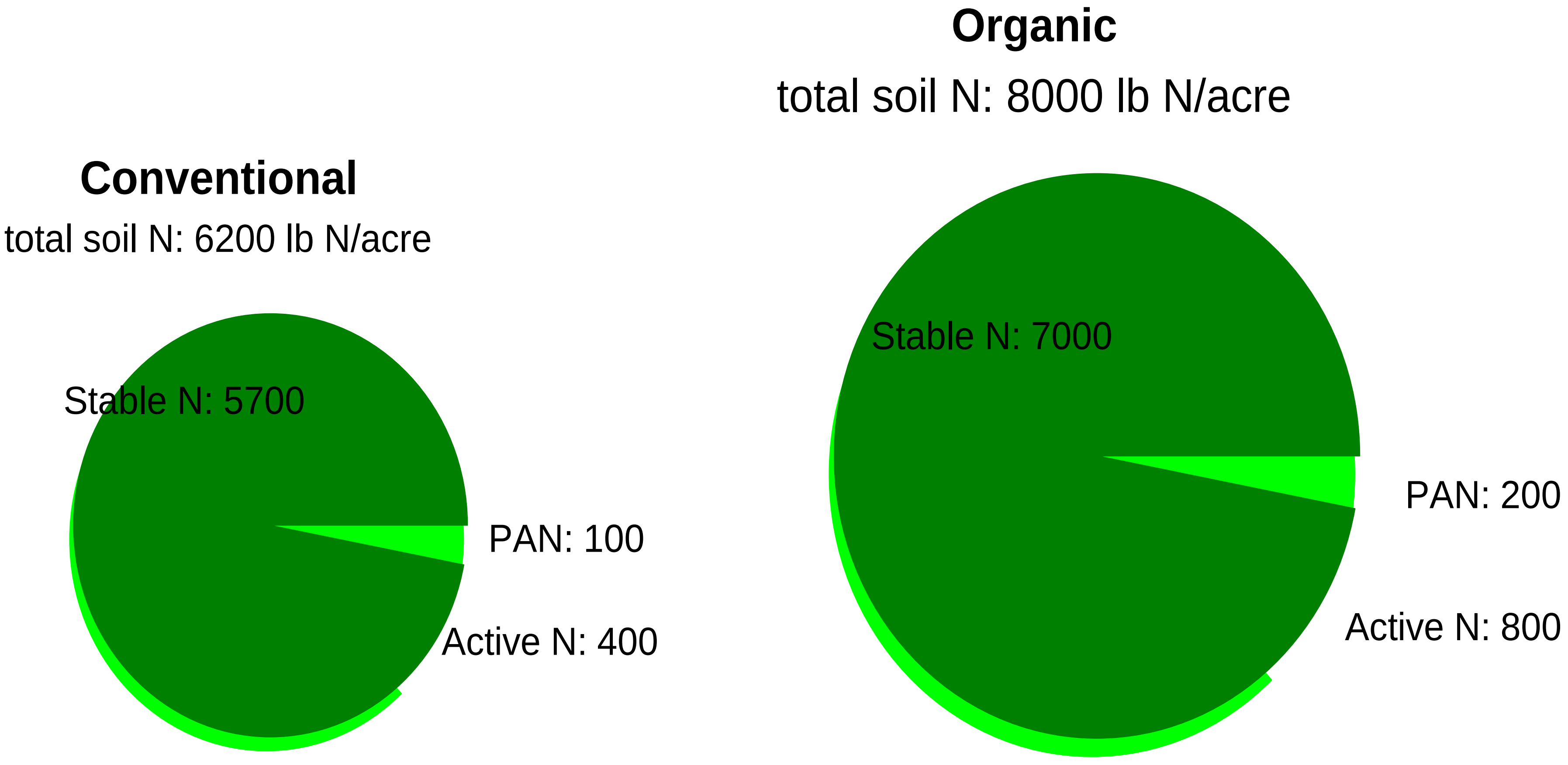
Soil N mineralization vs. N uptake by conventional sweet corn crop



2012 Corvallis with 4 inch soil temp
K for soil OM decomp = 0.0002 per day at 25 C
Soil OM = 3%
with average TFAC = 0.71

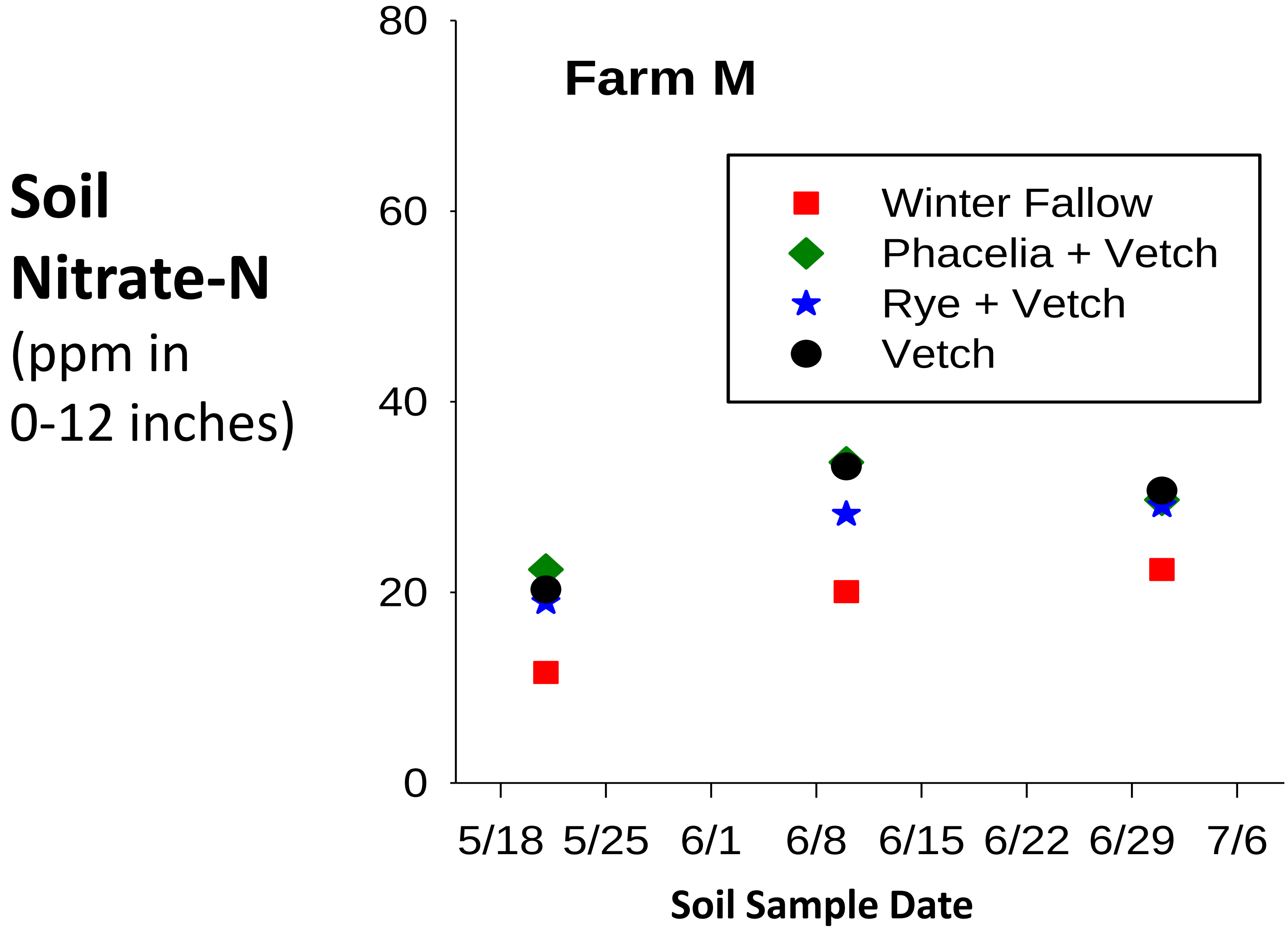
Hypothesized outcome of "soil building"

- Willamette Valley (OR)
- When soil OM increased from 3 to 4% (long-term)
- soil N mineralization rate doubles



Baseline N from CropTime can serve as comparison for your June soil nitrate-N values

Example:



Croptime

online vegetable scheduling

http://smallfarms.oregonstate.edu/croptime

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