Effects of Temperature on Insect Development

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PNVA Pest Management Session November 18, 2021, 8:30 AM 30 Minutes

How Increased Temperature Could Influence Insects

Geographic Range Expansion

Increased Overwinter Survivorship

Increased Generations per Season

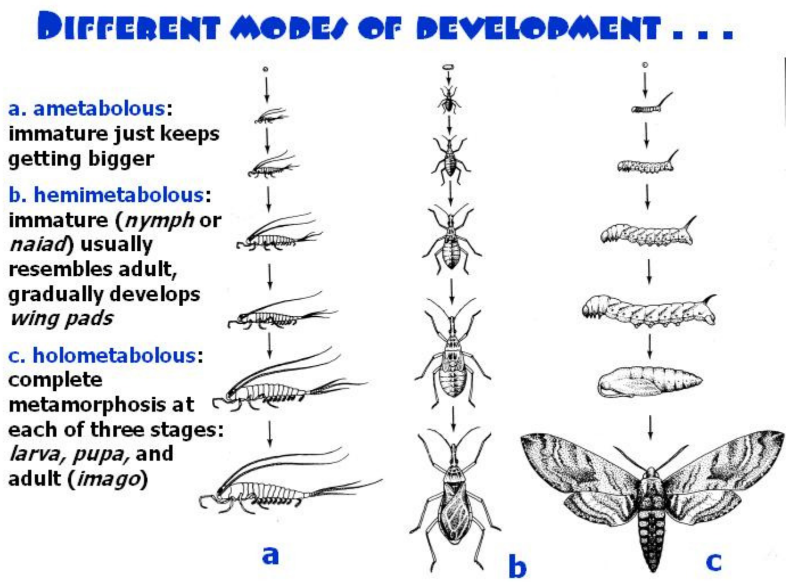
Changes in Interactions with Host Plants

How Temperature Influences Insects

- Developmental Physiology of Insects
  - Growing Degree Days
  - Intrinsic Rate of Growth
- Diapause
- Overwintering Success of Insects and Hosts
- Host plant quality
  - Maturity/Senescence
  - ~~Stress~~
  - Shifting Hosts
  - ~~Altered Architecture~~

Insect Development

- Insects are poikilotherms, or cold blooded, meaning they don't generate their own 'body heat' like humans do
- Each insect has its own developmental threshold, a temperature below which no development takes place
- Most insects also have an upper threshold limit, or a temperature at which their development rate doesn't increase or may even cease when it is exceeded



Growing Degree-Days

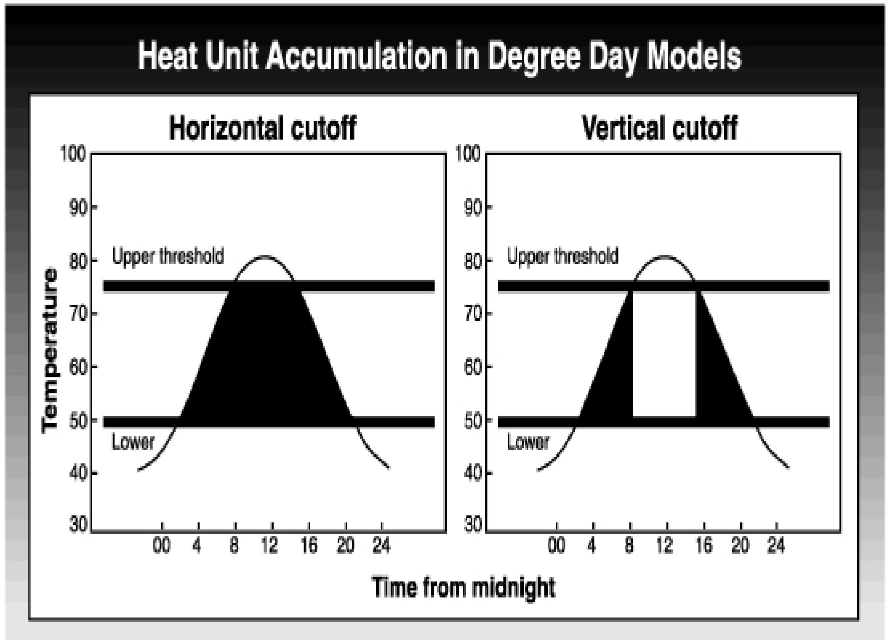
- Phenology is the study of relationships between the weather and biological processes such as insect development.
- Phenology models are also known as degree day models
- These models are based on the fact that an insect's growth is closely linked to the temperature where it is found.

Growing Degree-Day Models

- The number of degree days needed for a certain insect to develop can be calculated in a laboratory.
- Normally insects are reared at a constant temperature and the time needed for each insect to complete each stage-egg, larva, pupa and adult-is recorded.
- This is repeated at several different temperatures.
- The rate of development at the various temperatures is then plotted and from the graph the lower and upper development thresholds and the degree days needed to complete a stage of development can be calculated
- Degree-Day Models | WSU Tree Fruit | Washington State University

Degree-Day Models

- Most degree-day models use a sine-wave curve to approximate the daily temperature cycle from night to day. The upper threshold can have at least two forms:
- A horizontal cutoff, where degree-day accumulations above the upper threshold do not count
- A vertical cutoff where, once the upper threshold is surpassed, no more degree-days are accumulated until the temperature drops below the threshold again.



Dark areas represent accumulated degree days.

[Degree-Day Models | WSU Tree Fruit | Washington State University]()

Degree-Days

- Degree-days are used to measure the number of accumulated heat units.
- A degree-day is the heat experienced by the insect when the temperature is one degree above the lower threshold for 24 hours.
- The starting point for degree-day accumulation can be some easily observed event, such as first moth capture in a pheromone trap, often referred to as a biological fix point or “biofix.”
- Alternatively, it can be a calendar date, such as March 1, before which there is generally no degree-day accumulation. Using a biofix generally gives a better prediction of future life history events, such as egg hatch, because of a better synchronization between the insect’s development and degree-day accumulations.

Intrinsic Rate of Growth: Onion Thrips Example

- The maximum per capita growth rate for a population is called the intrinsic rate of increase
- Developmental duration, or the time it takes the insect to complete various life stages is most rapid at 86 degrees Fahrenheit.
- But the percentage of eggs that successfully hatch reduces from 80% at 77 to 60 degrees to only <u>10.5% at 86 degrees</u>.
- Further, the survival rate from egg to adult reduces to <u>67.5% at 86 degrees</u> from a high of greater than 90% at 60-70 degrees F.
- Similarly at 86 degrees F, longevity of adult thrips is reduced to only <u>12.8 days and eggs per female drops to just 62.6</u>.
- Under more favorable conditions in the 70-degree temperature range longevity is around 40 days, and each female can produce around 200 eggs.
- <u>Studies indicate that other species of thrips have improved success at higher temperatures compared to onion thrips.</u>
- <u>Onion thrips exhibit a lower rate of intrinsic growth compared to other species of thrips.</u>

Onion Thrips Survival, Fecundity and Generation Times (Days) at Various Temperatures

Modified from Murai 2000			
Factor	**68 F**	**77 F**	**86 F**
Survival (Days)	47	25	13
Eggs/Female	210	165	63
Generation time (Days)	48	30	17

Onion Thrips Population Growth

	Number of Females		
Date	68^0 F	77^0 F	86^0 F
July 1	1	1	1
July 8			
July 15			63
July 22			
July 29		165	3,969
August 5			
August 12			250,047
August 19	210		
August 26			15,752,961
September 2		27,225	
Number generations	1	2	4

Slide courtesy B. Nault, Cornell

Lethal High Temperatures for OT

- Shibao, M., Inoue, Y., Morkawa, S., and Tanaka, H. 2010. Lethal High Temperature of Onion Thrips, *Thrips tabaci* Lindeman (Thysanoptera Thripidae), and Control of the Thrips with Solar Radiation by Covering the Ground with Film. Japanese Journal of Applied Entomology and Zoology: 54(2):71-76.
- Adults were killed at exposure to:
  - 42 C, or 107.6 F for 2 hours
  - 44-50 C, or 111.2-122 F for 30 min
- In that 4 day period, 20 hours exceeded the threshold, at least 4 hours per day
- Also, we were over 111.2 for 6 hours
- If adult thrips did not achieve behavioral avoidance, they were exposed to lethal temperatures

Air Temp F	June 27th	June 28th	June 29th	June 30th
Noon	106	100.6	105.6	105.4
1 pm	107.3	102.3	109.1	107.6
2 pm	109	100.6	111.5	109.6
3 pm	108.3	108.3	112.7	111.1
4 pm	107.9	109.7	114	111.2
5 pm	106.4	109.1	113.3	110.6
6 pm	104.3	108.8	112.2	102.9
7 pm	100.8	107.5	104.5	97.6

Diapause

- A period of suspended development
- An adaptation by many species of insects to enable them to survive adverse conditions
- Seasonal and life stage diapause according to the influence of the environment or hosts
- Obligate diapause-all individuals enter diapause irrespective of environmental conditions (17 yr cicadas)
- Facultative diapause-not all enter diapause, a result of environmental conditions. (two spotted spider mites, orange overwintering adults)

Overwintering Success: Hosts: Volunteer Potatoes

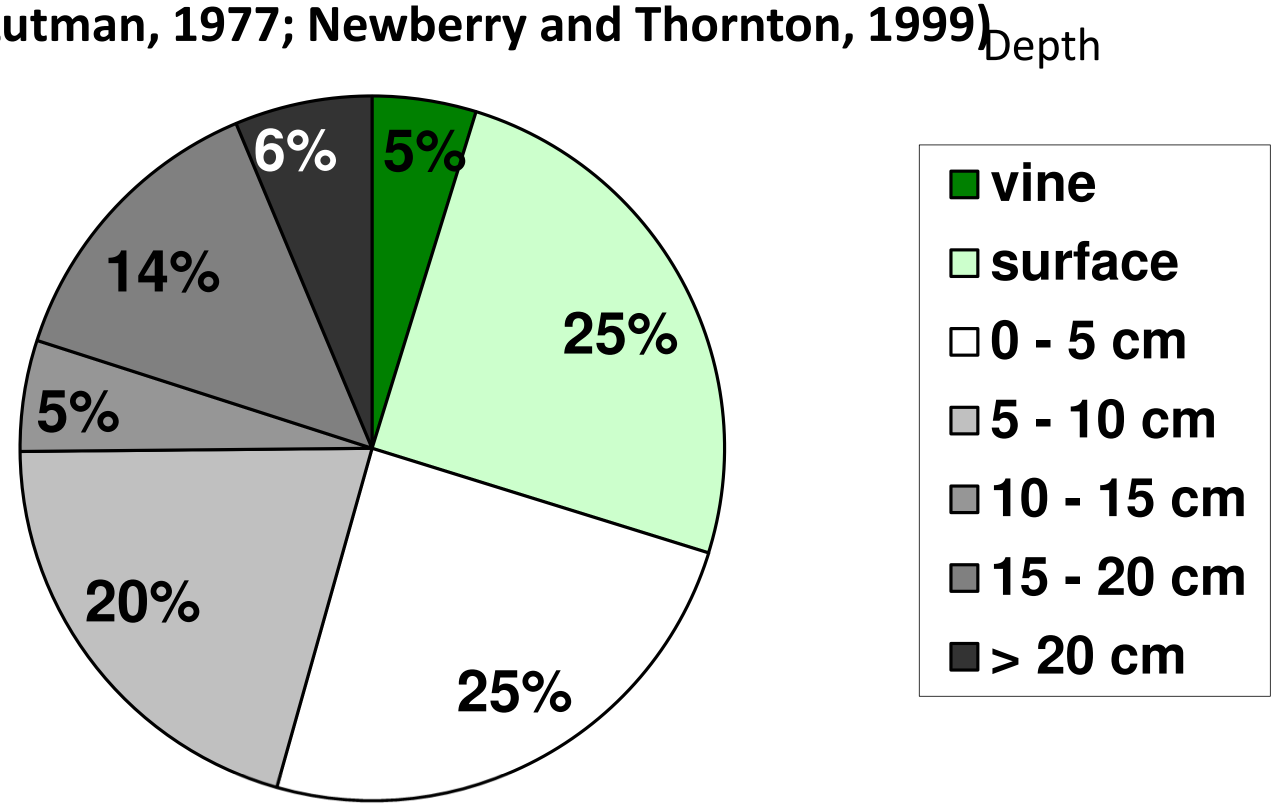
- 25 K to 186 K tubers/acre left following harvest (0.7 to 6 tons of tubers)
- Host for pathogen, insect, and nematode pests of potato. Can be a source of inoculums.
- Competes with crop for light, nutrients, and water. Reduces yields.
- **Soil temp at tuber depth must reach 28° F to kill.**
- Single control tactics rarely achieve more than 80% reduction in number of daughter tubers produced.

No silver bullet – requires an integrated approach.

Depth of tubers left in field after harvest
- deeper tubers less likely to freeze (28° F)

- **25,000 to 186,000 tubers/a**

  (Lutman, 1977; Newberry and Thornton, 1999)



- Keep tubers near soil surface after harvest (don't plow)

Subsequent CPB

- Volunteer potato serve as a host for emerging CPB.
- In absence of volunteers, emerging CPB migrate to production potato fields and are exposed to at plant insecticide
- When volunteers are present, they persist in the volunteers and complete a generation. When the rotation crop is harvested, a large population of CPB migrate to adjacent production fields where at plant insecticides are at too low of a concentration to cause mortality

Overwintering Success: Insects

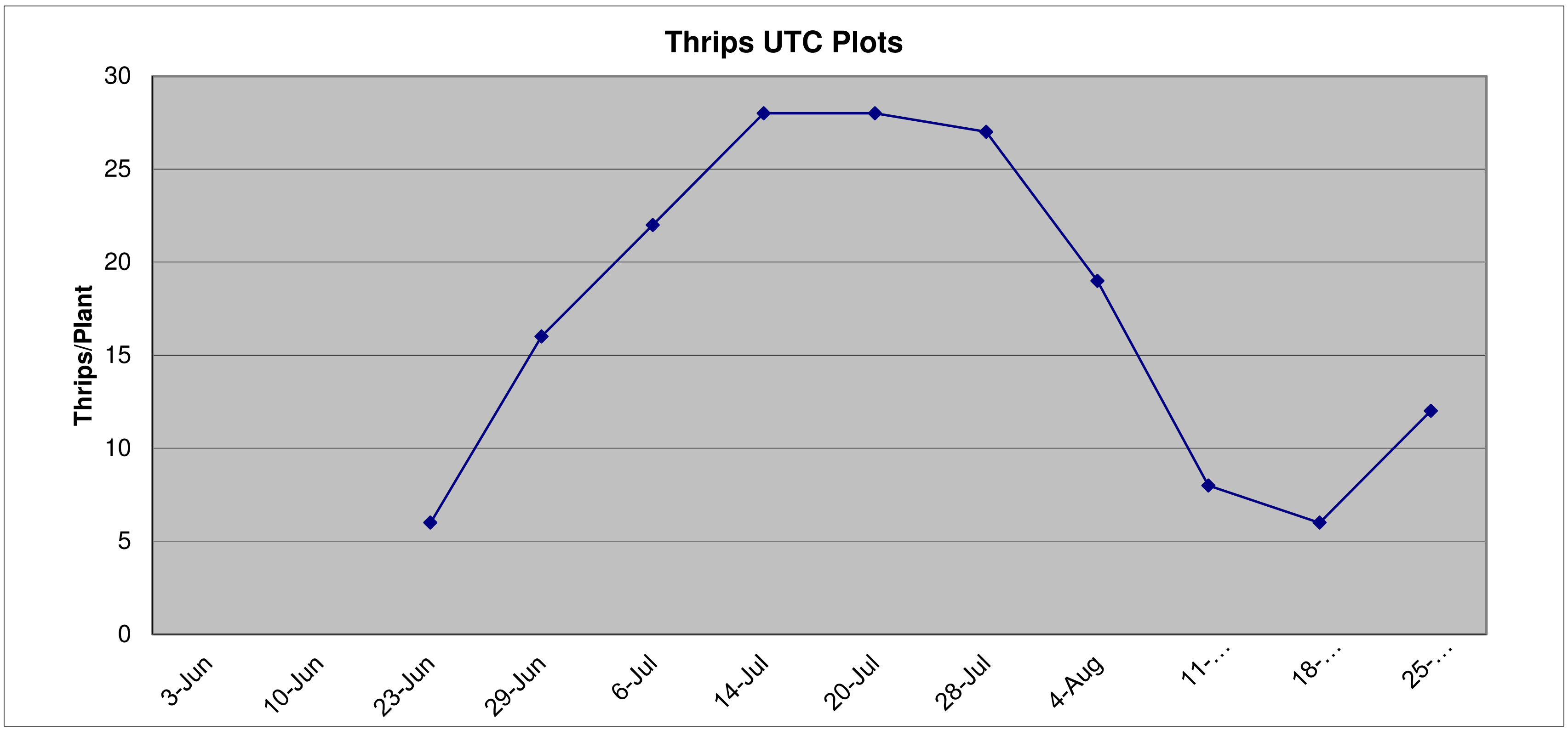
- Factors
  - Cold Hardiness
  - Temperatures they are exposed to
  - Temperature Fluctuations
  - Duration of Cold Spells
  - Amount of time Between Cold Spells

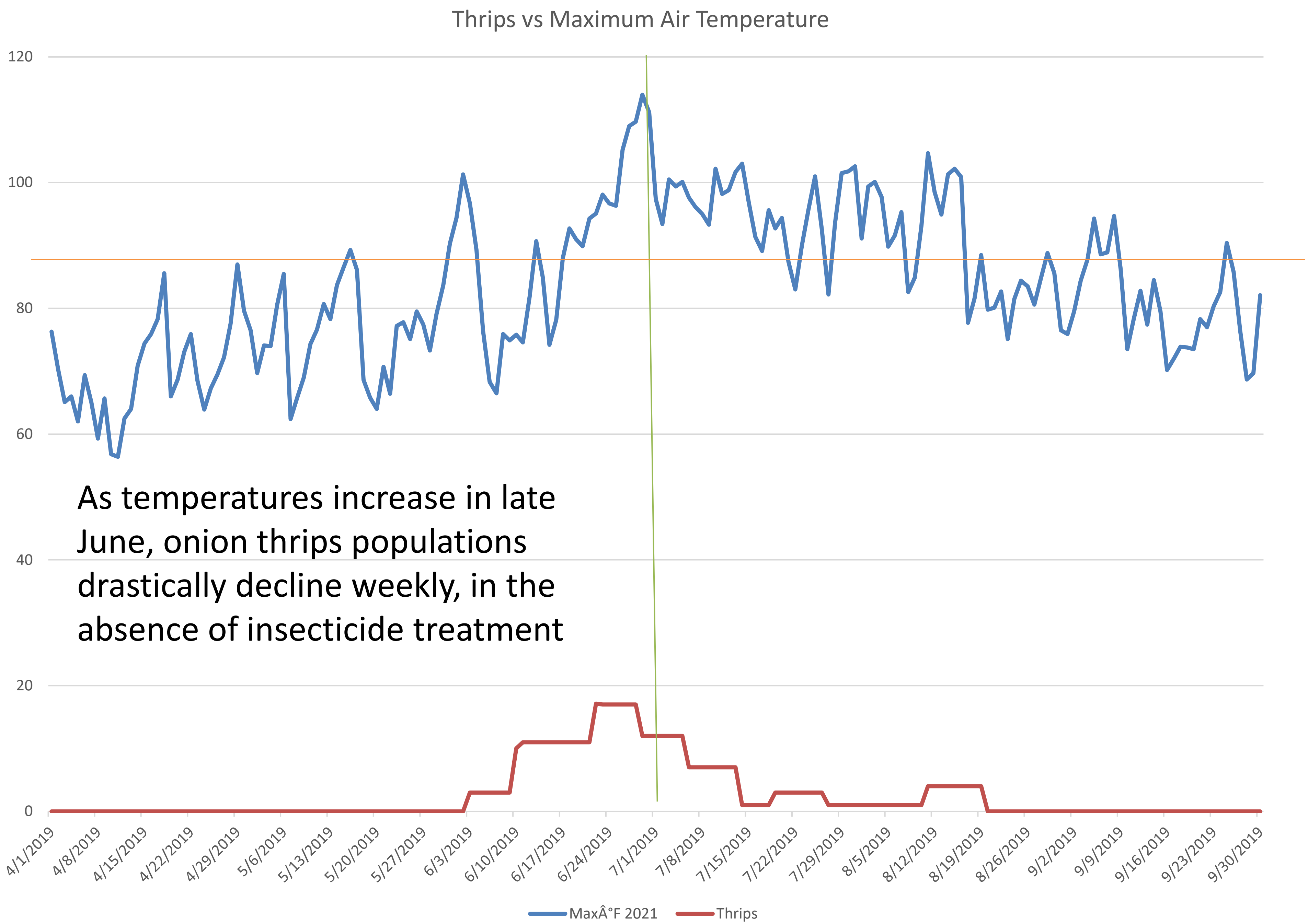
How Cold is too Cold?

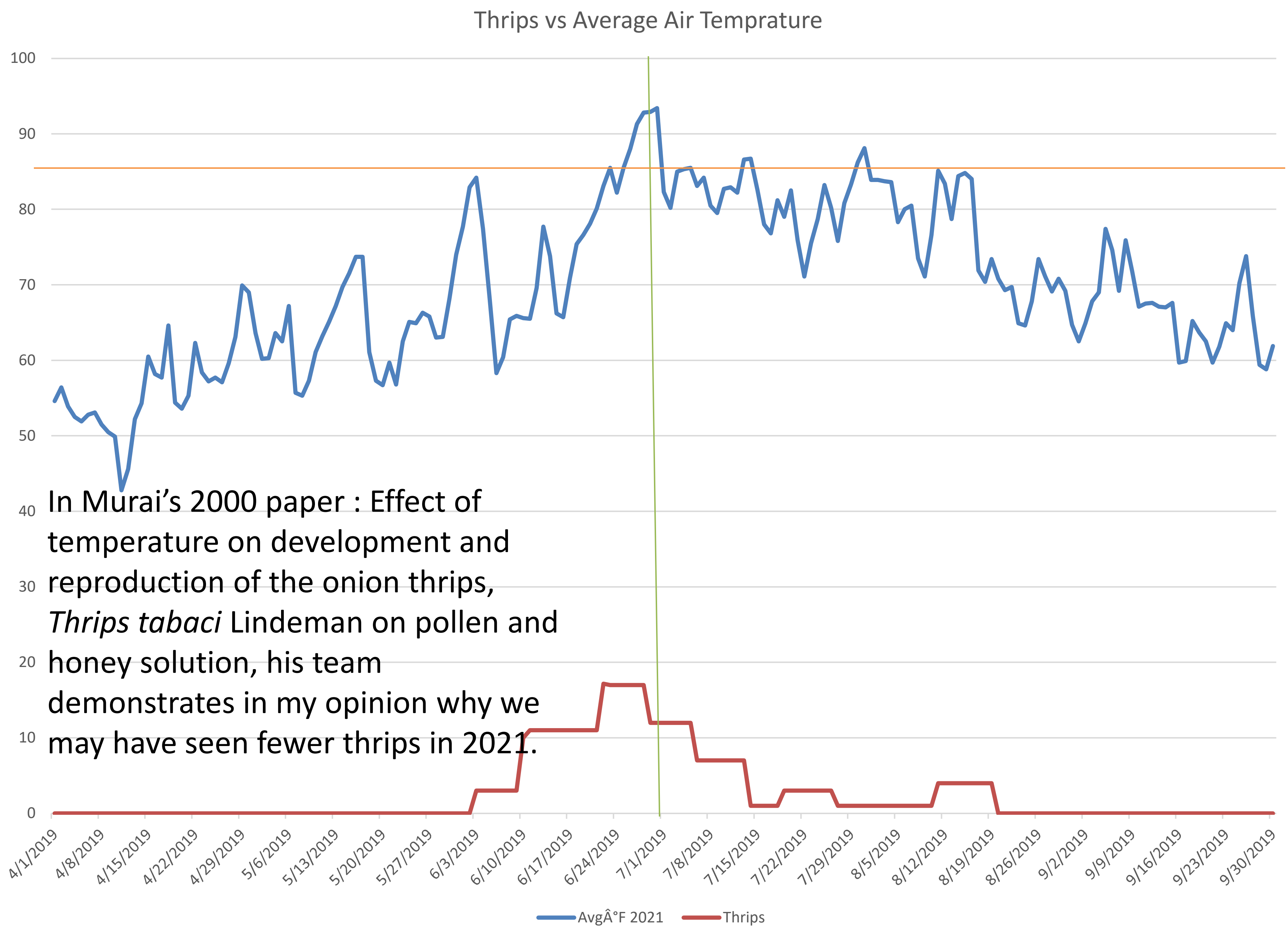
- Depends, right
- Insects survive cold by either: cryoprotectants, or producing antifreeze like compounds to lower their ‘freezing’ point
- Species and environment dependent.
- Many species overwinter in a diapause or resting stage, oftentimes as eggs or pupae
- Some species use behavioral avoidance of cold. Example, ladybird beetle hibernacula or mosquitoes moving indoors

Host Plant Quality

- Typically, thrips populations in the Columbia Basin begin to build once the onion crop reaches the three-leaf stage.
- These populations build rapidly as the onions grow and increase leaf area, then begin to reduce in number in onion fields as onions are no longer producing new foliage.

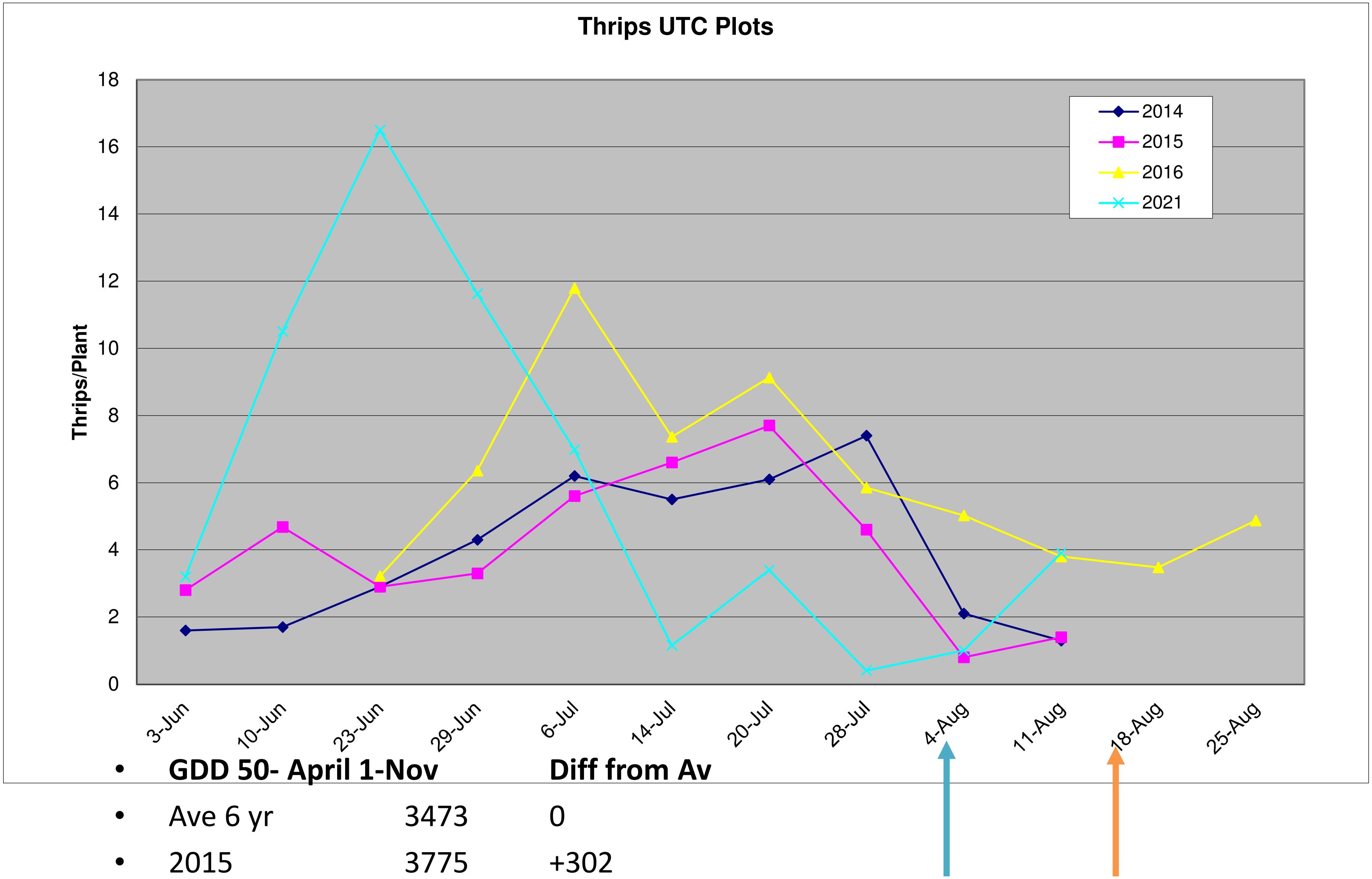



Thrips vs Maximum Air Temperature
120
100
80
60
40
20
0
As temperatures increase in late June, onion thrips populations drastically decline weekly, in the absence of insecticide treatment
4/1/2019
4/8/2019
4/15/2019
4/22/2019
4/29/2019
5/6/2019
5/13/2019
5/20/2019
5/27/2019
6/3/2019
6/10/2019
6/17/2019
6/24/2019
7/1/2019
7/8/2019
7/15/2019
7/22/2019
7/29/2019
8/5/2019
8/12/2019
8/19/2019
8/26/2019
9/2/2019
9/9/2019
9/16/2019
9/23/2019
9/30/2019
MaxÂ°F 2021
Thrips

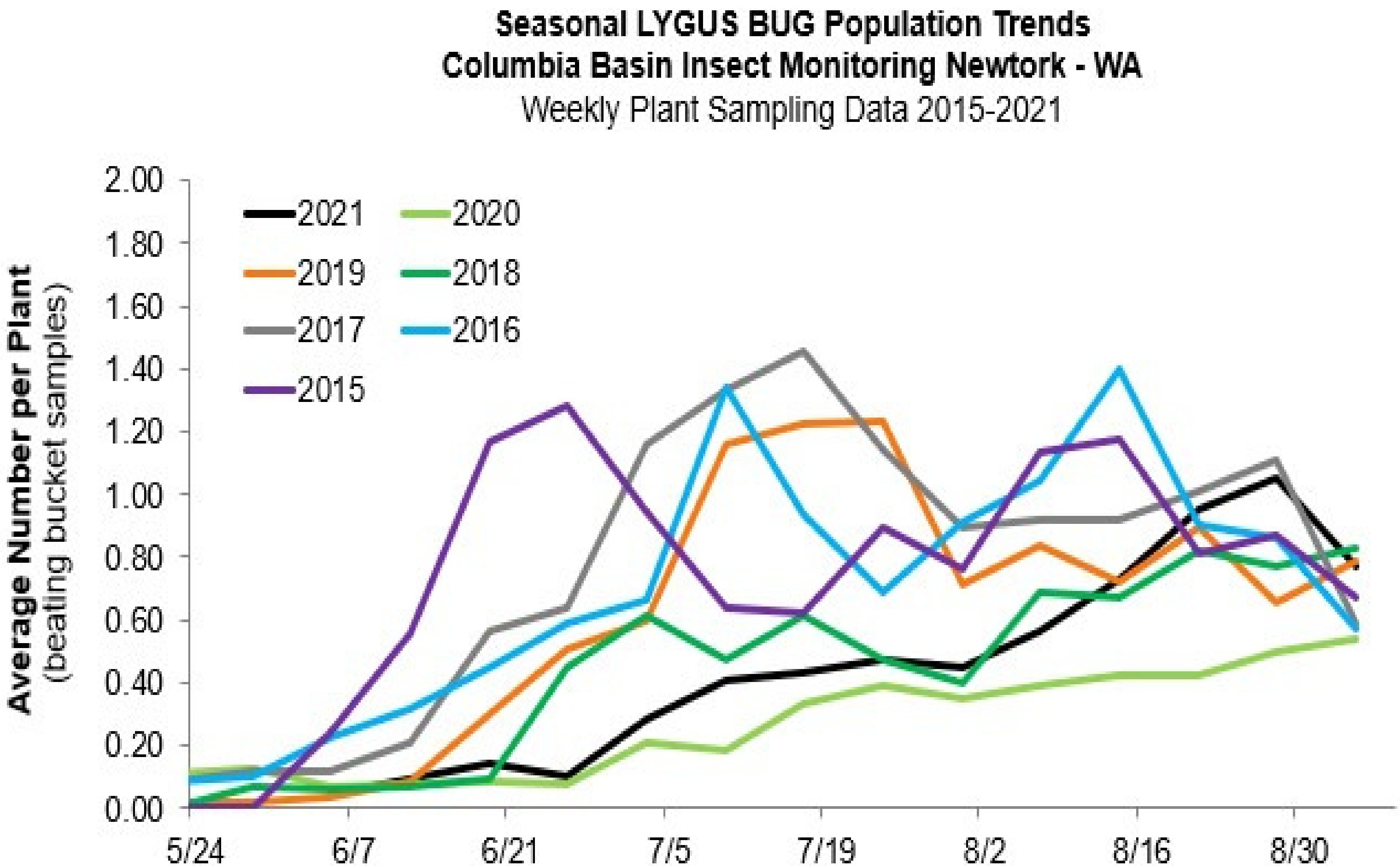


In Murai's 2000 paper : Effect of temperature on development and reproduction of the onion thrips, *Thrips tabaci* Lindeman on pollen and honey solution, his team demonstrates in my opinion why we may have seen fewer thrips in 2021.

Onion Maturity



GDD 50- April 1-Nov		Diff from Av
Ave 6 yr	3473	0
2015	3775	+302
2016	3475	+2
2021	3714	+241

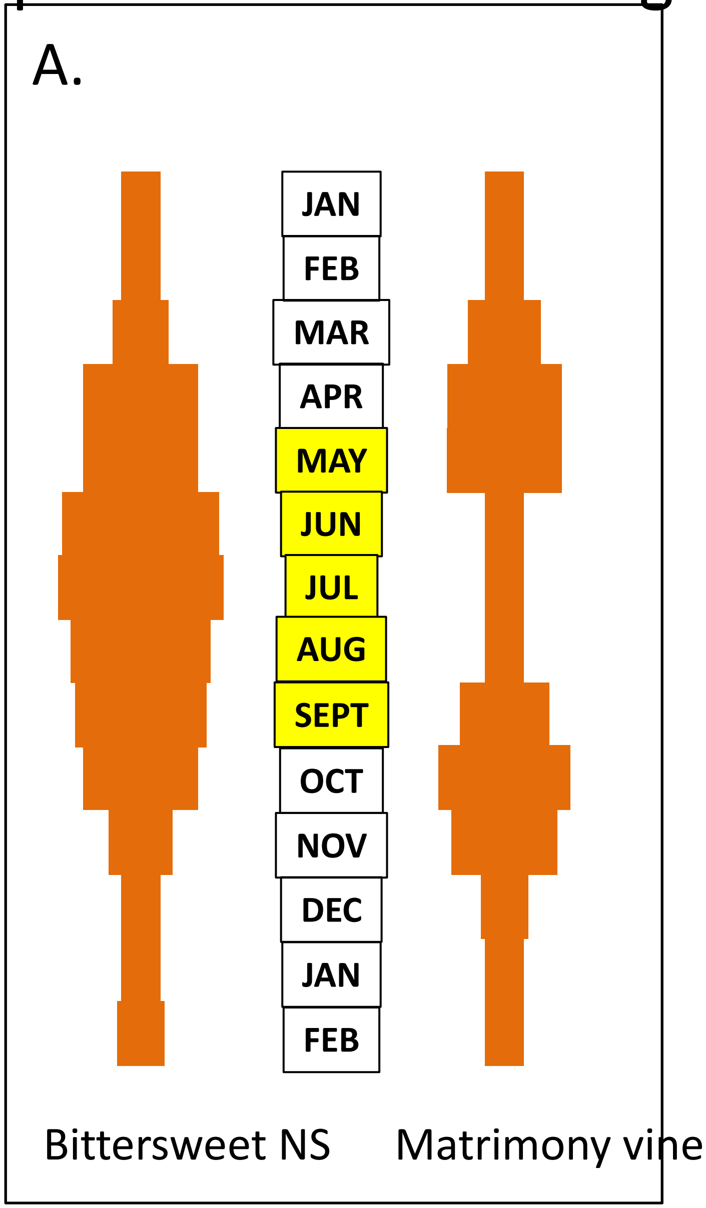


Highly Polyphagous Insects Not Always Impacted

Courtesy: C. Wohleb WSU 2021

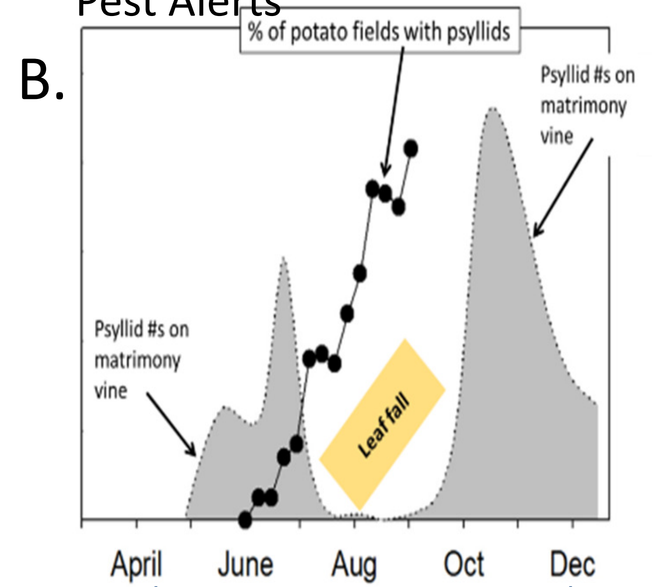
Host Shifting

Contrasting psyllid patterns-Host Shifting



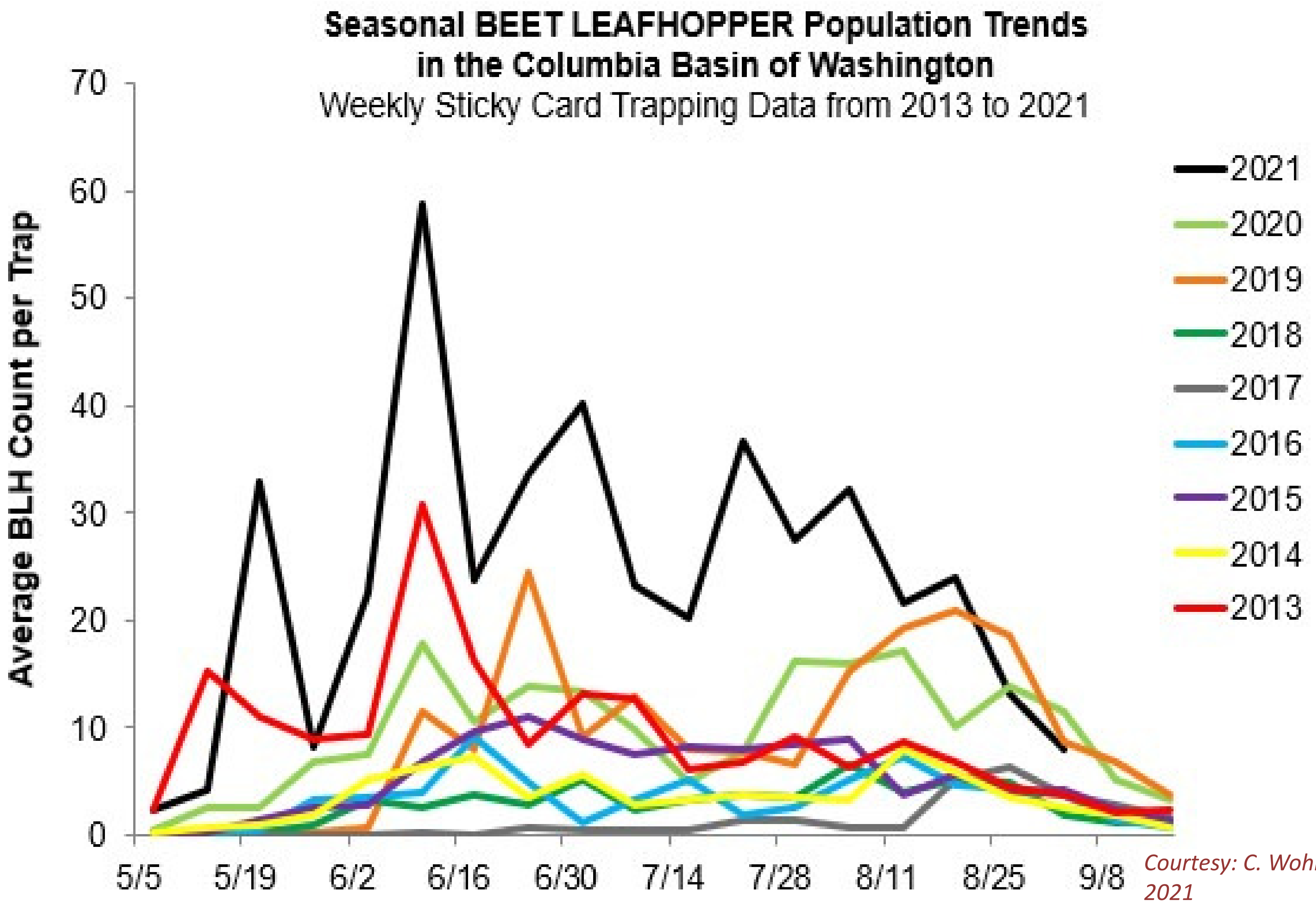
Courtesy: R. Cooper, USDA-ARS

Trapping data (solid black circles) from WSU Potato Pest Alerts



Horton et al. 2016. Potato Progress. Vol. XVI, number 14

For some polyphagous insects, when hosts become less favorable, they move more



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Increase Temperature, Increased Number of Generations of Insects per season

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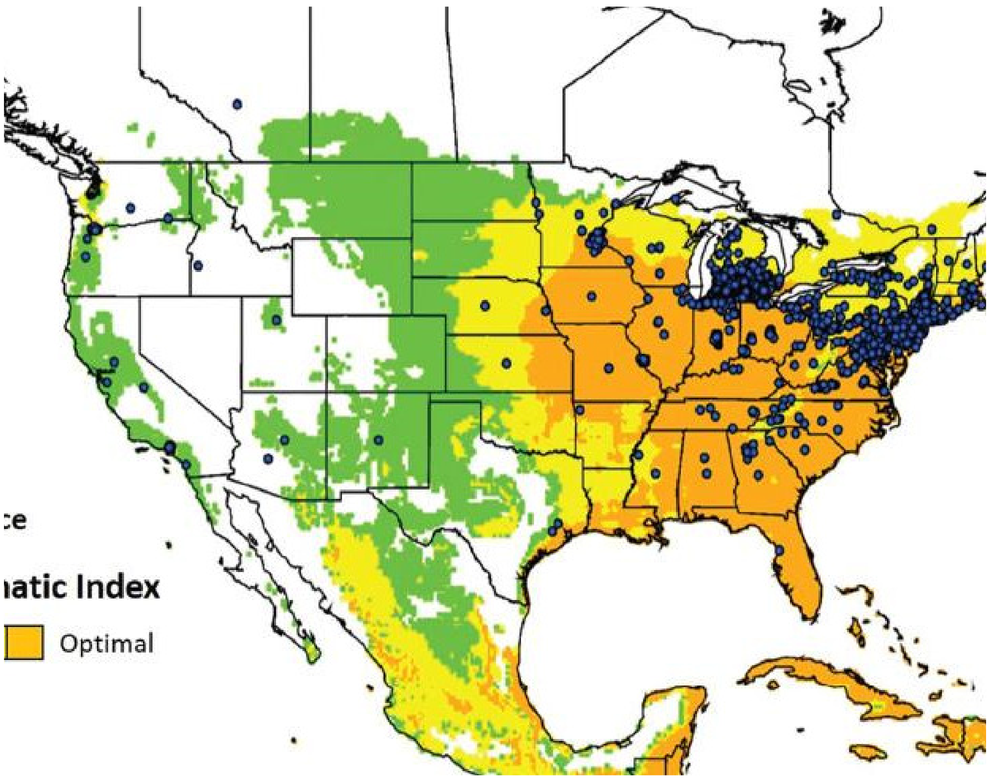
Increased Temperatures, Increased Range Expansion of Insects



- Possibility?
- Seeing Fall Armyworm sooner, and in bigger numbers
- Will they survive winters in E. WA like they hadn't previously?
- What are implications if they do?

Insects we care about

Thrips	Corn earworm	Armyworm	Spider mites
Leafhopper	Aphids	Wireworms	Spotted Lanternfly
Japanese Beetle	Grasshoppers	Seedcorn Maggot	Stink bugs

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http://benton-franklin.wsu.edu/agriculture/commerveg.htm




But Why Did Some Growers Have More Thrips?

- This may be the result of them having more Western flower thrips (*Frankliniella occidentalis* Pergande) than onion thrips.
- We have previously reported that in most onion growing areas, onion thrips are the predominant species, but in some areas Western flower thrips can be abundant.
- Western flower thrips have a higher intrinsic rate of growth at high temperatures compared to onion thrips which could explain why some growers encountered more thrips than others.
- Also, onion age and maturity likely influenced onion thrips numbers
- Nearby crops can also play a role