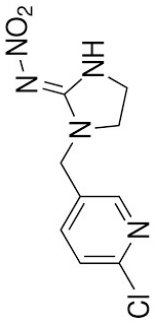
New Technology for Pest Management



Dr. Max Feldman

Research Geneticist

USDA-ARS Prosser, WA

Pacific Northwest Vegetable Association 2021

November 18th, 2021

Colorado potato beetle

Leptinotarsa decemlineata (Say)

The MOST important insect defoliator of potato

Preferred host is potato but it can also damage to other Solanaceous crops (tomato and eggplant)

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Larvae consume ~40 cm^2 of foliar tissue throughout larval stage

Adult beetles can consume ~9 cm^2 per day (Ferro et al., 1985)

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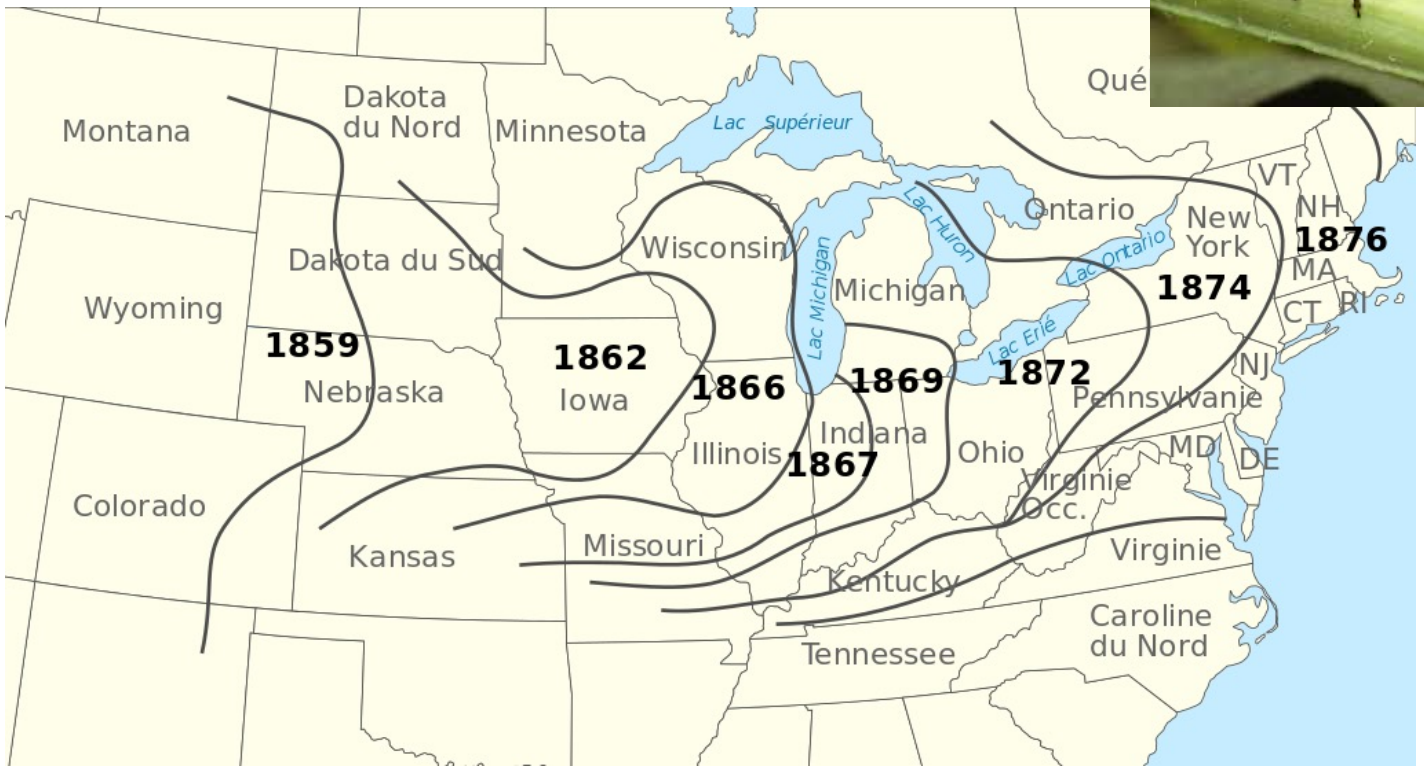
Adult beetles can consume ~9 cm^2 per day (Ferro et al., 1985)

Prolific fecundity (reproductive capacity)… 1 female can produce 300 – 800 eggs (Harcourt, 1971)

Geographical distribution

Most likely native to region between Colorado and northern Mexico.

First discovered in 1824 by Thomas Say in Rocky Mountains



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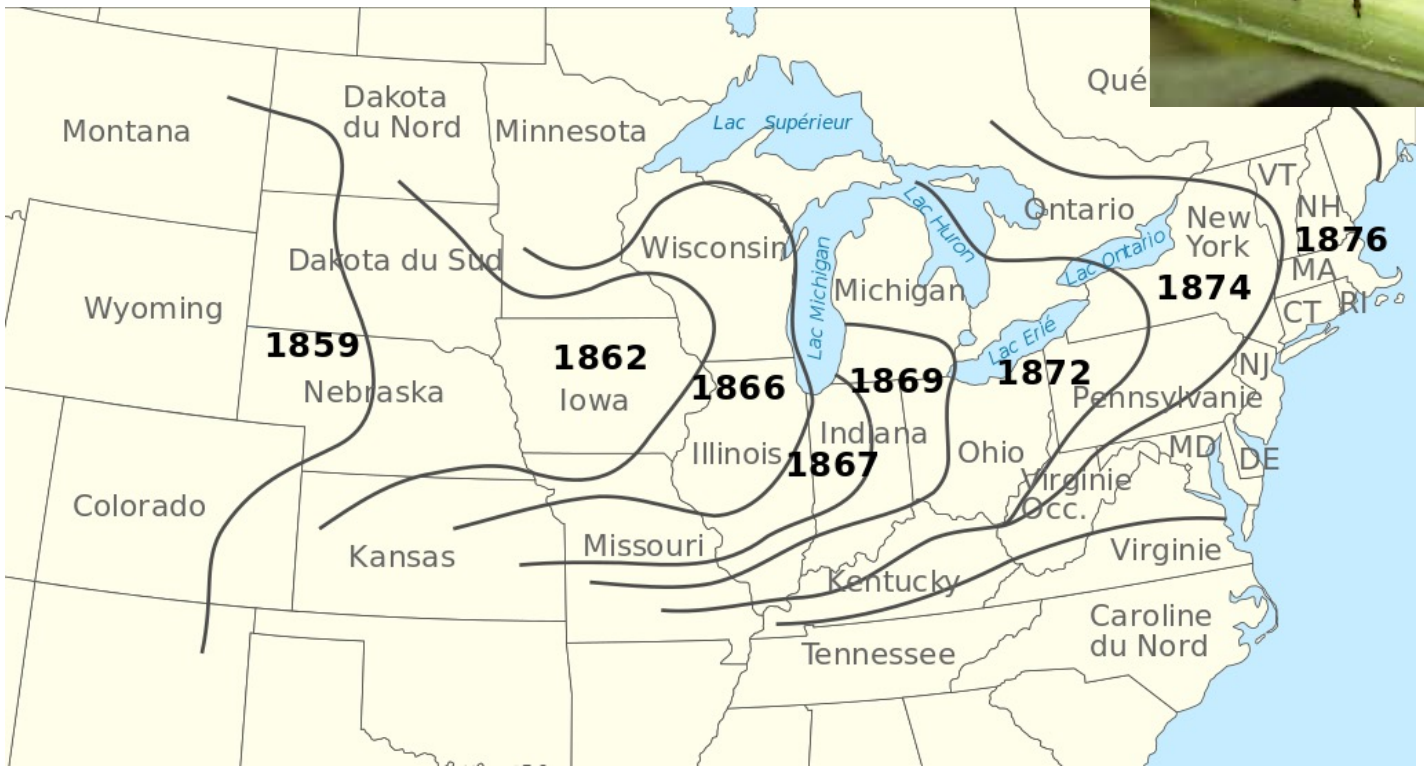

First discovered in 1824 by Thomas Say in Rocky Mountains

First associated with potato plants near Omaha, NE in 1859 (Walsh, 1865)

Spread by ~140 km per year…
Reached Atlantic Coast by 1874

Reached western states and Canada by 1920s (Tower, 1906; Gautier et al., 1981; Hsiao 1985)

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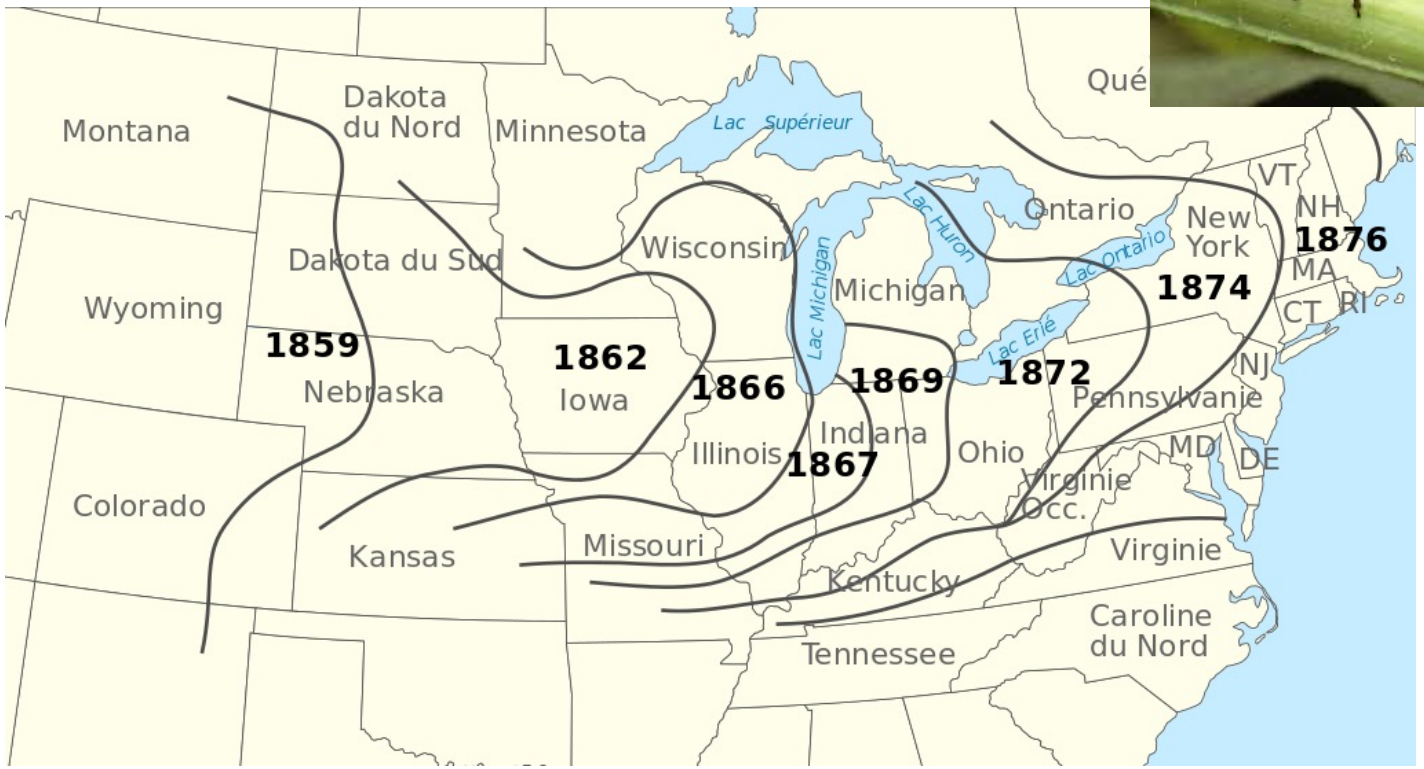


Now spread to the rest of the continental USA, only states not affected are AK, CA, HI, and NV

Reached western states and Canada by 1920s (Tower, 1906; Gautier et al., 1981; Hsiao 1985)

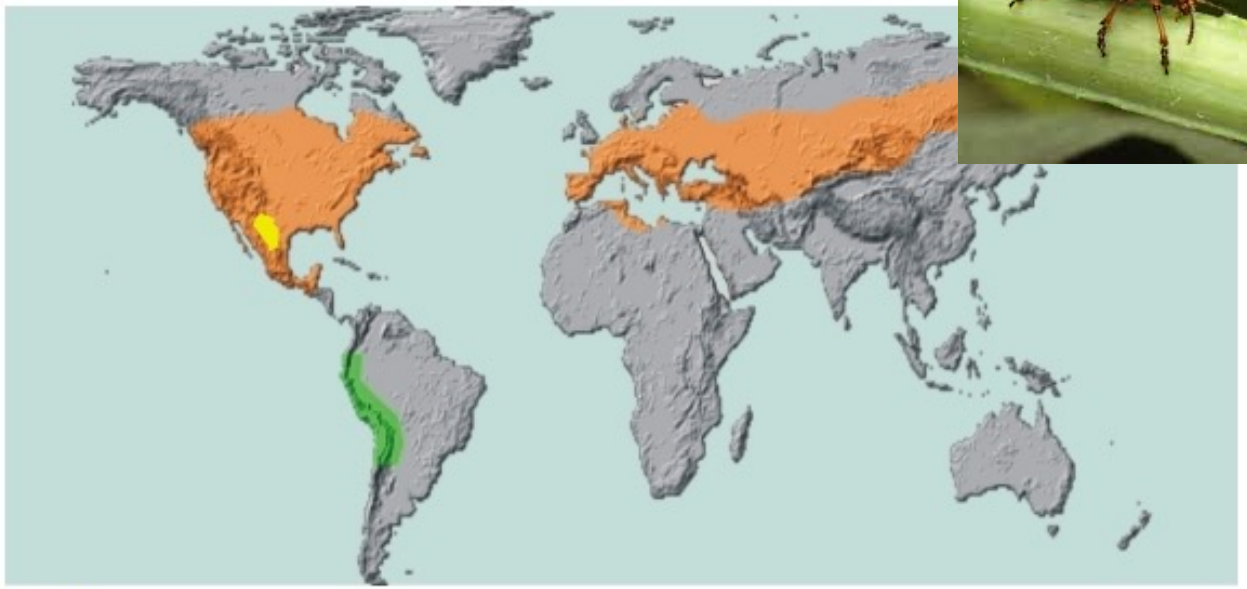
Currently affects about 8 million km^2 in North America (Hsiao, 1985)

Geographical distribution

Expansion into Europe (U.K) by 1877

Arrival near USA military bases in Bordeaux, France around WWI

Spread to Belgium, the Netherlands, and Spain following WWII and spread eastward to much of Europe



Geographical distribution

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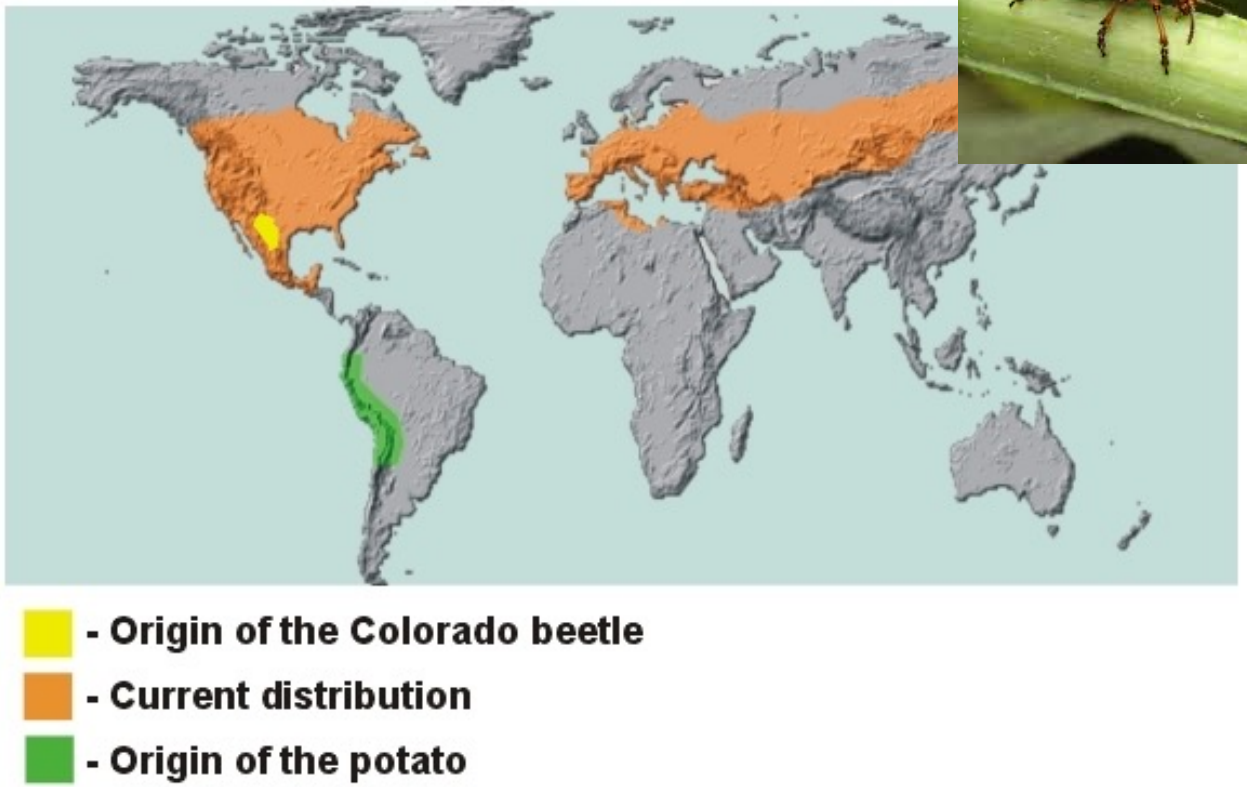
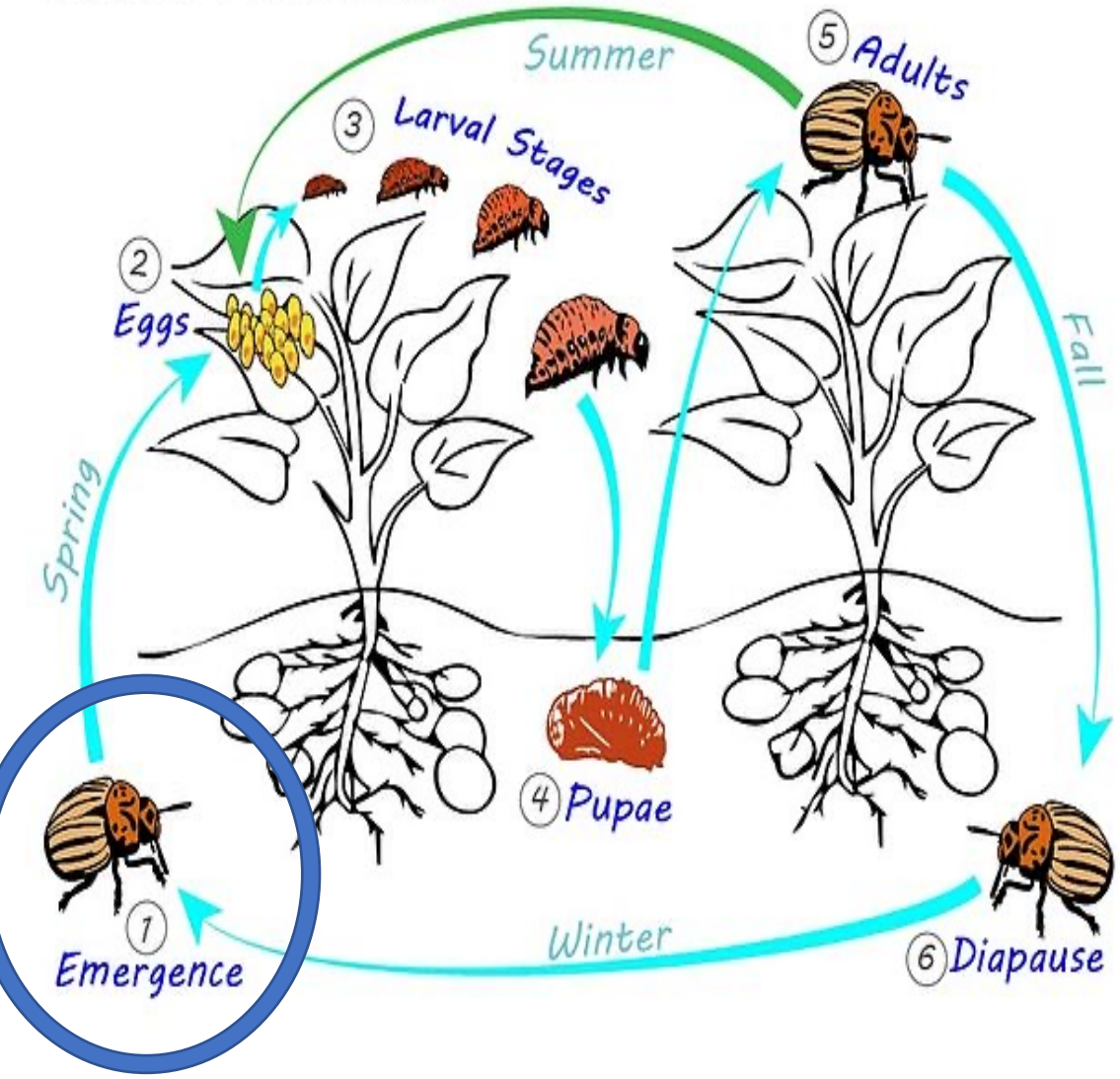
6 million km^2 in Europe and Asia (Jolivet, 1991)



CPB is now in western China and Iran. CPB can potentially colonize much larger areas in China and Asia Minor, spread to Korea, Japan, Russian Siberia, certain areas of the Indian subcontinent, parts of North Africa, and the temperate Southern Hemisphere (Vlasova, 1978; Worner, 1988; Jolivet, 1991).

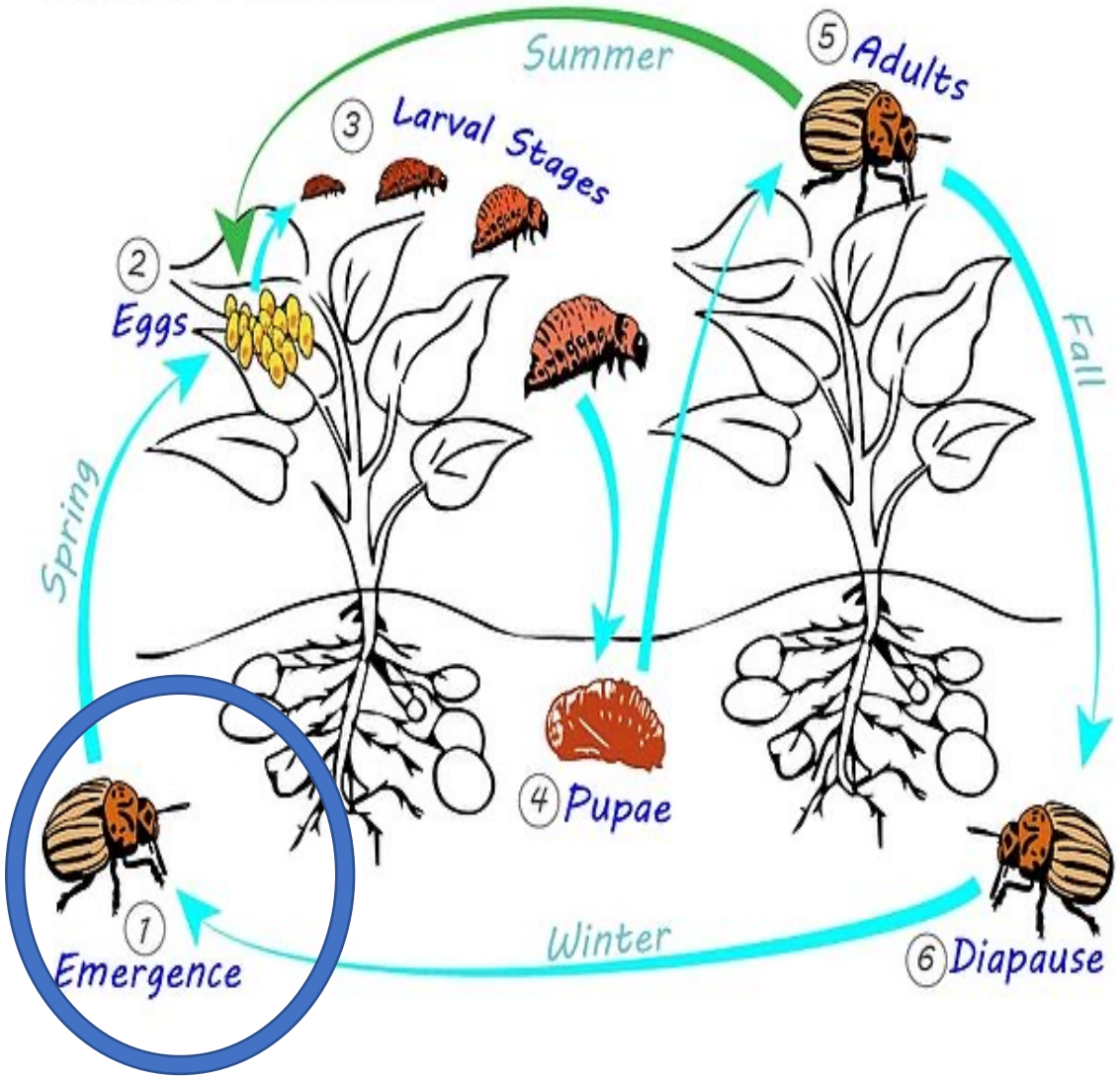
Colorado potato beetle life cycle



Graphic by Chad Keyser (AgBiome.com)

1. CPB emergence is synchronized with potato emergence

Colorado potato beetle life cycle



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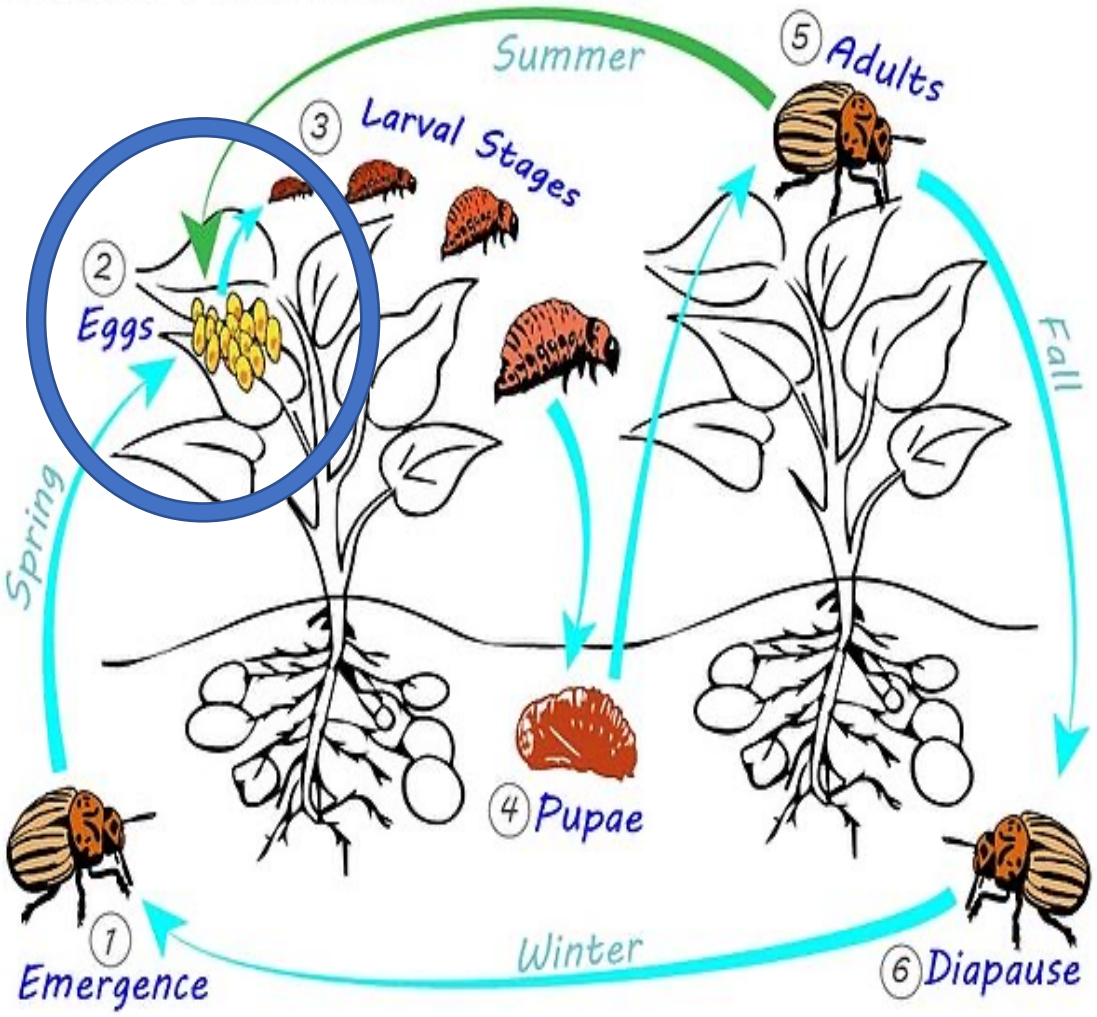
1. CPB emergence is synchronized with potato emergence

CPB will walk to nearby potato field (Voss and Ferro, 1990)

If no potatoes, CPB can fly several kilometers (Ferro et al., 1985; Ferro et al., 1991)

Colorado potato beetle life cycle



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1. CPB emergence is synchronized with potato emergence

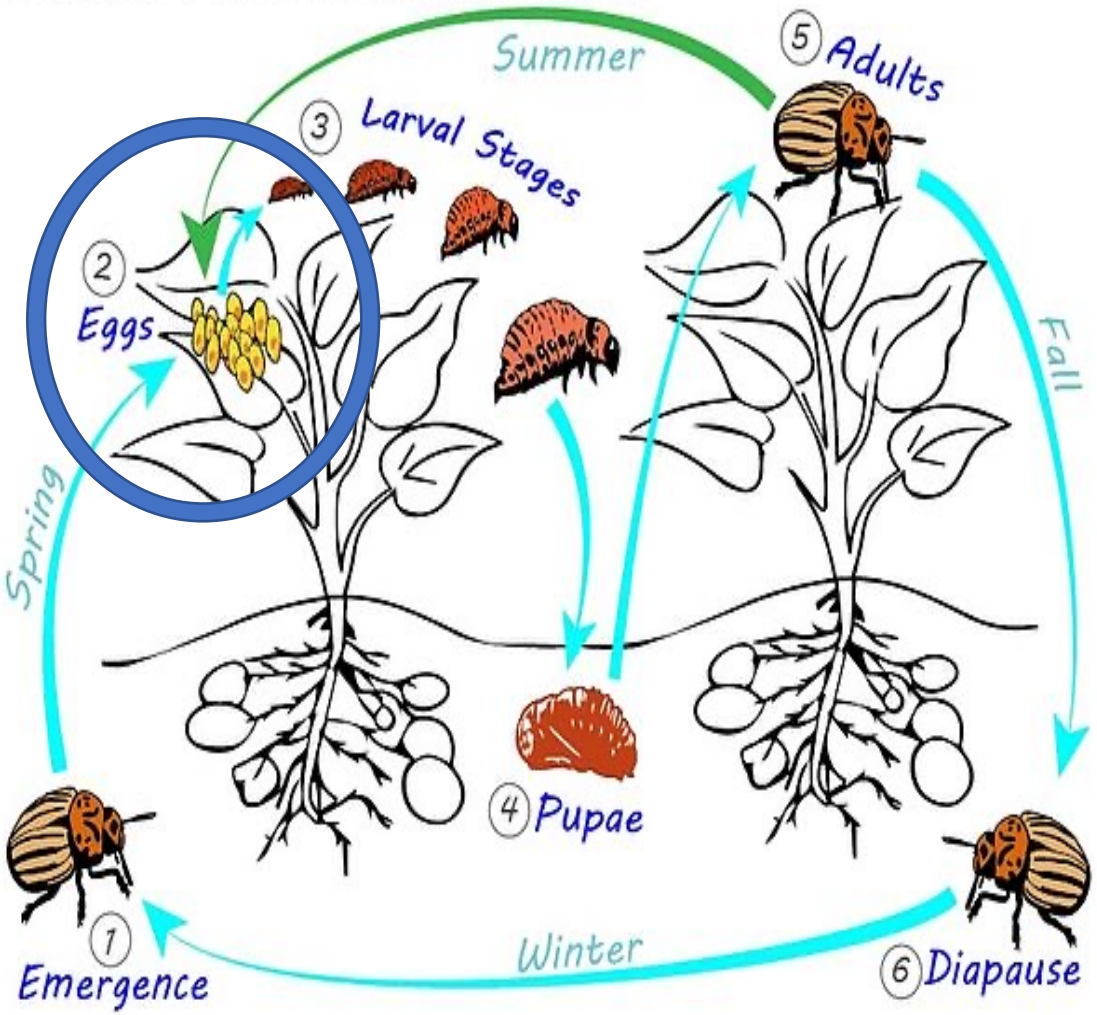
CPB will walk to nearby potato field (Voss and Ferro, 1990)

2. CPB will feed and then lay eggs within 5-6 days, egg laying can last up to a month

If no potatoes, CPB can fly several kilometers (Ferro et al., 1985; Ferro et al., 1991)

20-60 eggs/cluster

Colorado potato beetle life cycle



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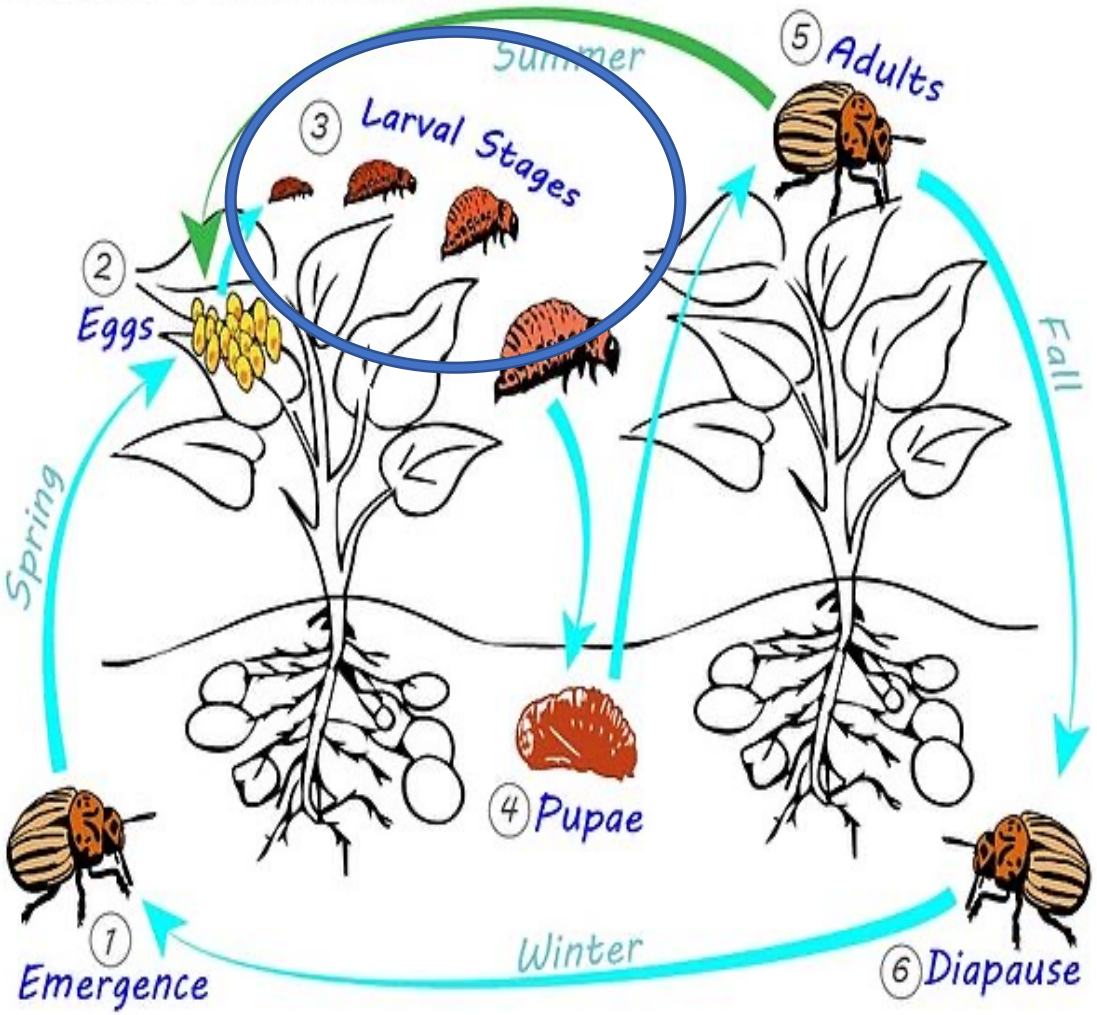
2. Eggs hatch within 4 - 10 days

Colorado potato beetle life cycle



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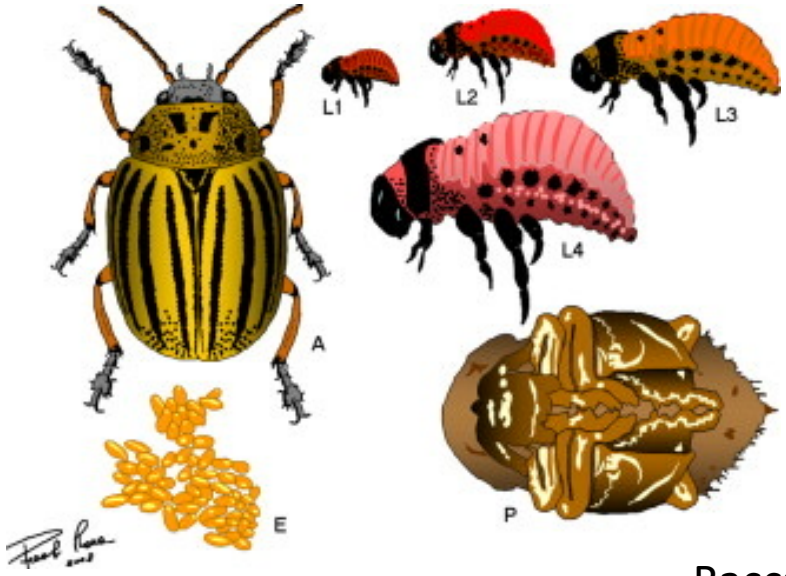
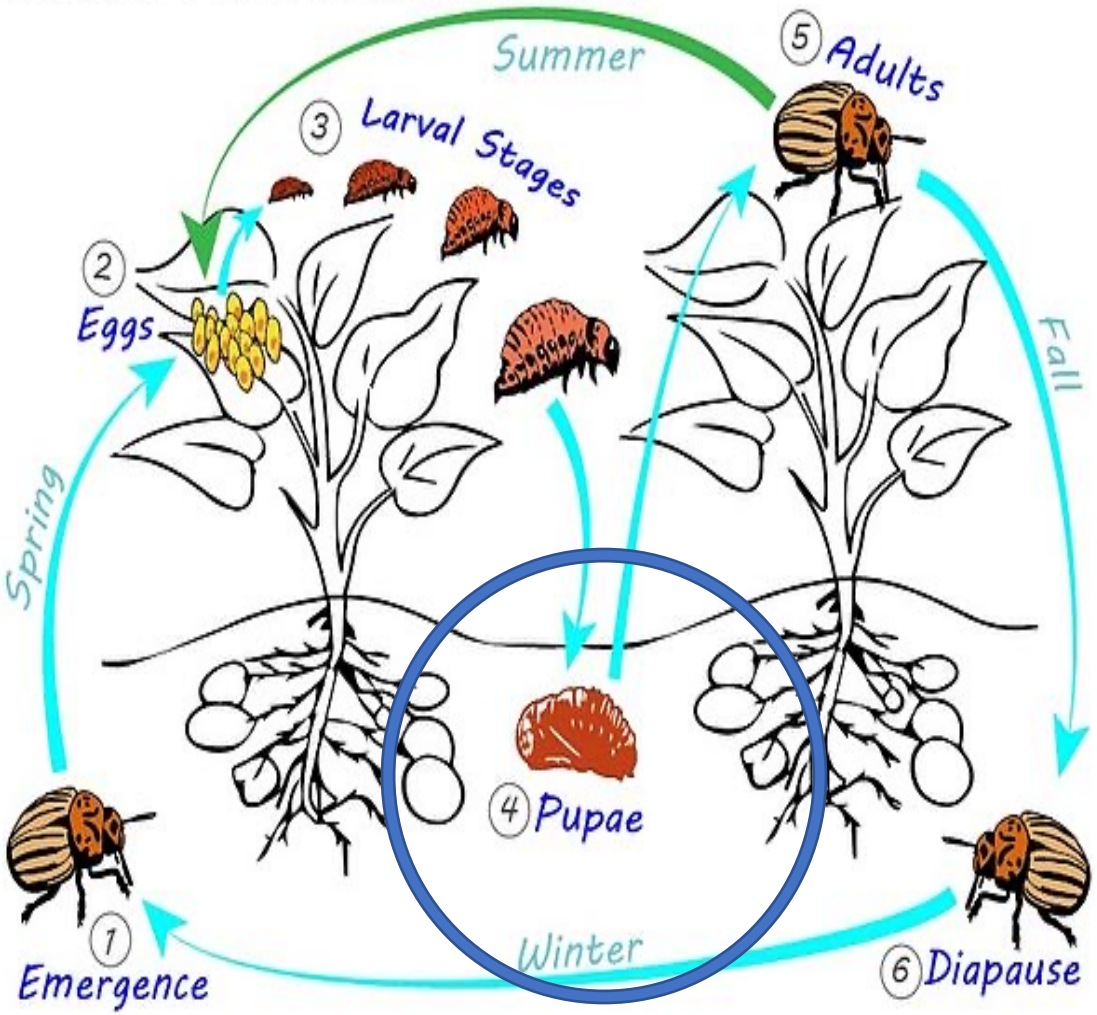
2. Eggs hatch within 4 - 10 days

3. Four larval instars last ~21 days



Racca et al., 2014

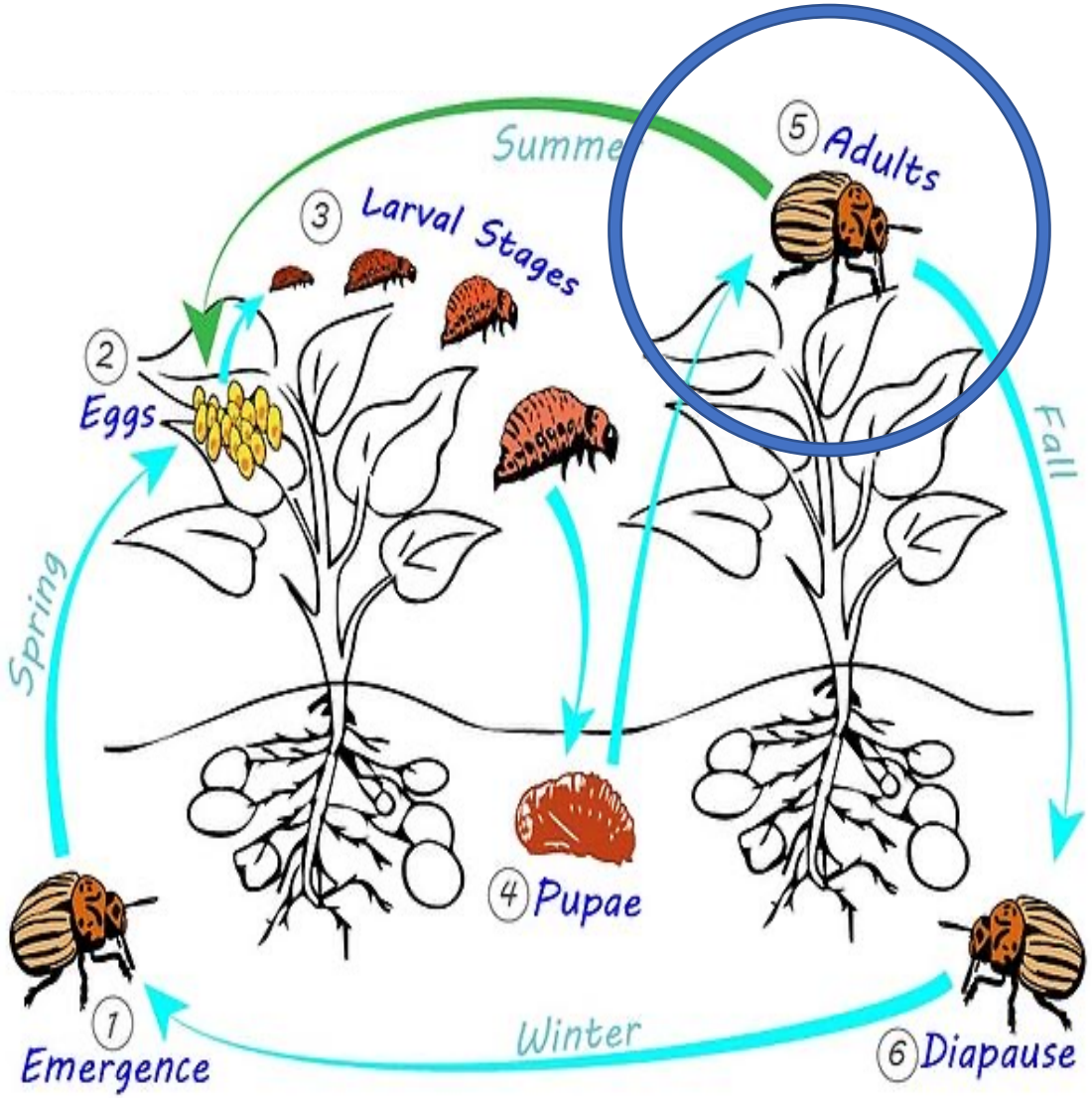
Colorado potato beetle life cycle



4. After 2-3 weeks as larvae, CPB return to soil to pupate

Graphic by Chad Keyser (AgBiome.com)

Colorado potato beetle life cycle

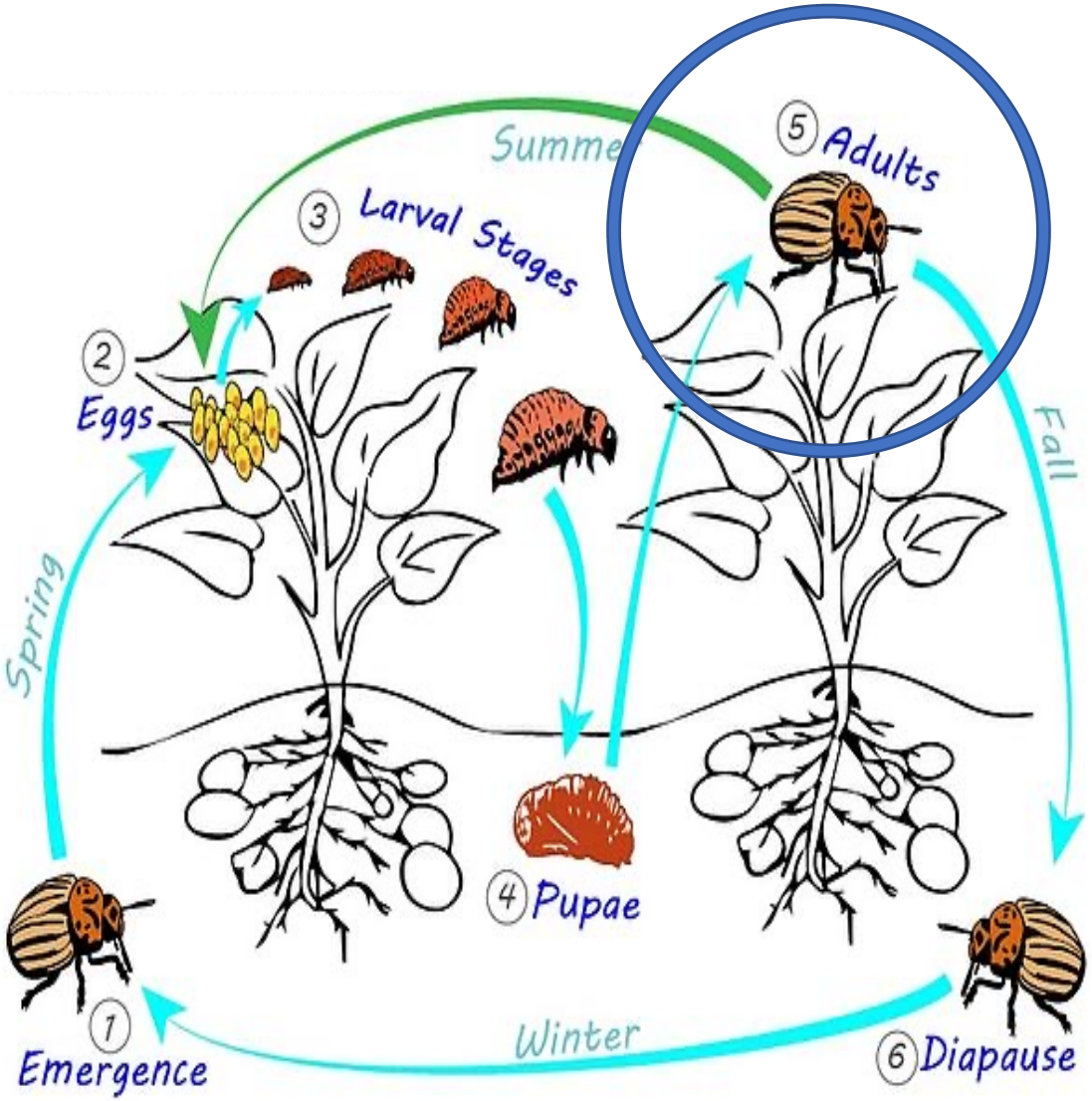


4. After 2-3 weeks as larvae, CPB return to soil to pupate

5. Adult CPB will emerge 10-14 days after pupation

Graphic by Chad Keyser (AgBiome.com)

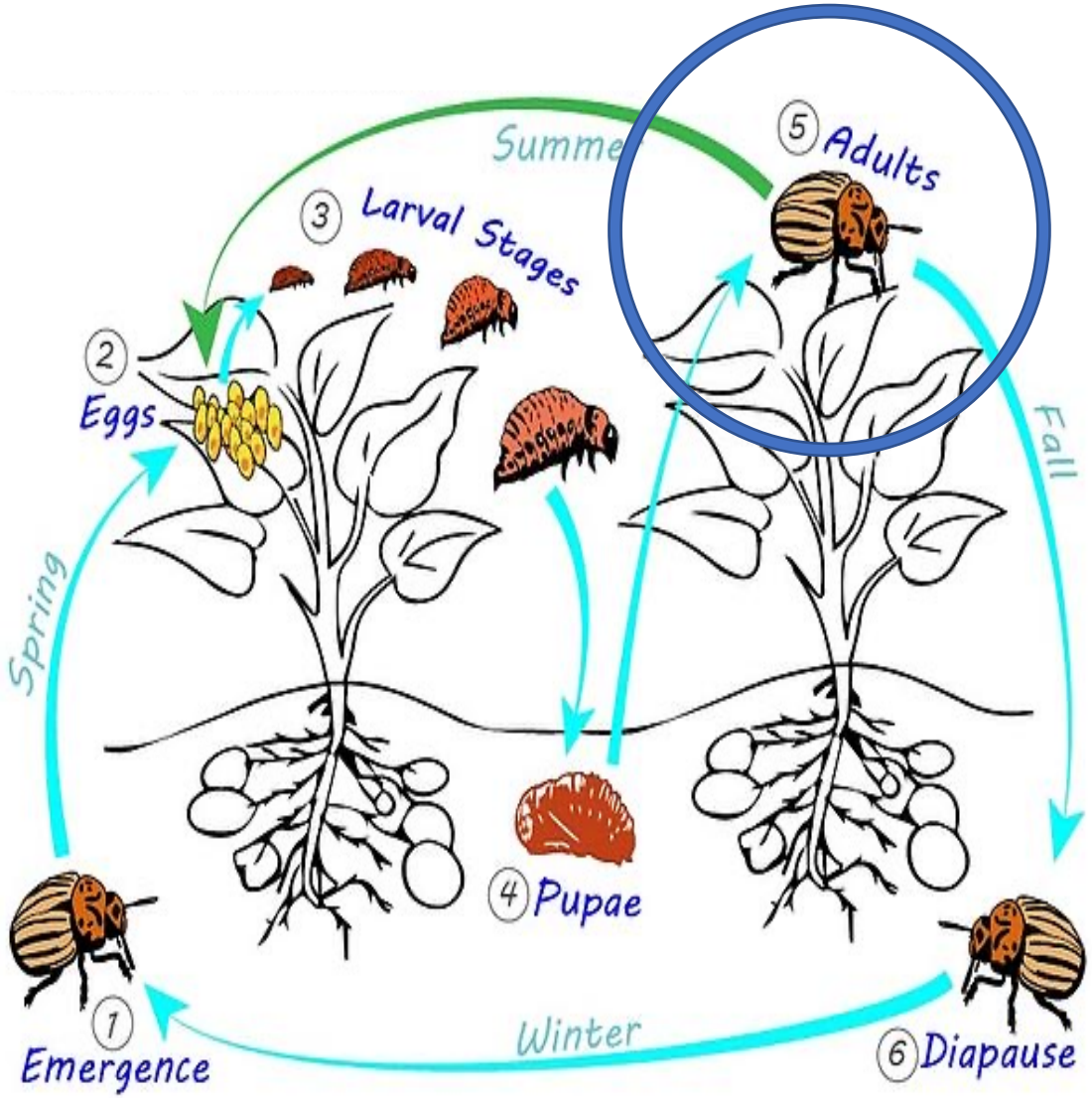
Colorado potato beetle life cycle

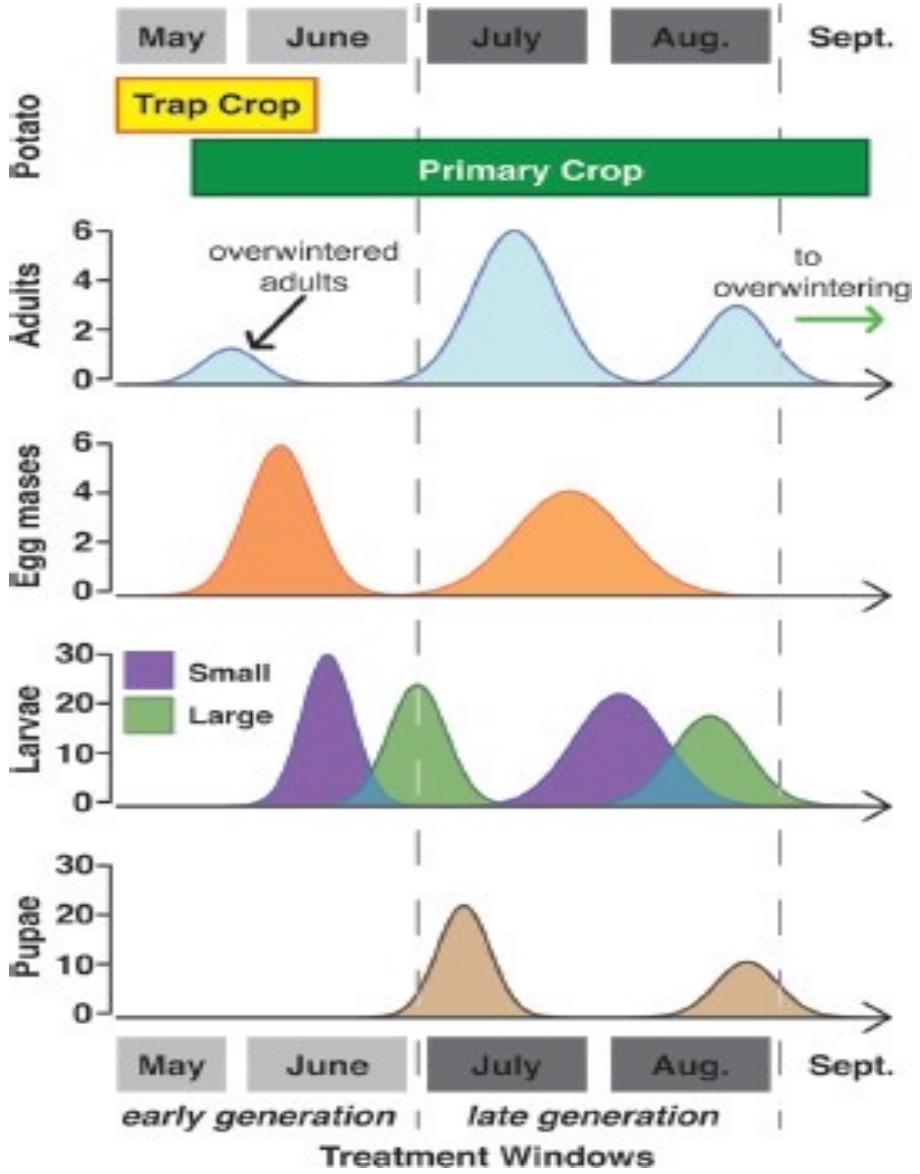


5. CPB can complete 2-3 generations per field season

Graphic by Chad Keyser (AgBiome.com)

Colorado potato beetle life cycle





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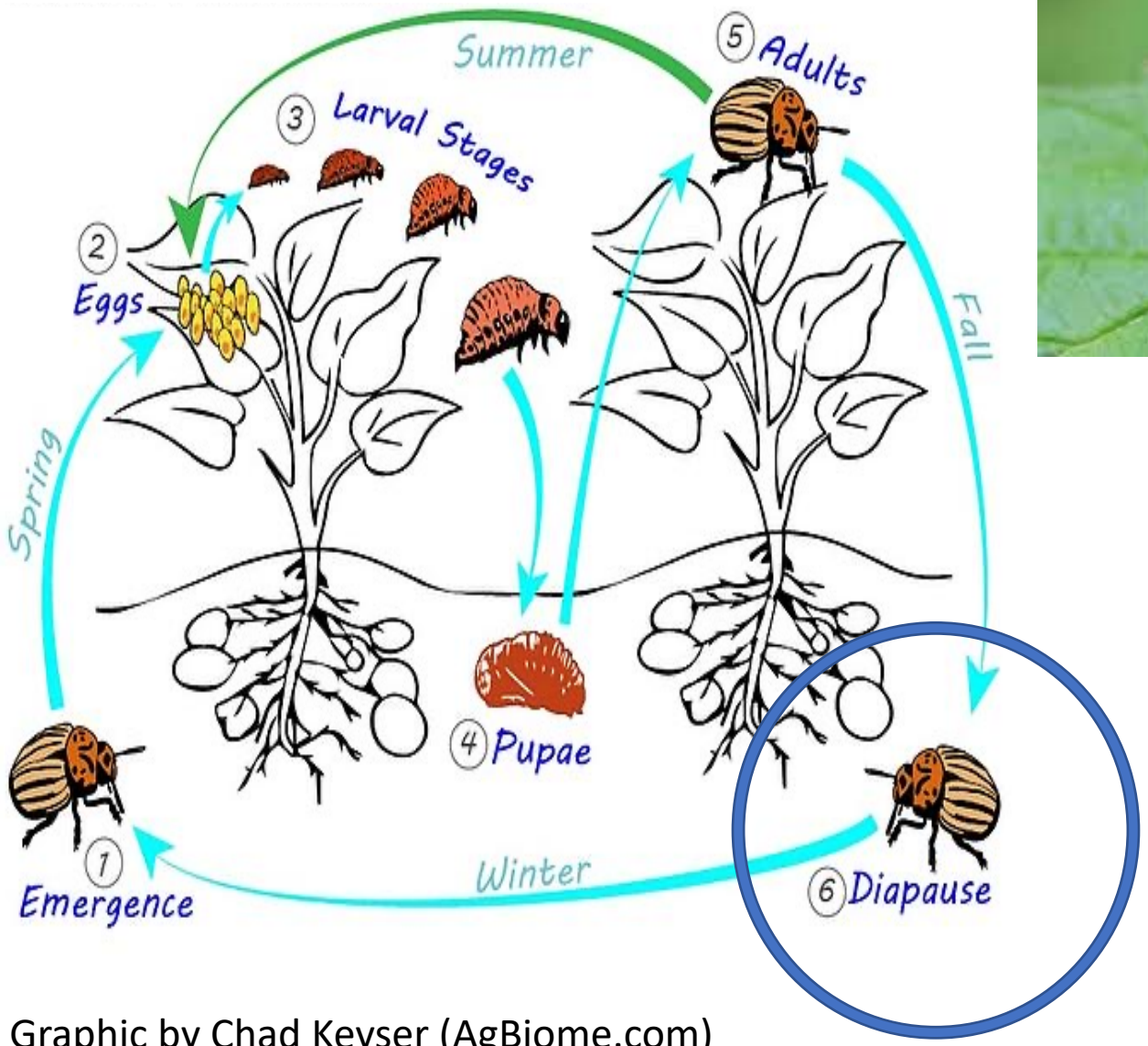

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5. CPB can complete 2-3 generations per field season

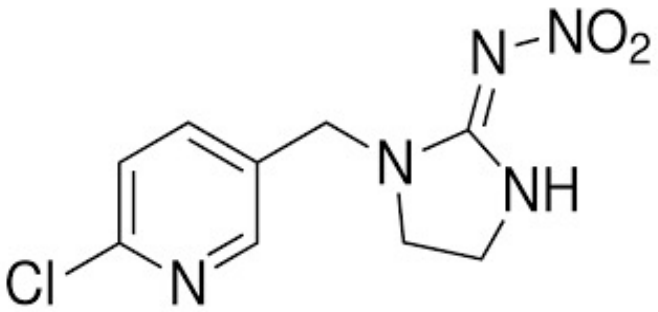
6. Day length queues signal diapause, CPB over-winters nearby potato field underground

Mortality high (50-75%)

Current control strategies

Current control strategies

Chemical



Chemical control of CPB

Insecticide application is the major control strategy

Currently >30 active ingredients are registered for use against CPB in the U.S., efficiency varies by region

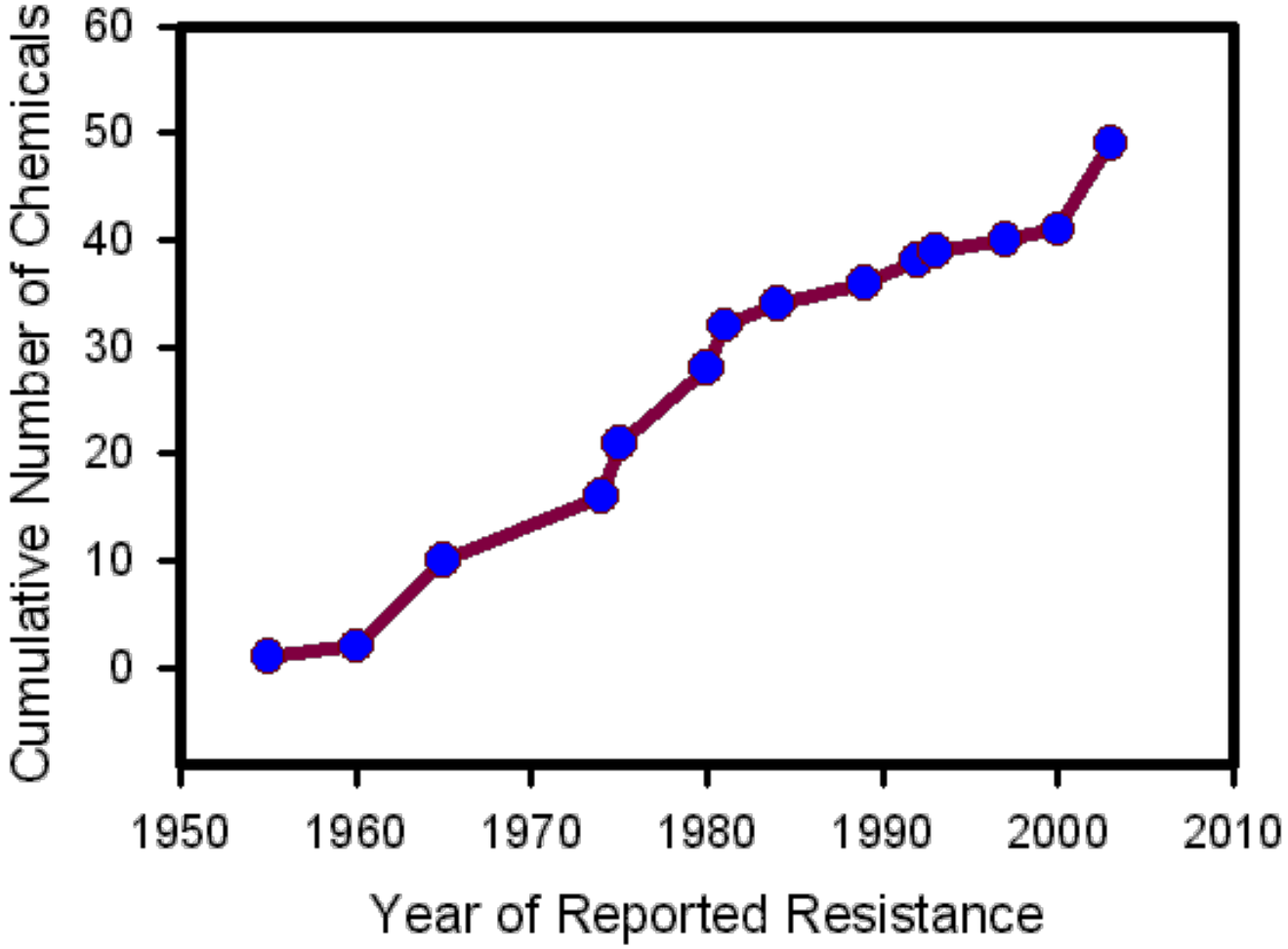
Treatment window	Active ingredient	IRAC MoA group	Delivery[a]	Common trade names
Early generation	Abamectin	6	F	Agri-Mek, generics
	Chlorantraniliprole	28	F	Coragen
	Cyantraniliprole	28	F, IF	Exirel, Verimark
	Imidacloprid	4A	IF, ST	Admire Pro, generics
	Novaluron	15	F	Rimon
	Spinetoram	5	F	Radiant
	Spinosad	5	F	Blackhawk, Entrust
	Thiamethoxam	4A	IF, ST	Platinum, Cruiser Maxx Potato
Late generation	Abamectin	6	F	Agri-Mek, generics
	Chlorantraniliprole	28	F	Coragen, Voliam Xpress[b]
	Cyantraniliprole	28	F	Exirel
	Imidacloprid	4A	F	Admire Pro, generics
	Indoxacarb	22A	F	Avaunt
	Spinetoram	5	F	Radiant
	Spinosad	5	F	Blackhawk, Entrust
	Thiamethoxam	4A	F	Actara, Endigo ZC[c]
	Tolfenpyrad	21B	F	Torac
Trap crop	Indoxacarb	22A	F	Avaunt

Most common control strategy is single application of neonicotinoid mode of action (MoA) 4A at planting as in-furrow or seed treatment

Chemical control of CPB

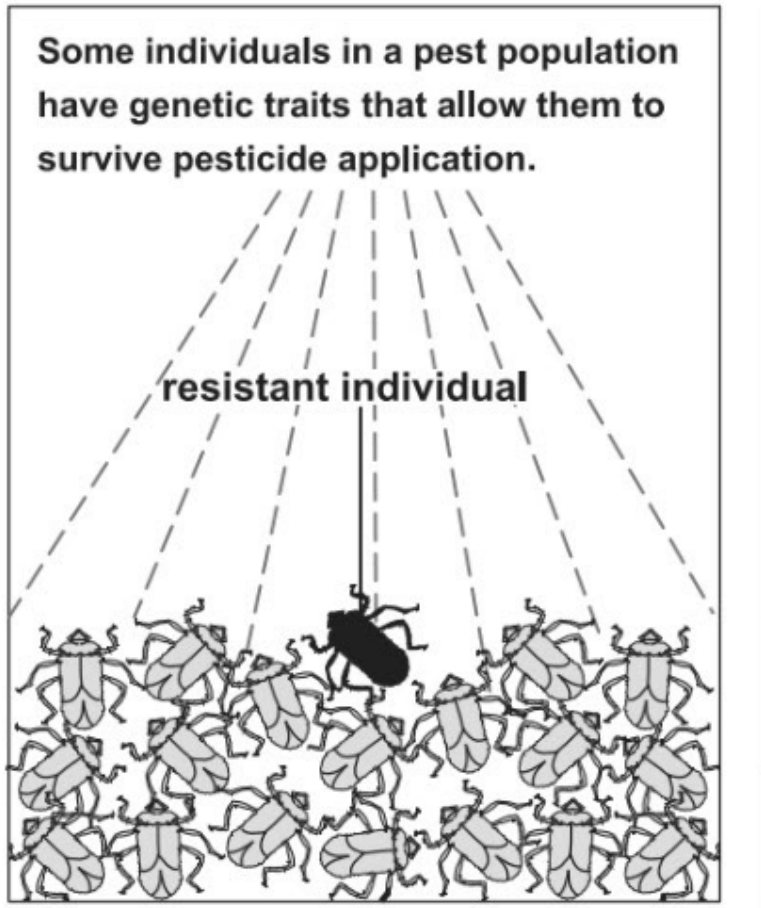
CPB has legendary ability to develop resistance to insecticides…

Insecticide resistance has been reported for all major classes including: arsenicals, organochlorines, carbamates, organophosphates, pyrethroids, neonicotinoids, etc.



Neonicotinoid resistance first reported in 1995; now has been reported in most potato growing regions

How does pesticide resistance evolve?



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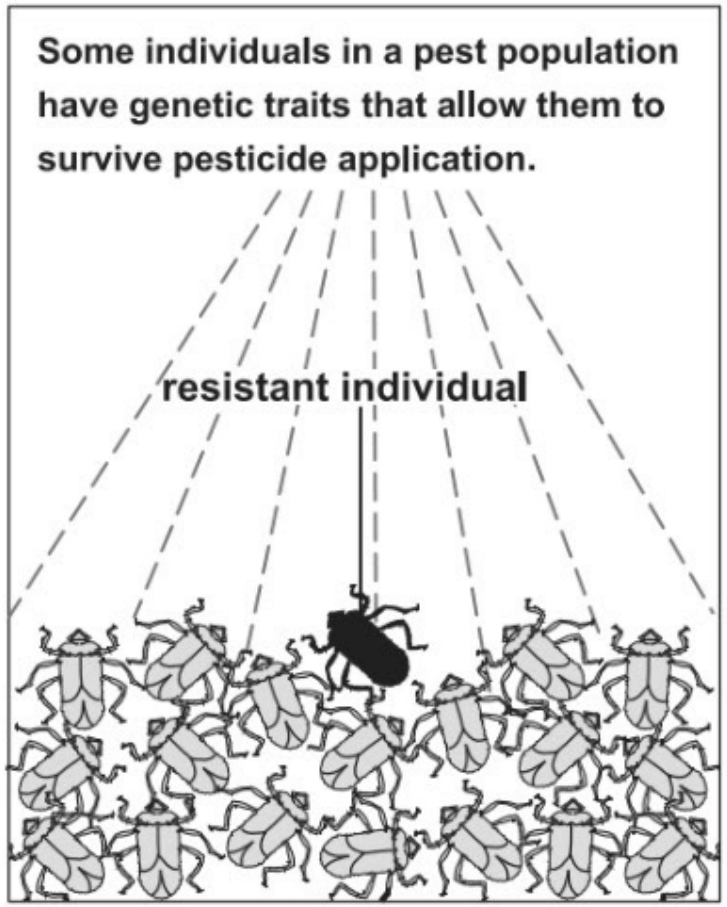

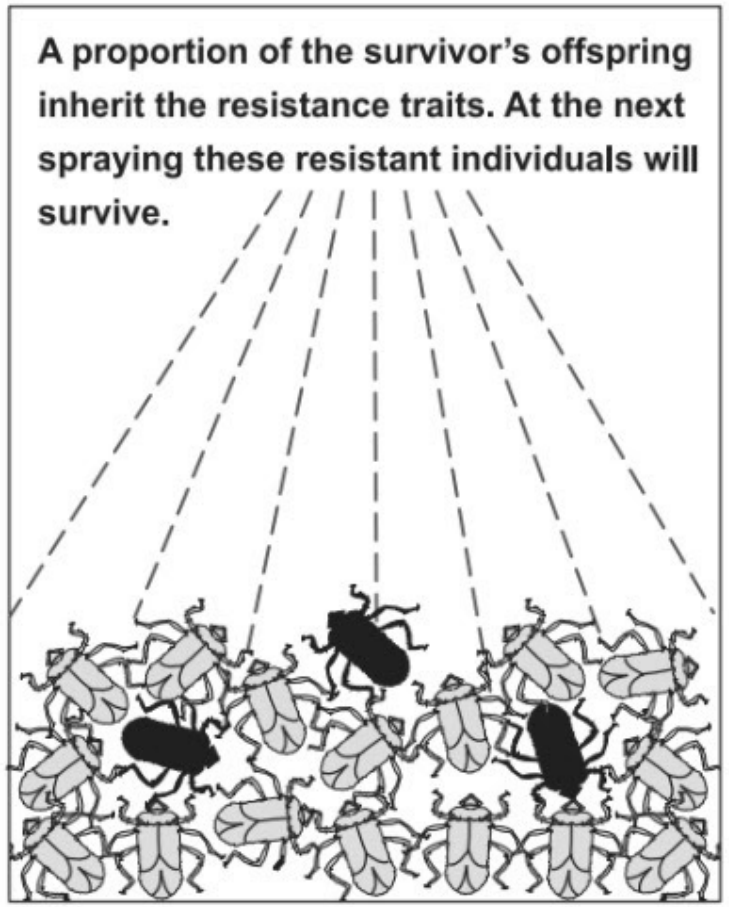

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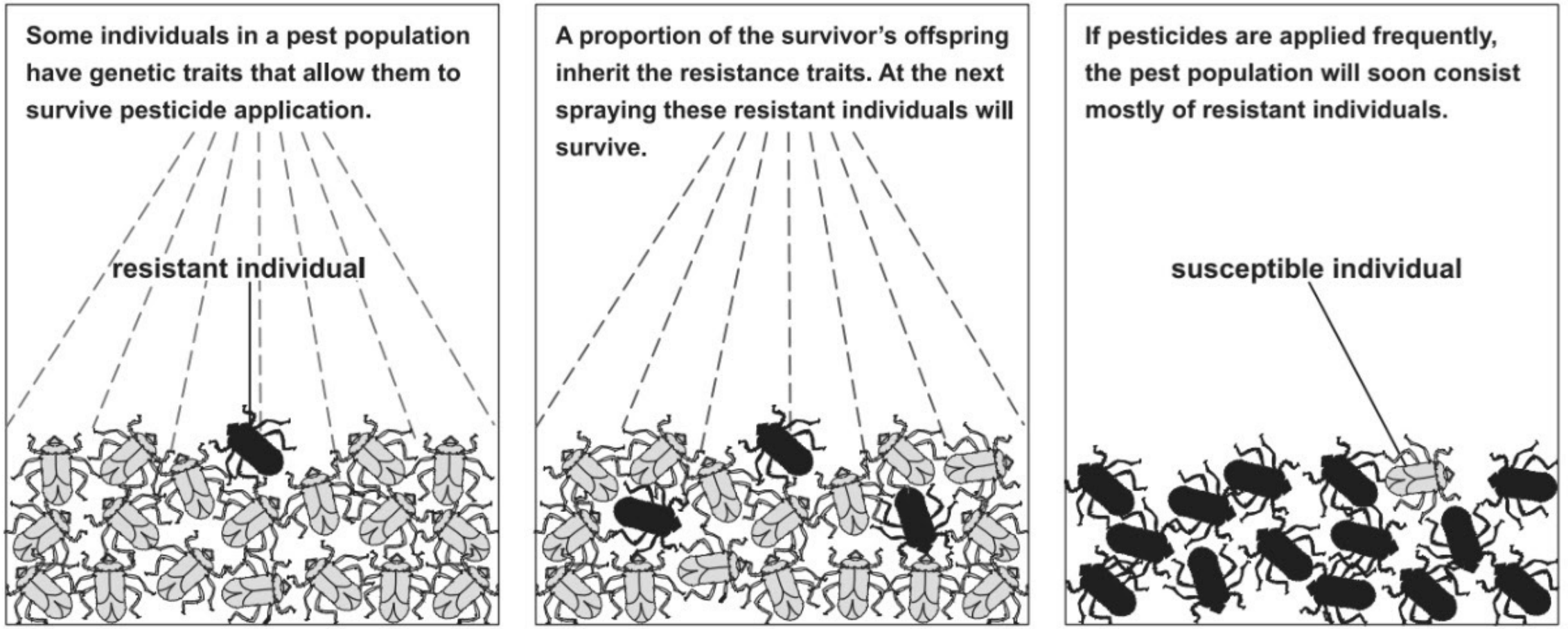
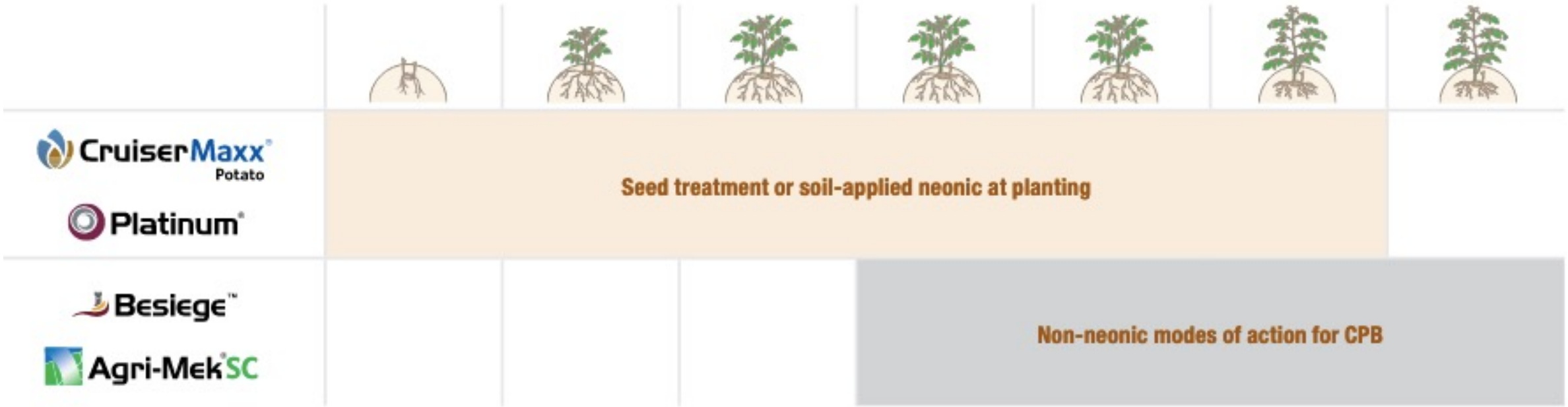


Pesticide resistance develops over time as resistant individuals survive to reproduce.
Adapted from the University of California, *The Safe and Effective Use of Pesticides*

Chemical control of CPB

Don’t use same mode of action (MoA) back-to-back in the same field year



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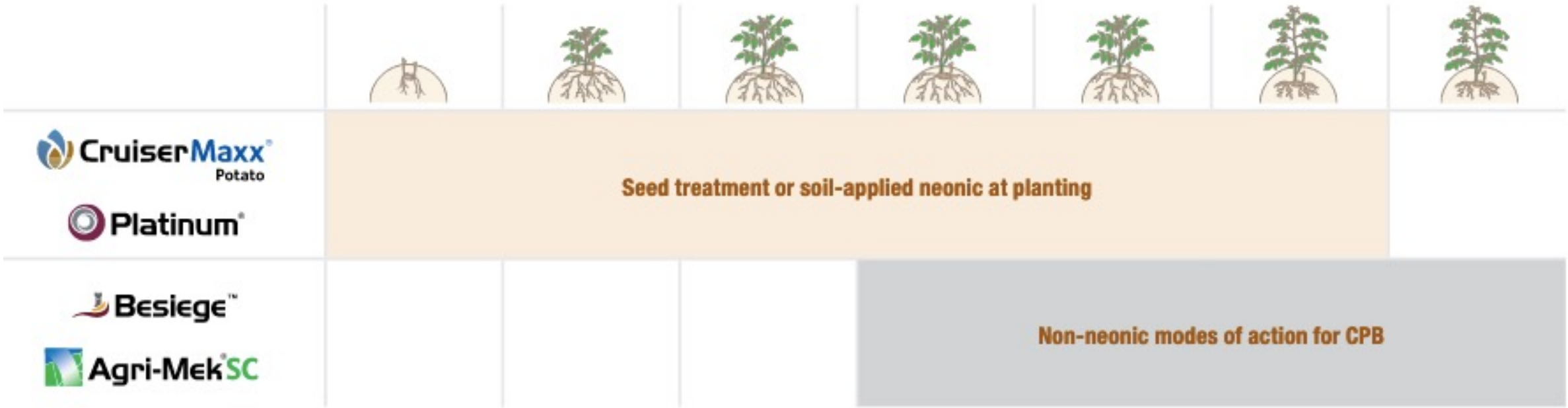
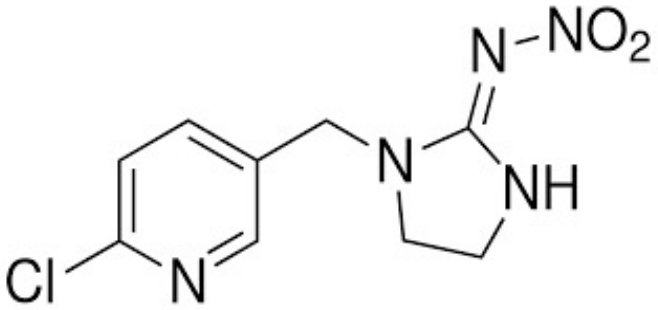


Foliar application needs to be applied at larval stage (need scouting)

Pesticide formulations with >1 MoA may contribute to faster evolution of insecticide resistance

Current control strategies

Chemical



Cultural

Cultural practices to control CPB

Crop rotation

Most widely practiced, non-chemical strategy

Maximize interannual potato separation distance

Rule of thumb is 400 – 1500 M of distance between fields across years

Can reduce pressure by >95% (Wright 1994)

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Trap cropping

Early planting of smaller trap potato plots adjacent to previous year's field (or nearby current field) can help

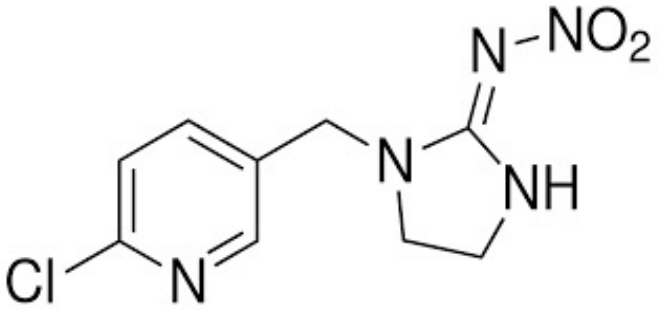
Trap crop planted without insecticide, should have canopy cover before main crop emergence

These can be paired with CPB aggregation pheromones

Beetles are killed before they can infest main crop

Current control strategies

Chemical



Cultural

Physical

Physical practices to control CPB

Pitfall traps

Dig trench around the field to trap beetles and prevent them from reaching potato crop

50 cm deep, 30 cm wide, line with plastic

Beetles will walk into trench and die (up to 95%; Misener et al., 1993)

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Mulch application

A 6-10 cm layer reduces defoliation 2-5 fold (Zehnder and Hough-Goldstein 1990; Brust 1994)

CPB have difficulty finding potatoes for reproduction (Stoner 1993) and may increase predatory pressure (Brust 1994)

Physical practices to control CPB

Flame insects

Should be performed early in season from emergence until plants 6 inches height

Flame 8-10 inches above the ground at 4-6 MPH

No yield penalty

Remove with vacuum

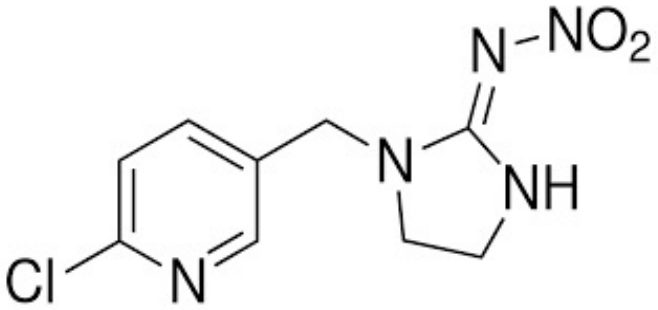
Burst of wind knocks beetles off plants, then sucked up by vacuum

Vacuum is most effective when combined with flaming

Most often used to eliminate CPB from trap crop

Current control strategies

Chemical



Cultural

Physical

Biological

Biological control

Beauveria bassiana

Beauveria bassiana (Hyphomycetes) is a pathogenic fungus that infects CPB and other insects

Can reduce CPB populations by up to 75% (Cantwell et al., 1986)

Available as a commercial formulation that can be applied with a conventional pesticide applicator

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Other biological predators

Lady beetle
(Coleomegilla maculate)

Stink bugs
(Perillus bioculatus and *Podisus maculiventris)*

Ground beetles
(Lebia grandis)

Parastic wasp
(Edovum puttleri)

Plan of action to prevent pesticide resistance in the PNW

Dr. Andrei Alyokhin
(University of Maine)

Plan of action to prevent pesticide resistance in the PNW

1) Do not rely solely on insecticides

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5) Use full label rate of insecticides

Dr. Andrei Alyokhin
(University of Maine)

New strategies to attack CPB

UAV based field scouting

Can we use UAV for remote scouting? Is there variation in clone susceptibility?

Untreated Imidacloprid

Natural insect pressure

Larvae class counts, index scoring of **defoliation**, multispectral measurements taken on a weekly basis

Dr. Silvia Rondon

Can we use UAV for remote scouting? Is there variation in clone susceptibility?

Untreated Imidacloprid

Natural insect pressure

Larvae class counts, index scoring of **defoliation**, multispectral measurements taken on a weekly basis

Germplasm evaluated (10 clones):

High acreage russets/breeding lines:

Alturus, Castle Russet, Clearwater Russet, Payette Russet, Russet Norkotah, Russet Burbank

Experimental clones:

Dakota Diamond (Thompson, NDSU), Echo Russet (Sathuvalli, OSU), F14085 (De Koeyer, AAFC)

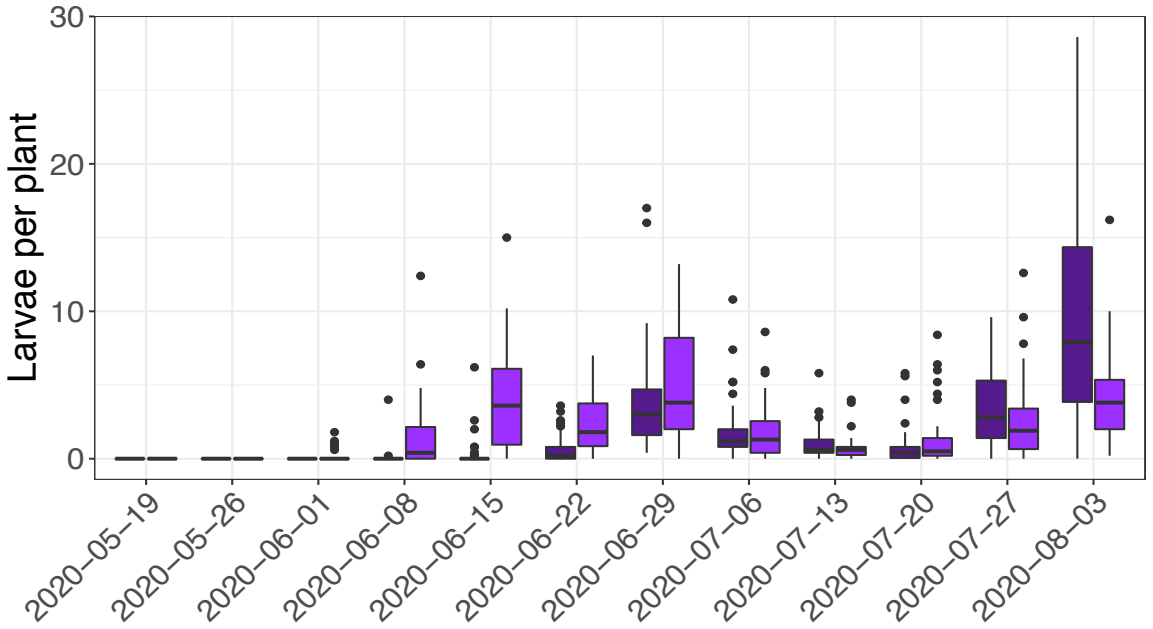
Reported susceptible:

Shepody

Planted on April 23rd 2020 at HAREC (Hermiston, OR)

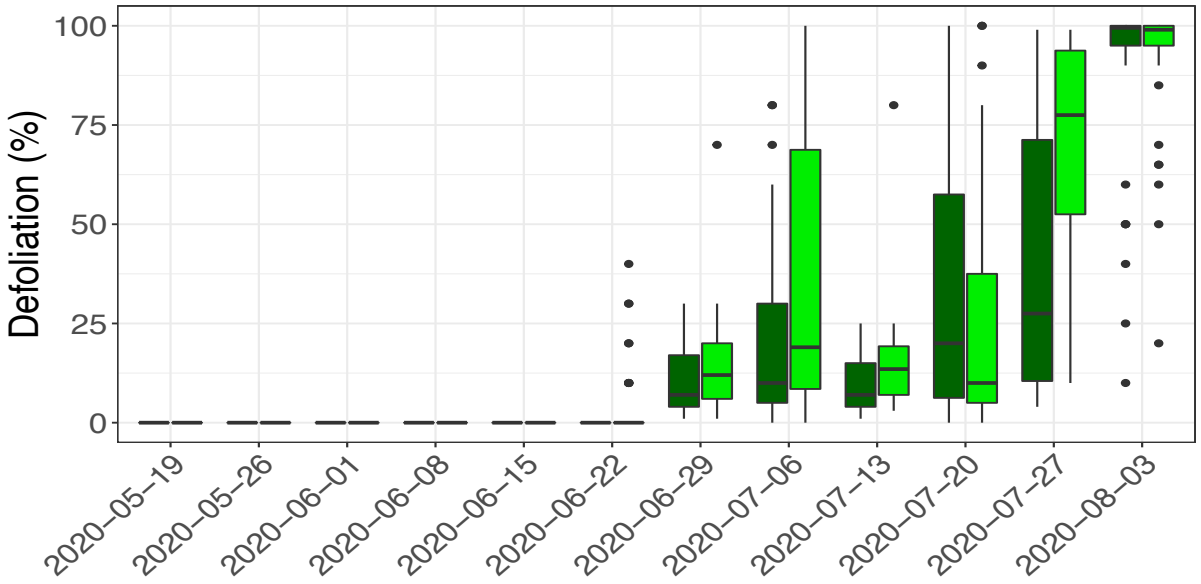
Dr. Silvia Rondon

Larvae counts



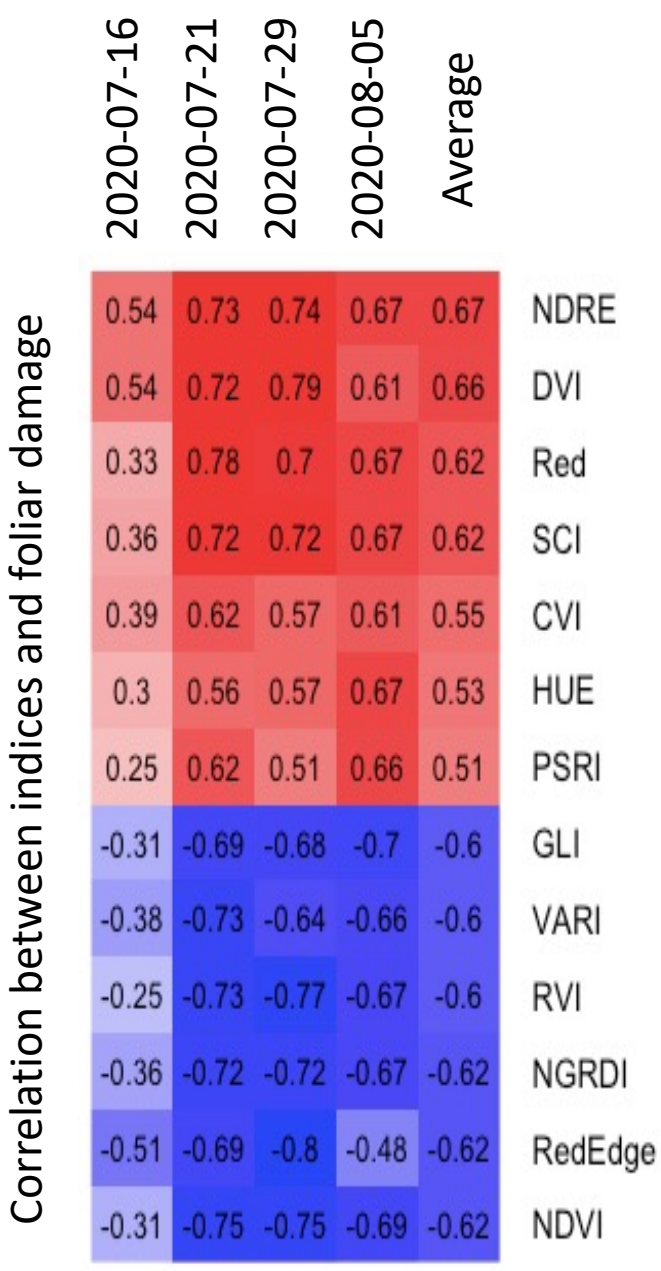
6-7 weeks post planting

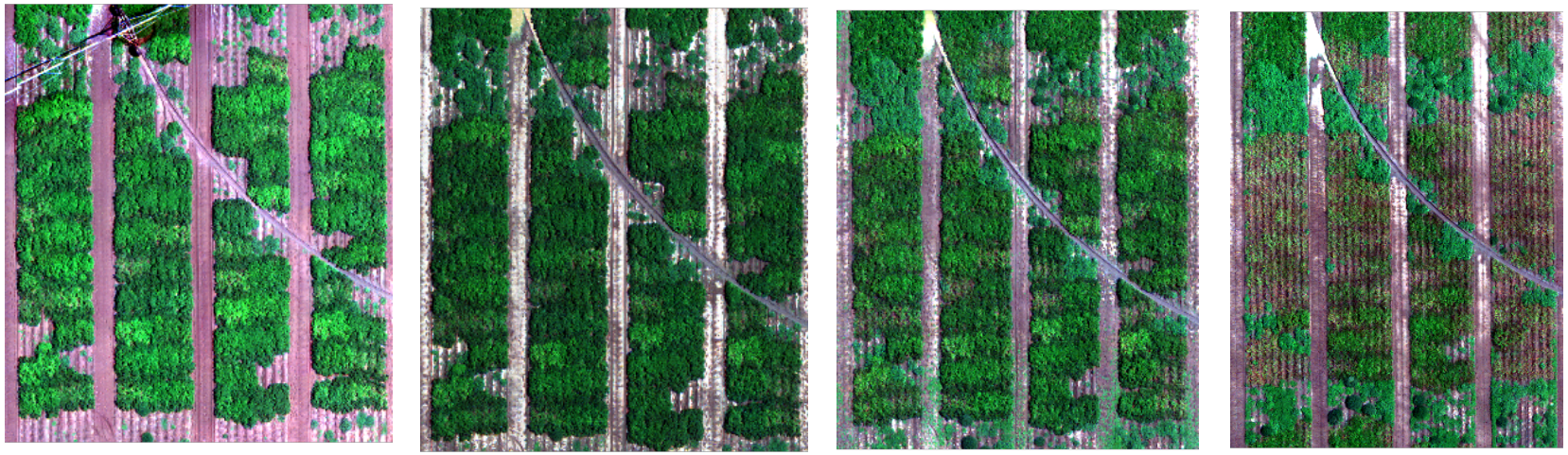
Defoliation

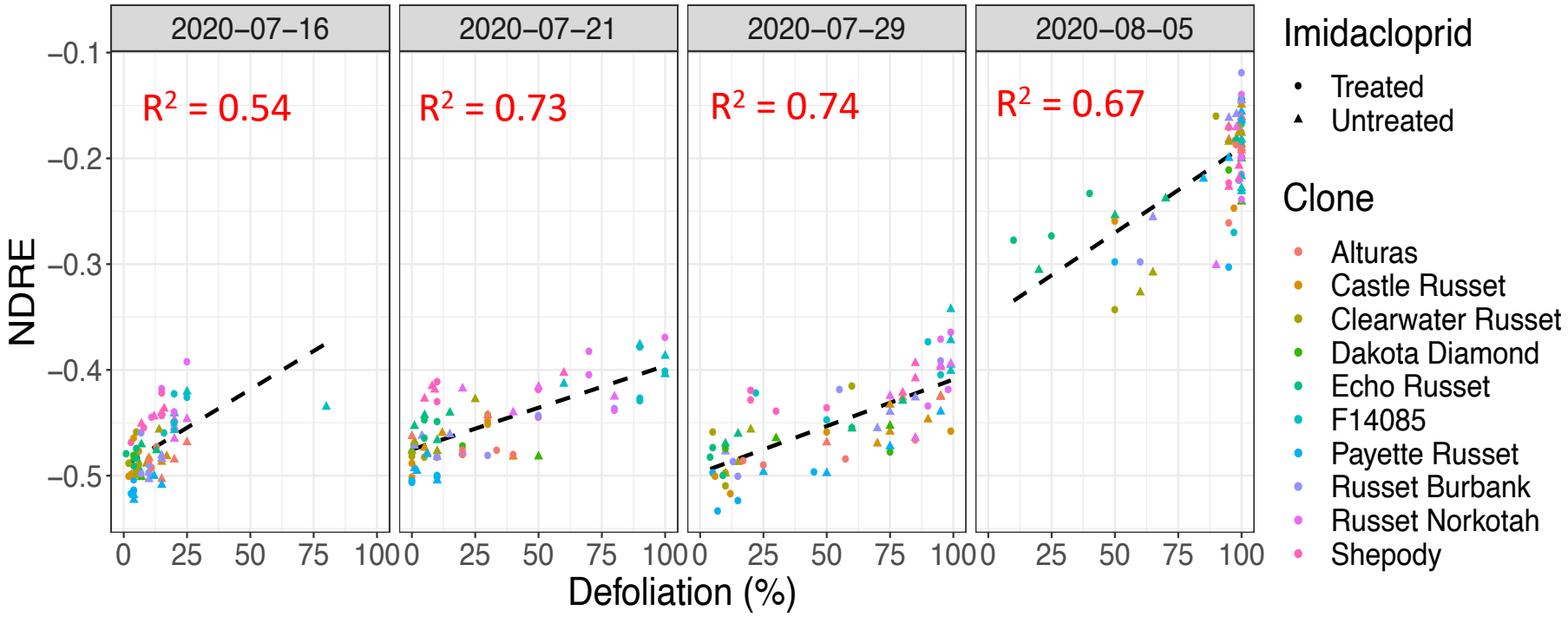


9-10 weeks post planting

Dr. Silvia Rondon


Correlation between indices and foliar damage
2020-07-16
2020-07-21
2020-07-29
2020-08-05
Average
0.54 0.73 0.74 0.67 0.67 NDRE
0.54 0.72 0.79 0.61 0.66 DVI
0.33 0.78 0.7 0.67 0.62 Red
0.36 0.72 0.72 0.67 0.62 SCI
0.39 0.62 0.57 0.61 0.55 CVI
0.3 0.56 0.57 0.67 0.53 HUE
0.25 0.62 0.51 0.66 0.51 PSRI
-0.31 -0.69 -0.68 -0.7 -0.6 GLI
-0.38 -0.73 -0.64 -0.66 -0.6 VARI
-0.25 -0.73 -0.77 -0.67 -0.6 RVI
-0.36 -0.72 -0.72 -0.67 -0.62 NGRDI
-0.51 -0.69 -0.8 -0.48 -0.62 RedEdge
-0.31 -0.75 -0.75 -0.69 -0.62 NDVI

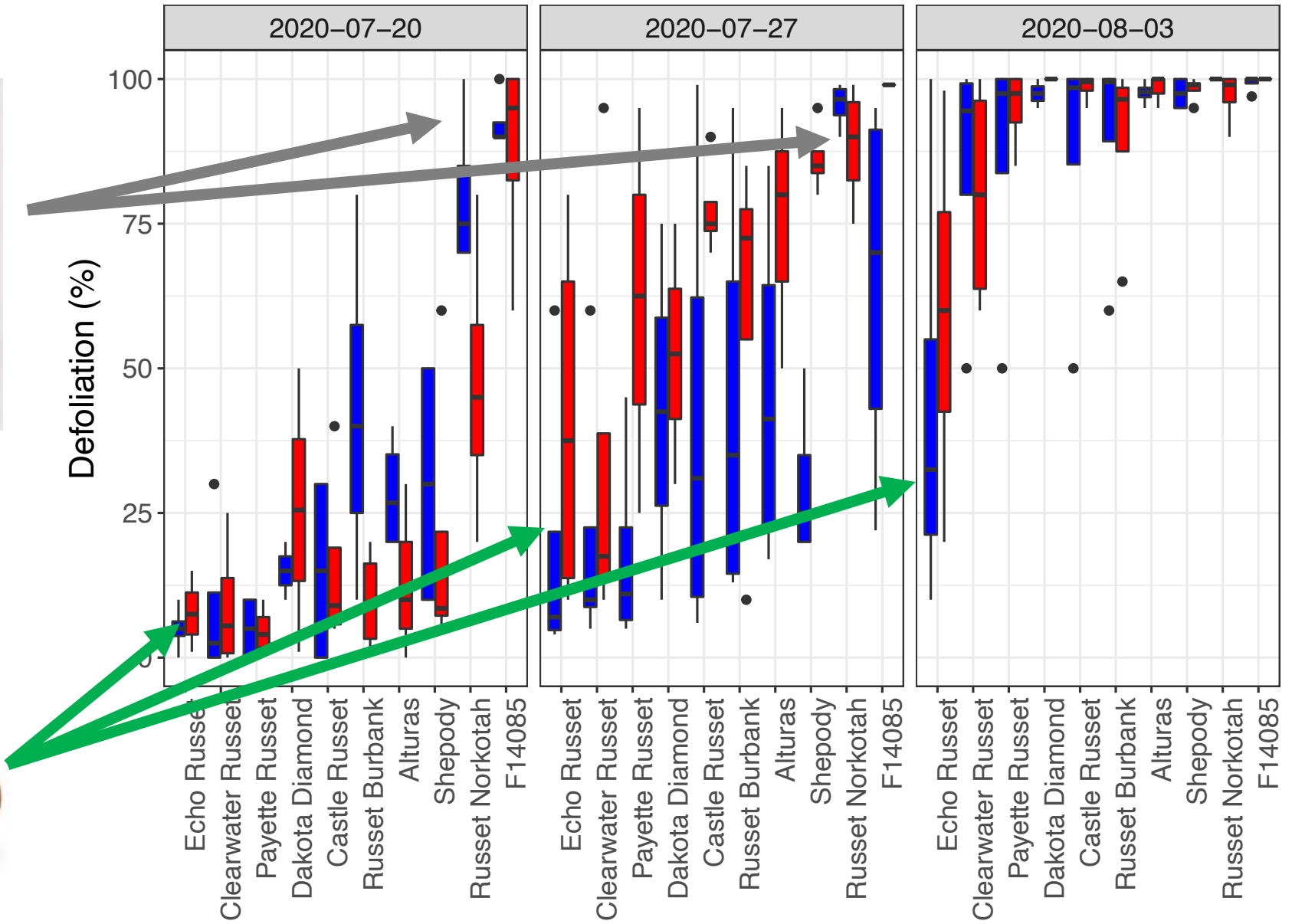

2020-07-16
2020-07-21
2020-07-29
2020-08-05


2020–07–16
2020–07–21
2020–07–29
2020–08–05
R² = 0.54
R² = 0.73
R² = 0.74
R² = 0.67
NDRE
−0.1
−0.2
−0.3
−0.4
−0.5
0 25 50 75 100
Defoliation (%)
Imidacloprid
Treated
Untreated
Clone
Alturas
Castle Russet
Clearwater Russet
Dakota Diamond
Echo Russet
F14085
Payette Russet
Russet Burbank
Russet Norkotah
Shepody

Germplasm performance

Russet Norkotah
(susceptible)

Echo Russet
(tolerant)



What have we learned from this study?

Multispectral measurement may provide a reasonably proxy measurement for defoliation

Ground truth data is essential

Provide throughput needed for breeding applications

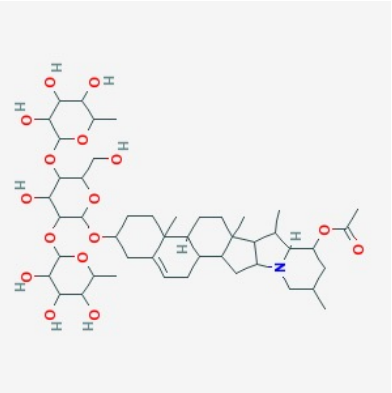
Provides very nice spatiotemporal documentation of field experiments

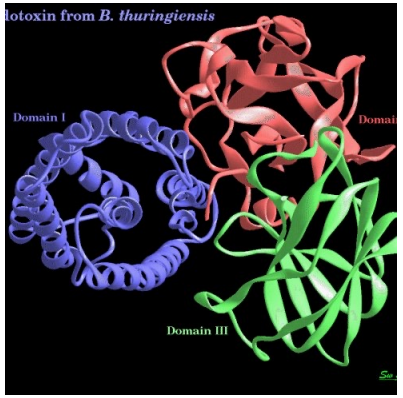
More work is needed to evaluate genotype, temporal, seasonal, and management effects

Dr. Silvia Rondon

New strategies to attack CPB

UAV based field scouting





Host plant resistance

Natural resistance

Transgenic resistance

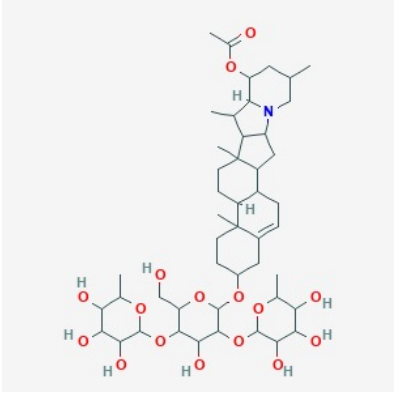
THERE IS NO STRONG NATURAL RESISTANCE TO CPB IN DOMESTICATED POTATO

Insect resistance mechanisms in *Solanaceous* plants

Chemical

Solanum chachoense

Leptine glycoalkaloids

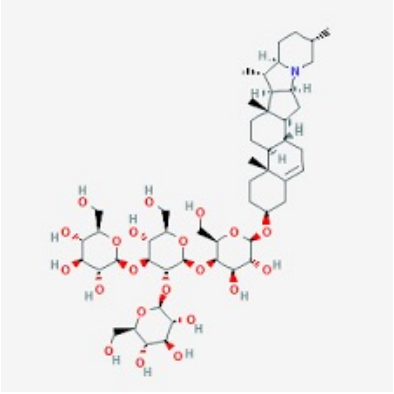


Feeding toxin for insects

Heavily studied in USDA8380-1

Solanum brevicaule (as S. oplocense)

Dehydrocommersonine



Identified as a metabolite associated with resistance in *S. oplocense*

Physical and chemical

Solanum berthaultii

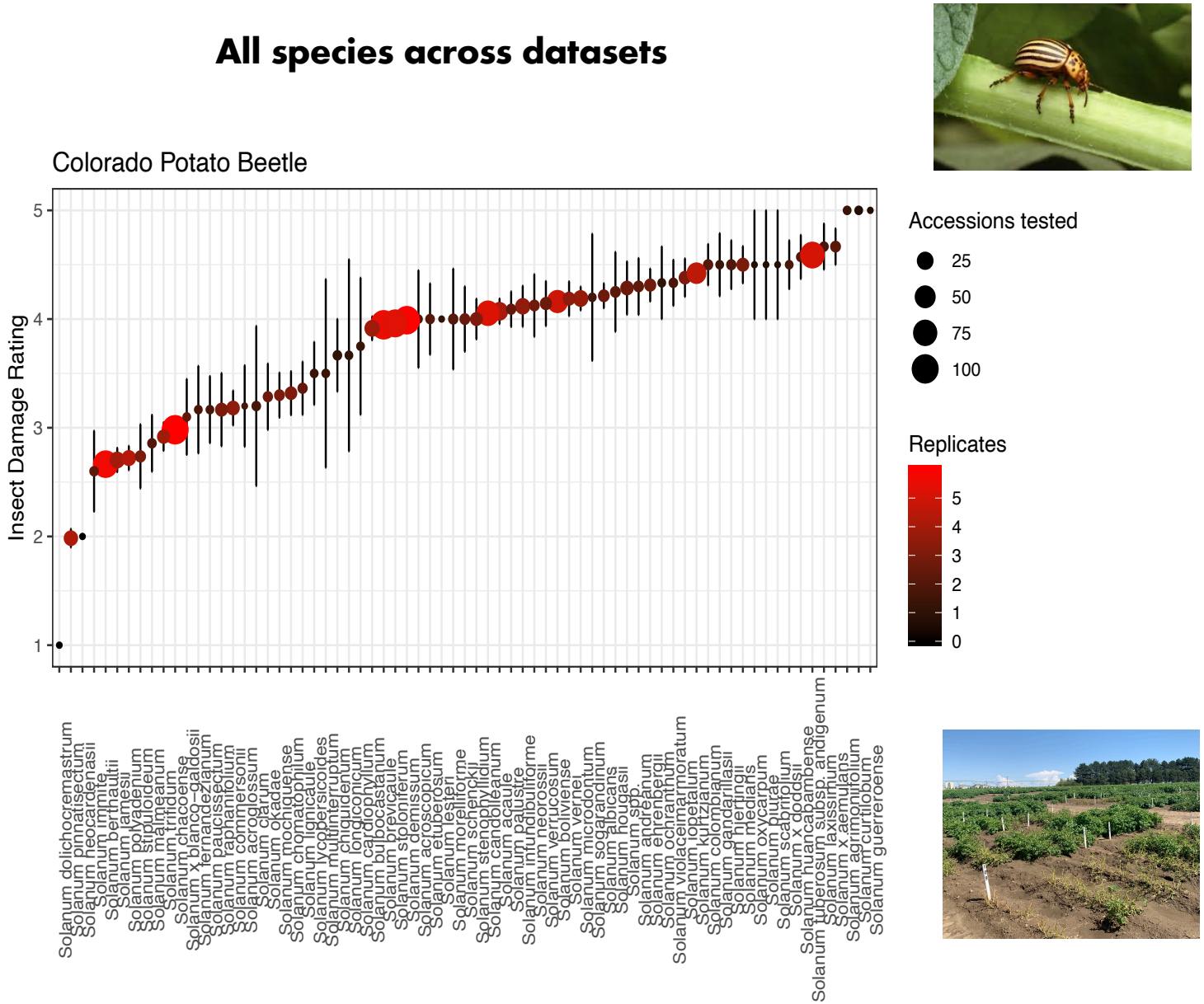
S. berthaultii most studied

Two trichome types

Type A: Smaller, contain PPO

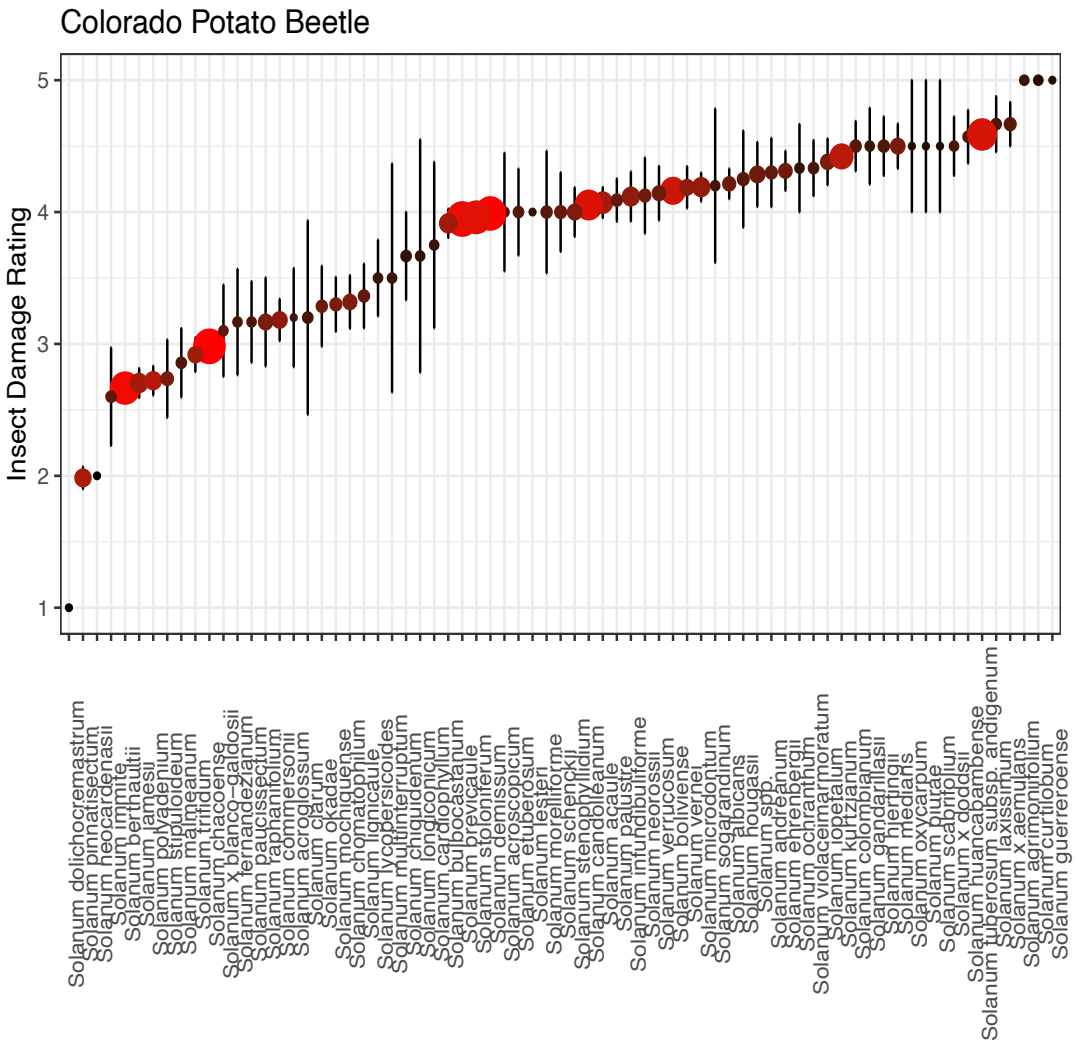
Type B: Larger, contain sucrose esters

What can we learn from historical data in GRIN?



What can we learn from historical data in GRIN?

All species across datasets



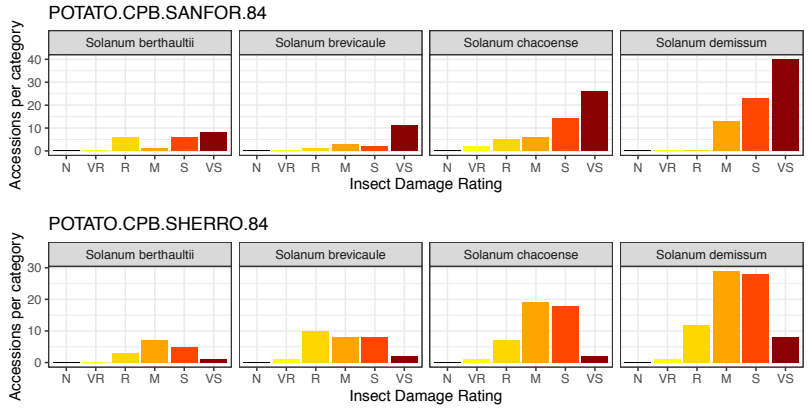
Accessions tested

- 25
- 50
- 75
- 100

Replicates

5 4 3 2 1 0

Value distribution within experiments



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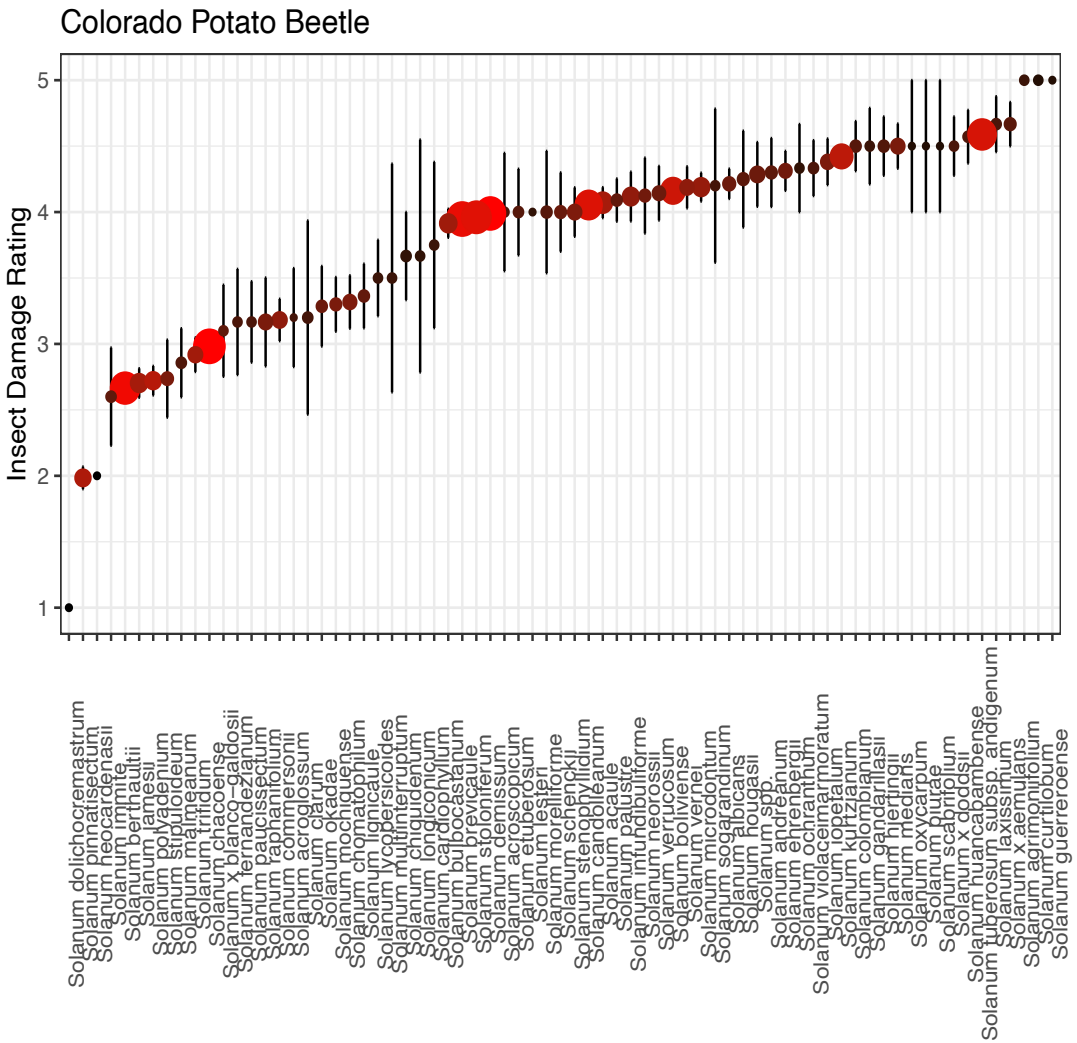

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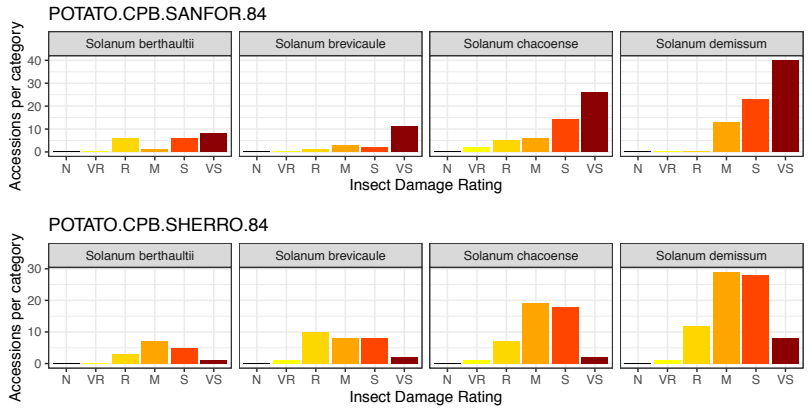
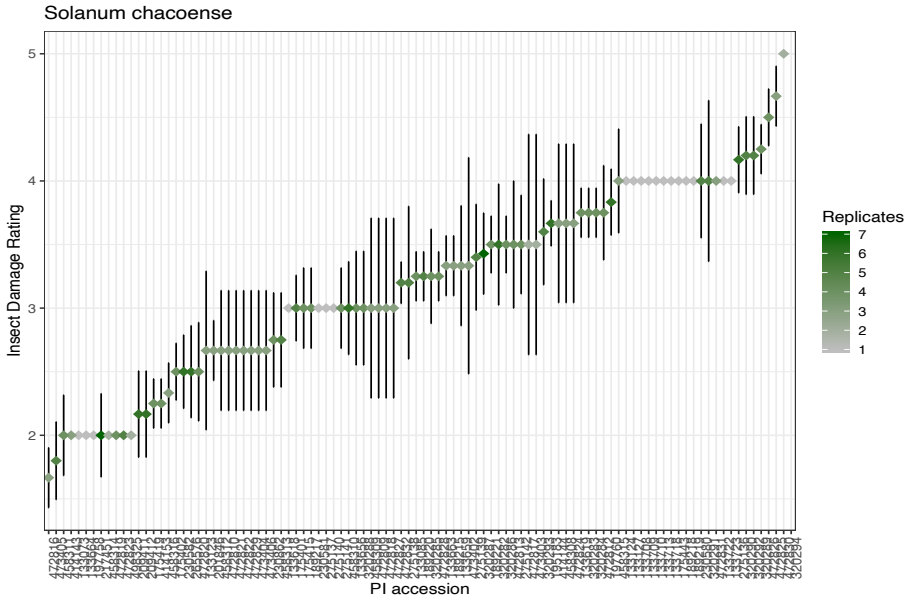
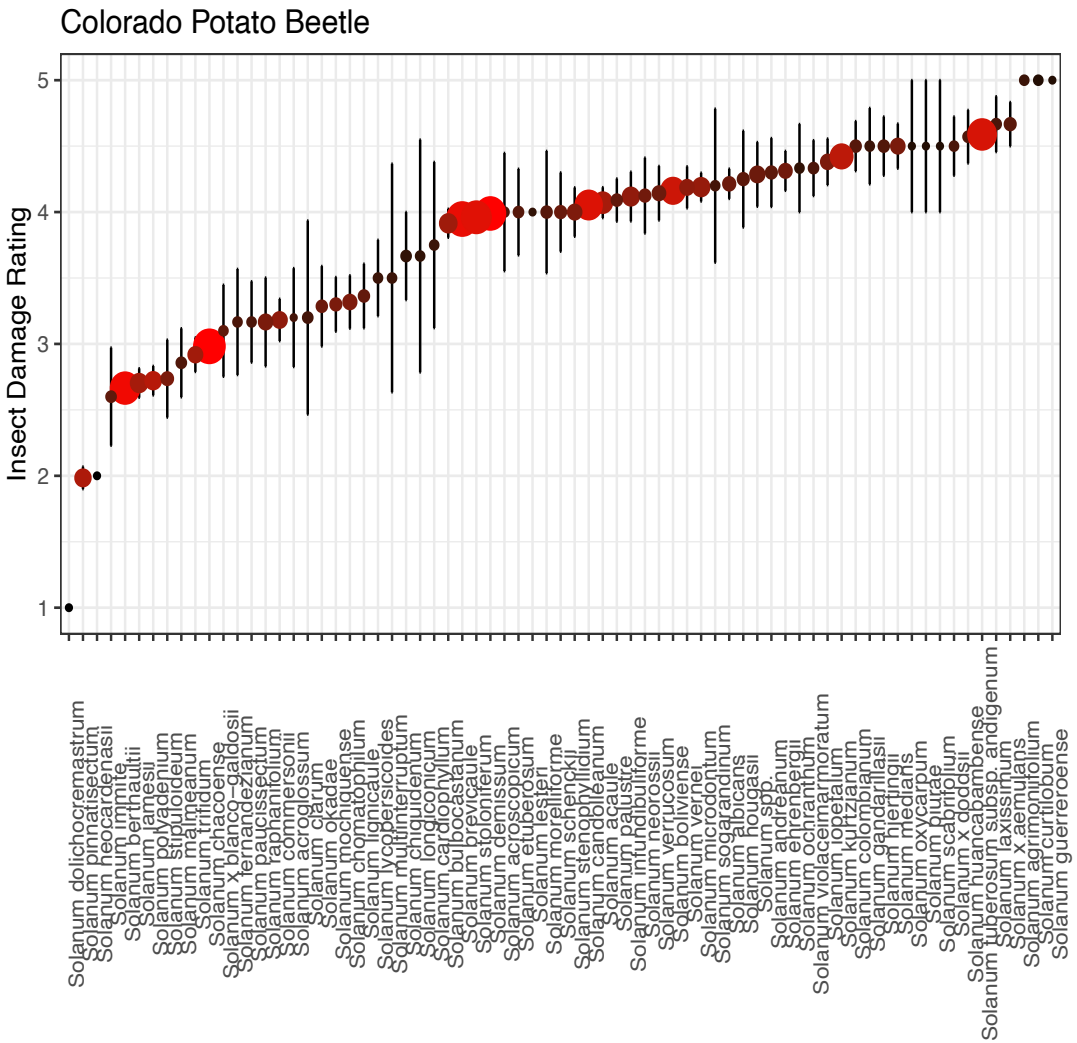


Value distribution across accessions, within species



What can we learn from historical data in GRIN?

All species across datasets



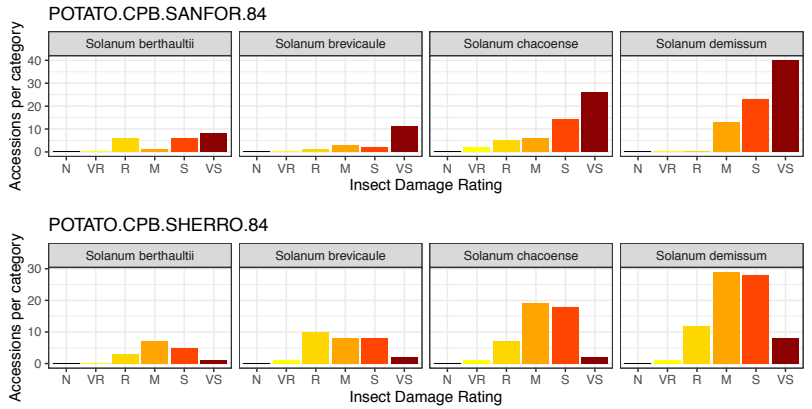
Accessions tested

- 25
- 50
- 75
- 100

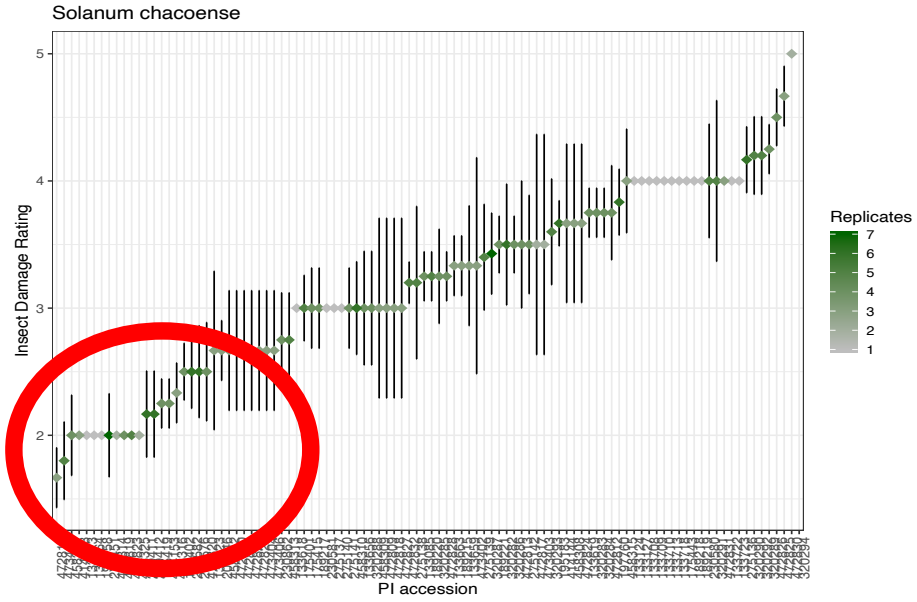
Replicates

5
4
3
2
1
0

Value distribution within experiments



Value distribution across accessions, within species

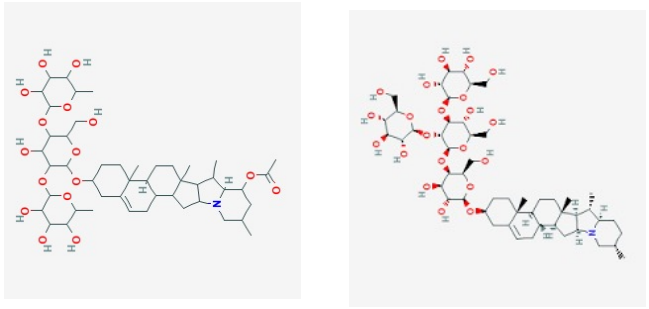


Can we develop resistant varieties?

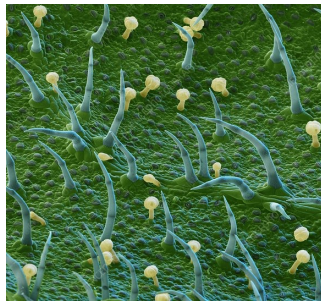
We've acquired 94 different accessions from 32 different species that have been reported as CPB resistant in >1 study

First step is to confirm resistance and assess mechanism

Chemical



Structural

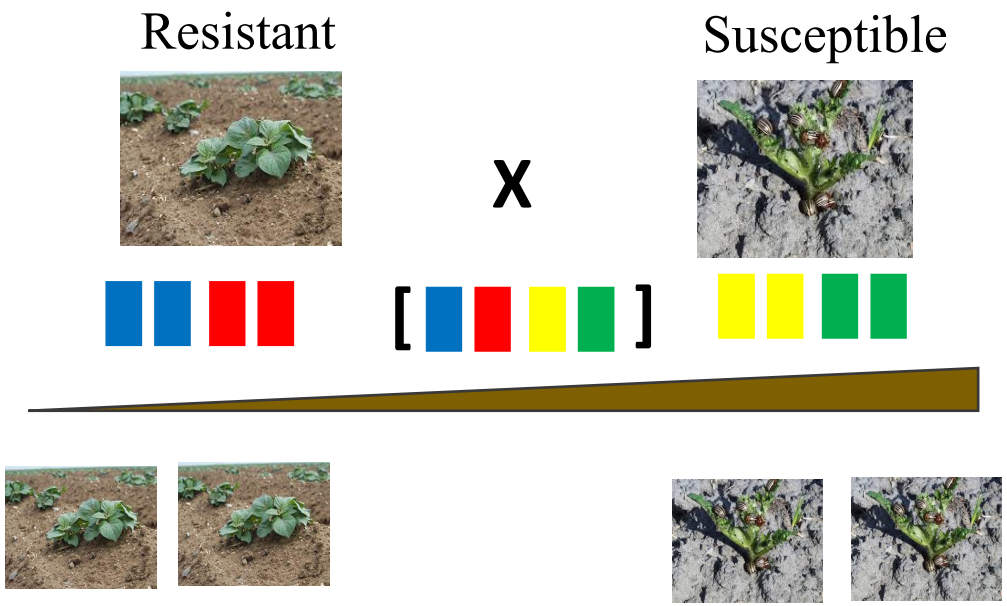


Other?

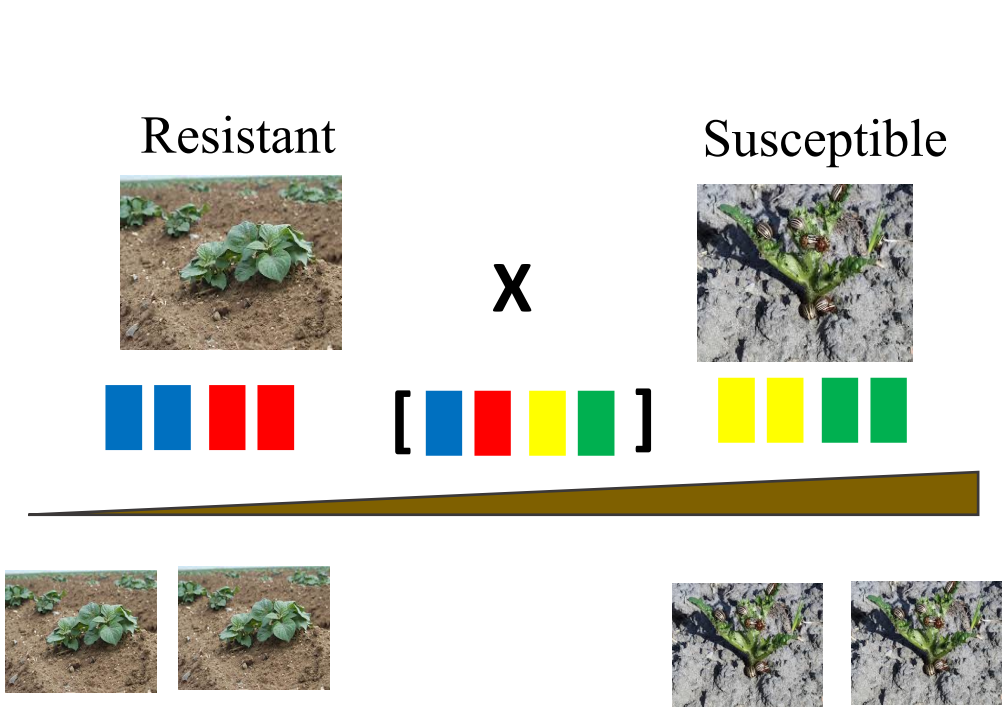
Will cross these accessions to self-compatible diploid parents (M6, Yoshi6, US-W4, etc.)

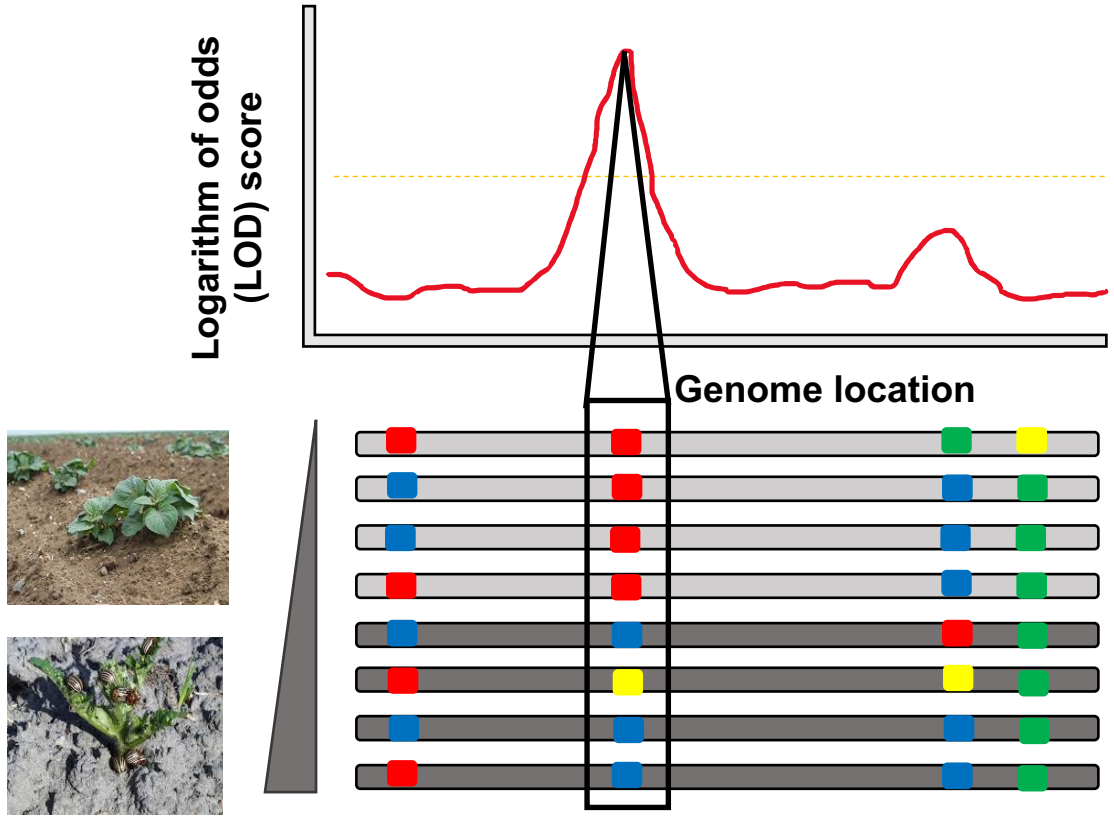
Photo credit: cultivariable.com

Genetic mapping and marker assisted selection



Genetic mapping and marker assisted selection





Mapping of quantitative trait loci (QTL)

Develop markers and apply marker assisted selection > 1 trait

Pest resistant

Elite (with high combining ability)

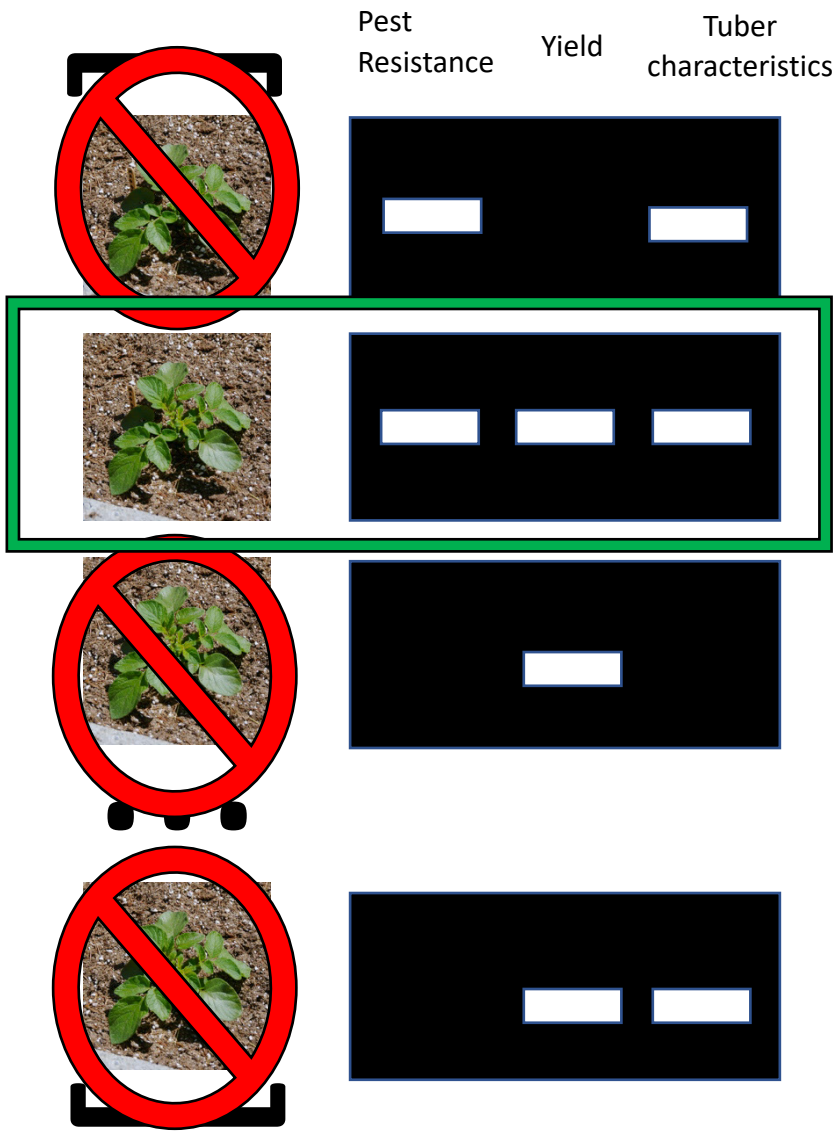
X

Mini-tubers

Select here before field trial

Field trial

Did it work?



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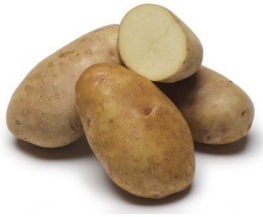
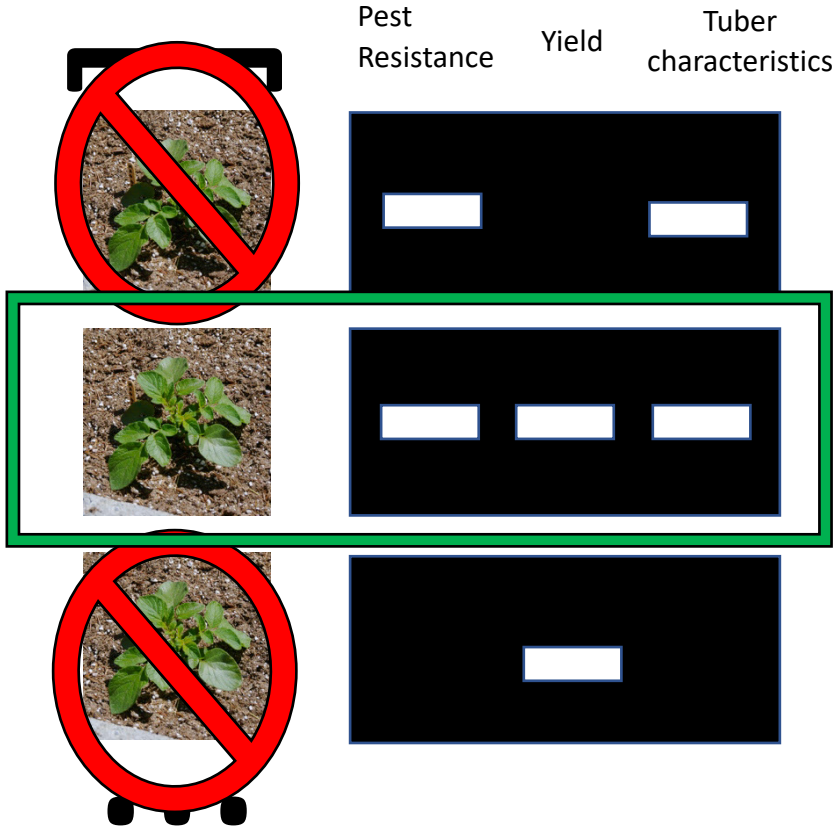


X

Mini-tubers

Field trial



Select here before field trial

Did it work?

Focus on introgression of traits and development of diploid specialty potatoes for the organic market

Transgenic potatoes

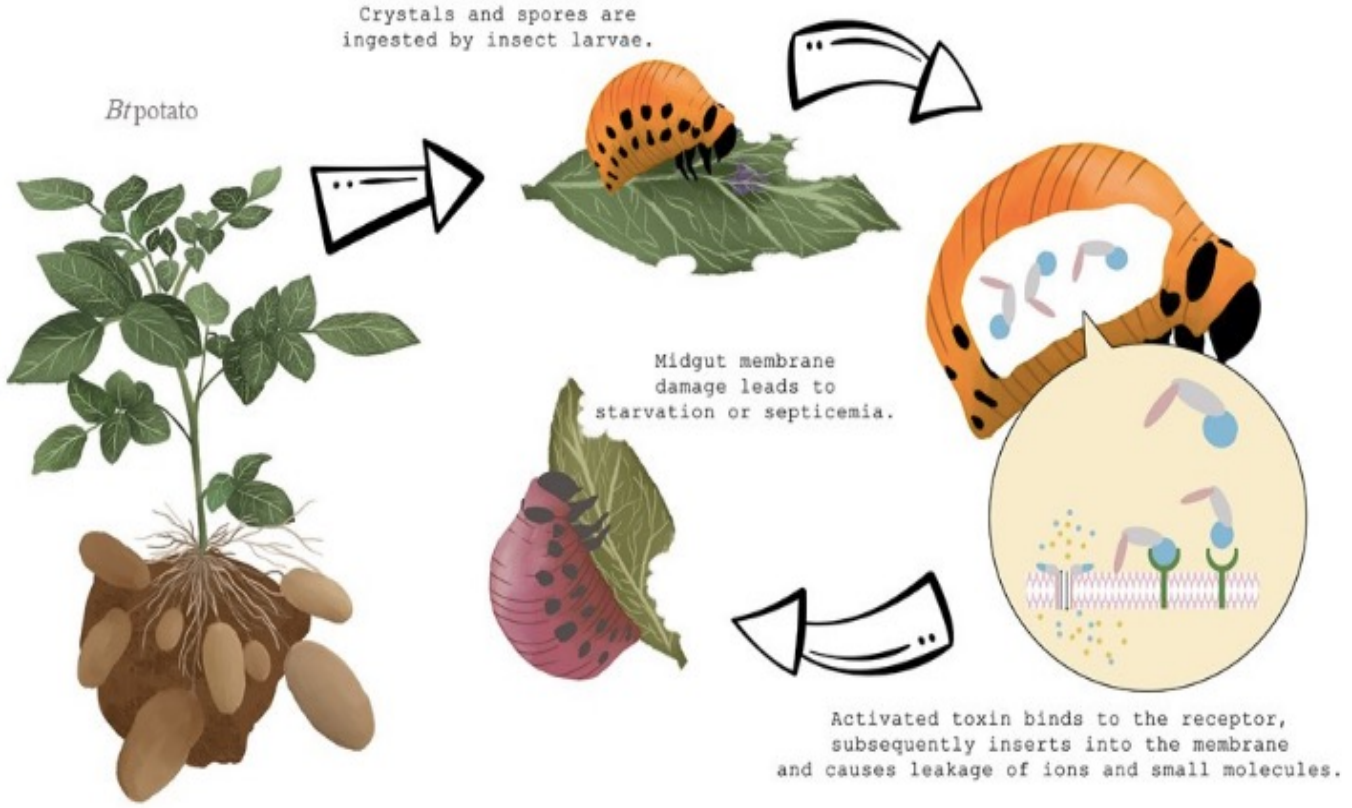
Transgenic potatoes

Monsanto developed one of the first transgenic potatoes that produced *Bacillus thuringiensis* (Bt) toxin

Potato could produce Cry3A protein (insect toxin)

Extremely effective insect control, non-toxic to humans

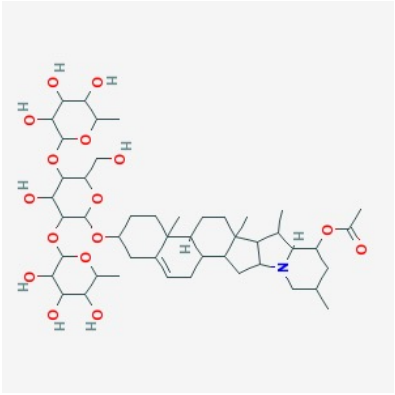
Available from 1996 - 2001

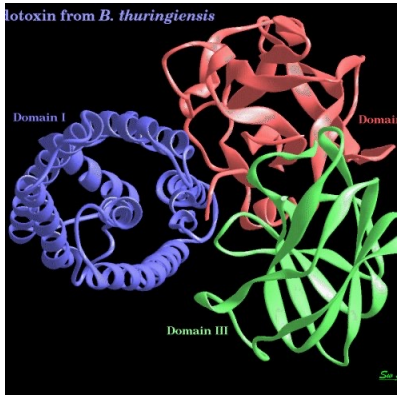


Removed from market due to lack of acceptance of GMO technology

New strategies to attack CPB

UAV based field scouting



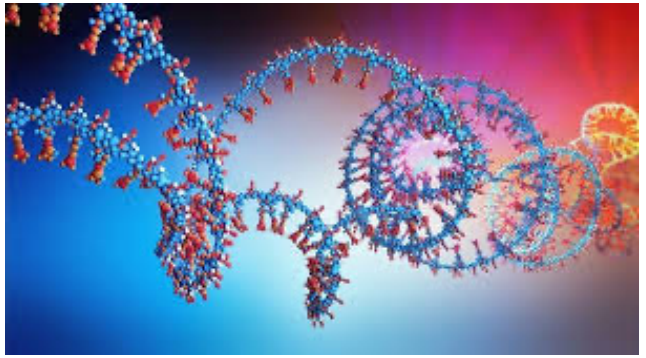


Host plant resistance

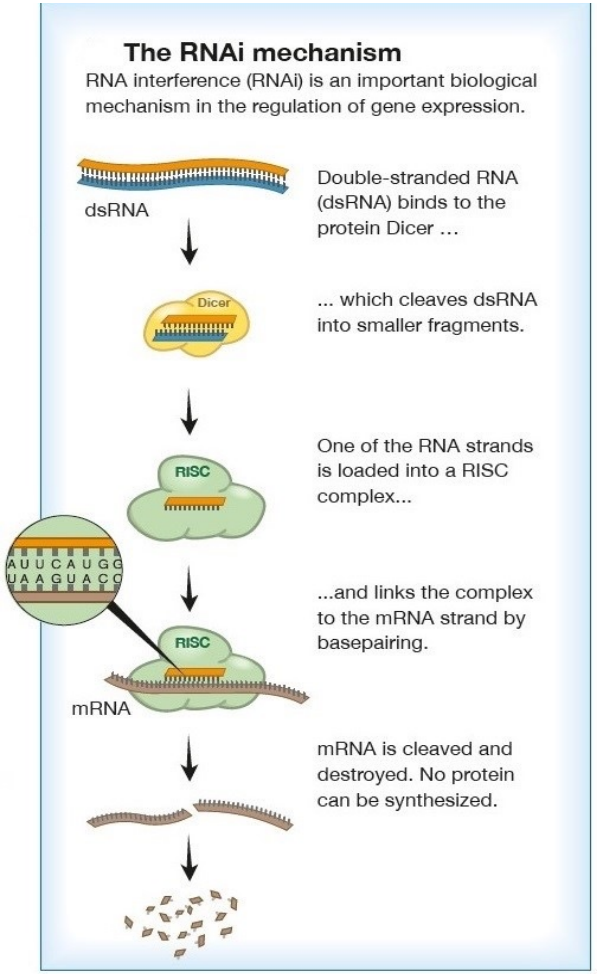
Natural resistance

Transgenic resistance

RNA interference (RNAi) based pesticides

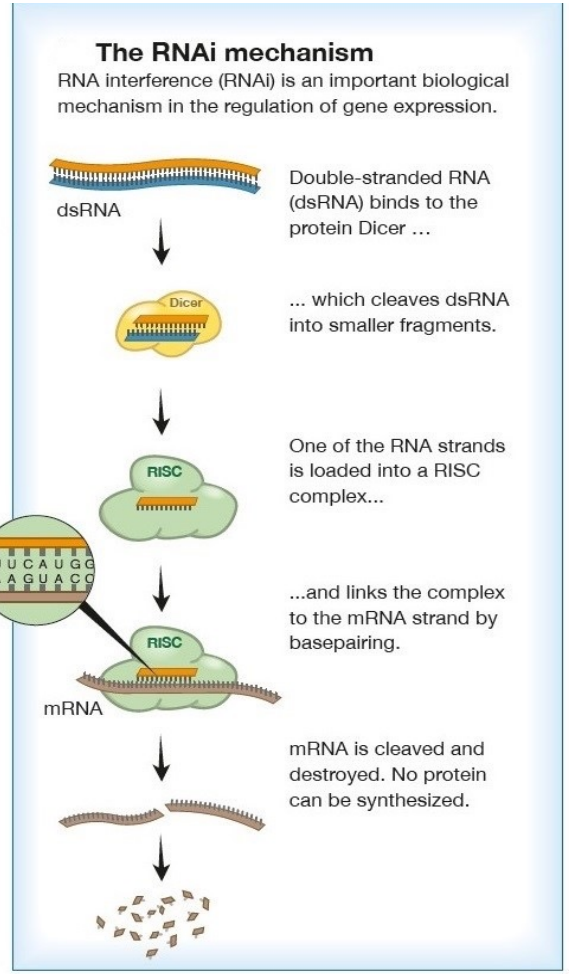


RNAi mediated control of CPB



RNAi is an ancient molecular process cells use to fight against viruses

RNAi mediated control of CPB



Design dsRNA molecule to target essential CPB gene/transcript/protein (many targets potentially, very specific)

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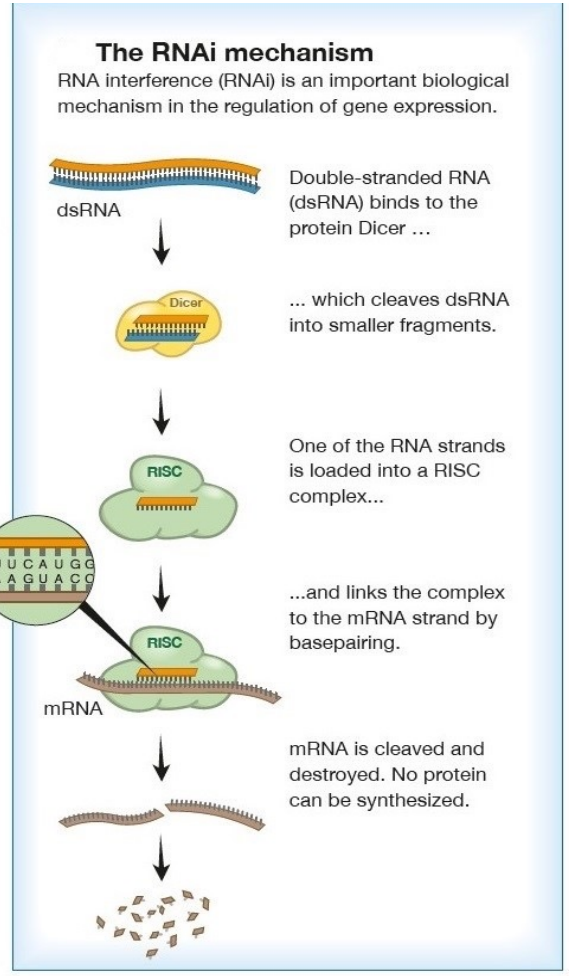

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Shut off essential gene

CPB dies

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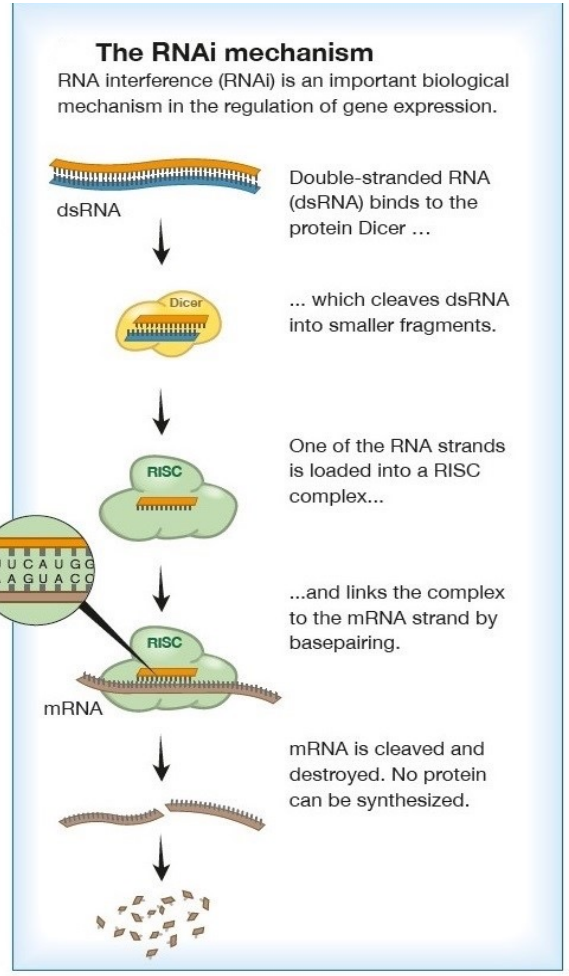

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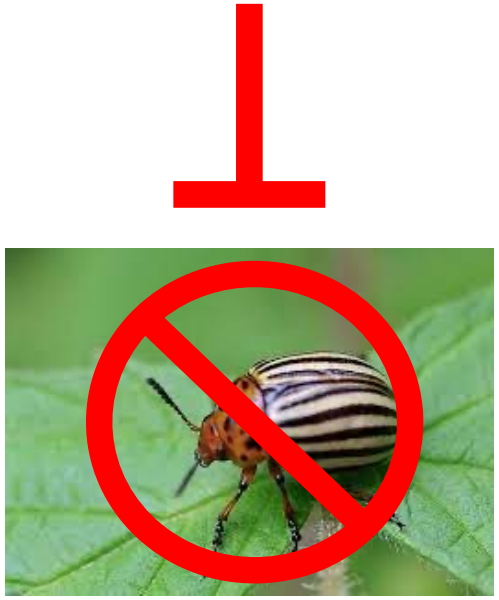
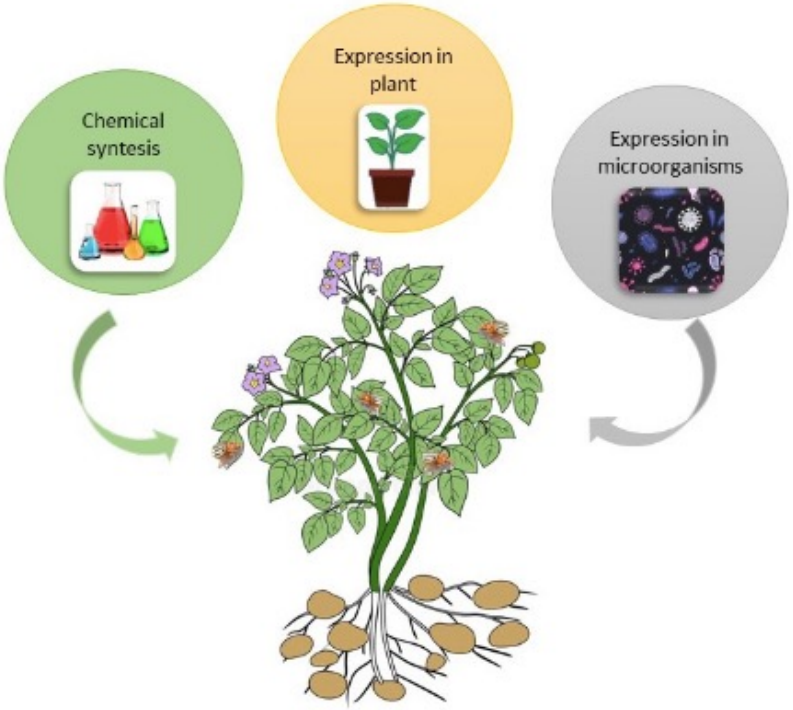


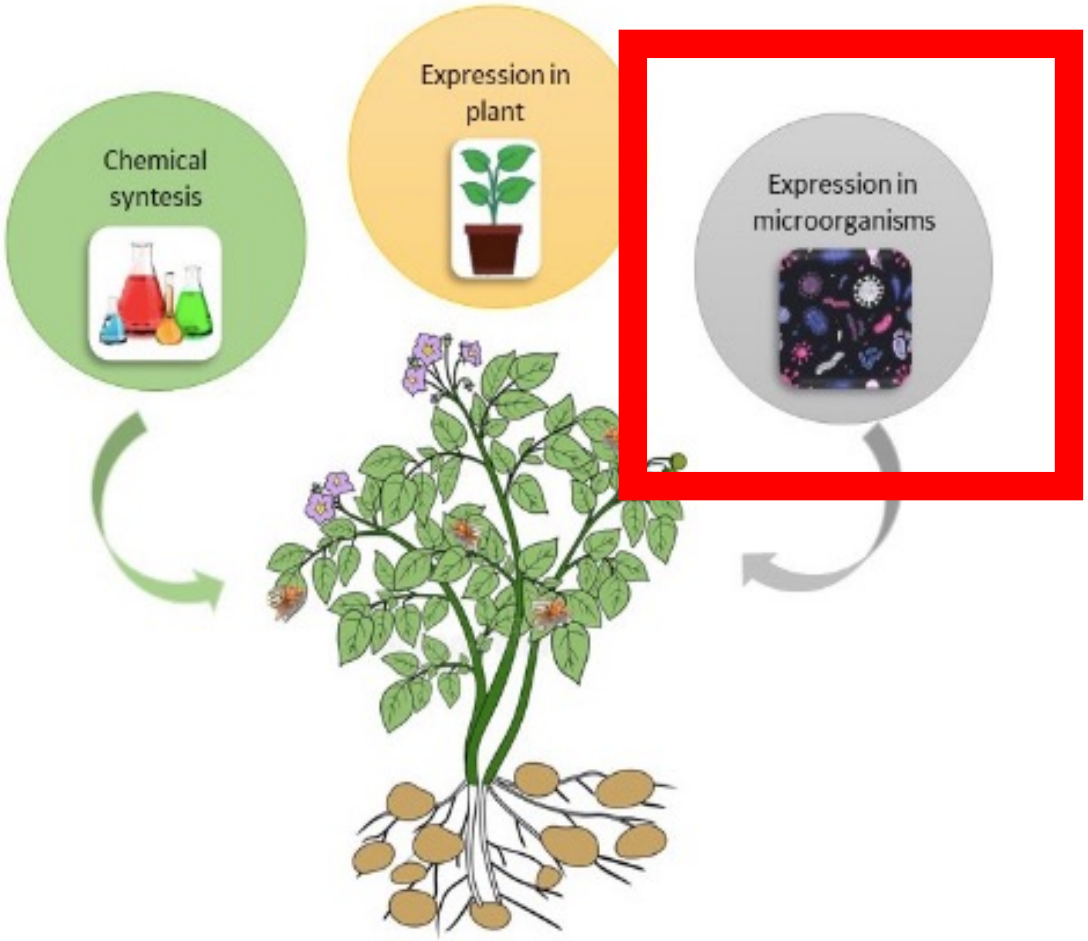
Shut off essential gene
CPB dies



RNAi is an ancient molecular process cells use to fight against viruses

Difficult part is how to deliver dsRNA to the insect

RNAi mediated control of CPB

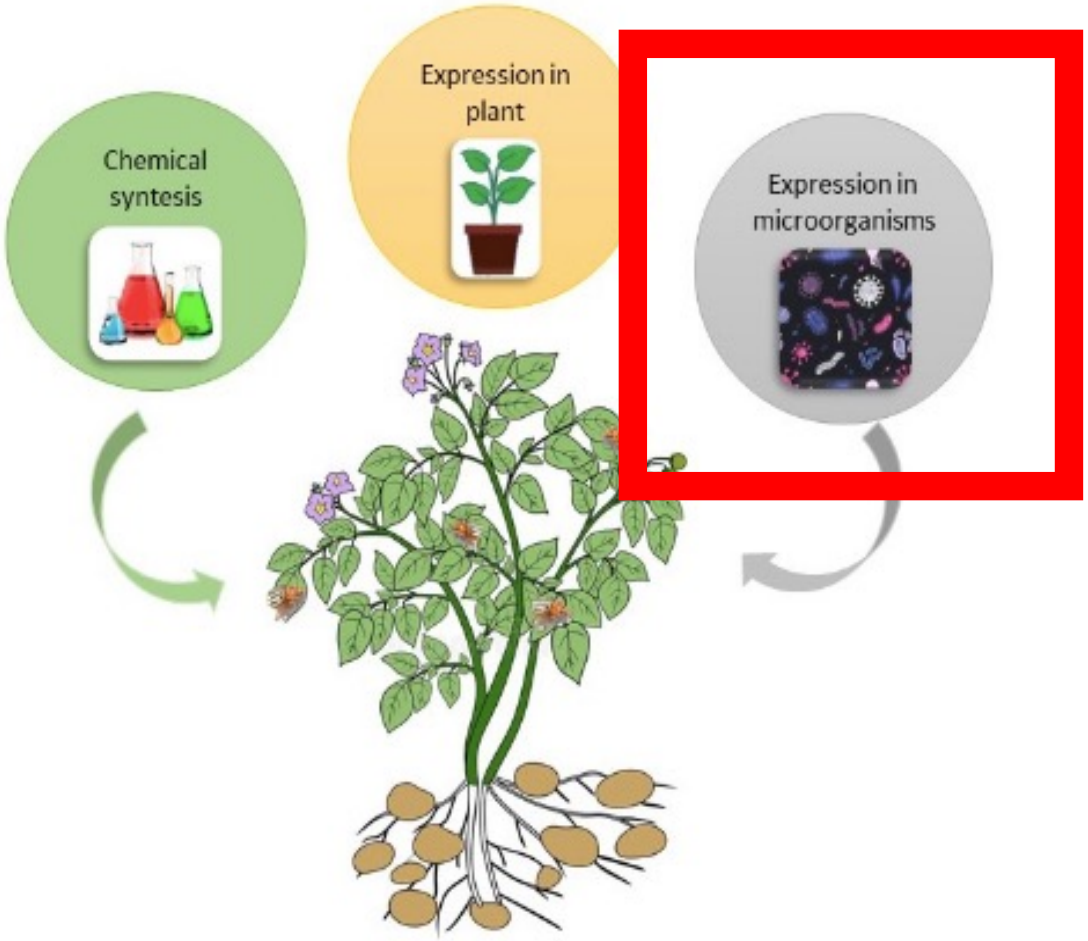


Use of yeast delivery system

Ease of production scale up

RENAISSANCE BIOSCIENCE

RNAi mediated control of CPB



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Method is very CPB specific

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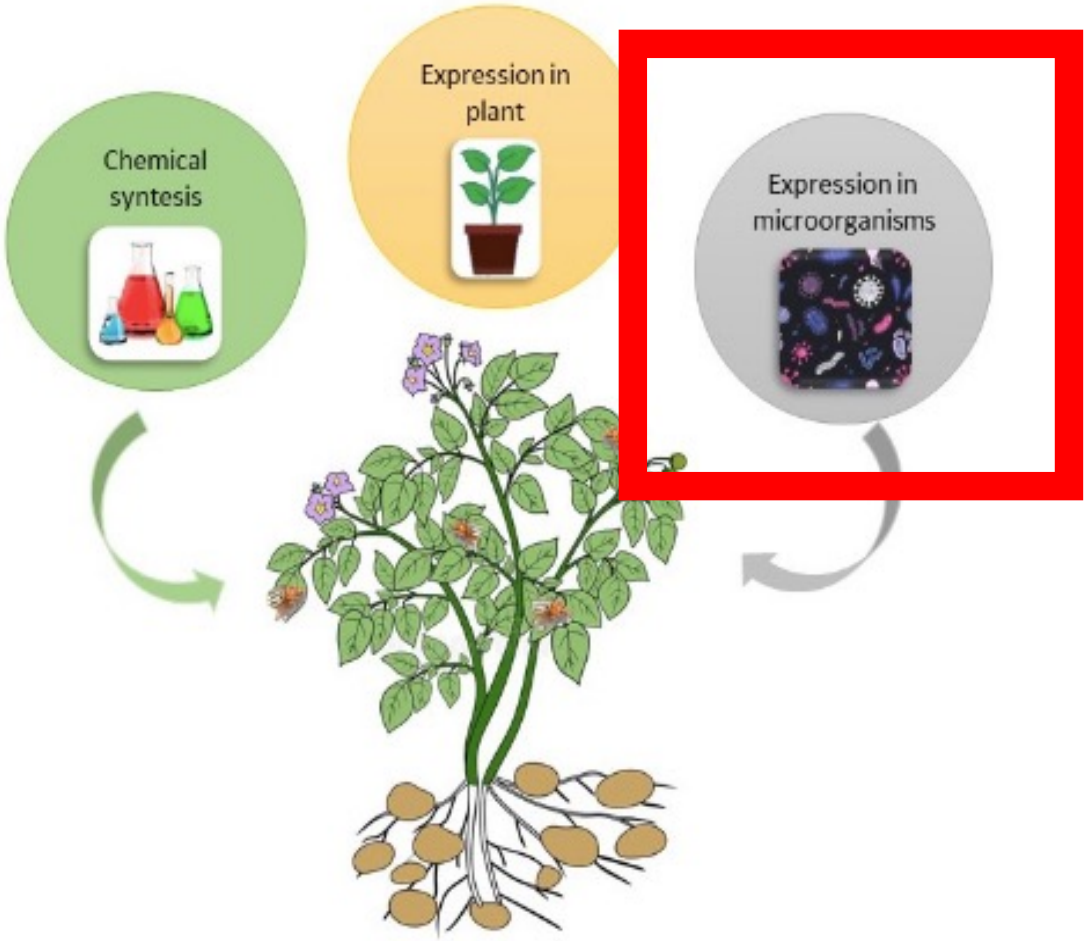

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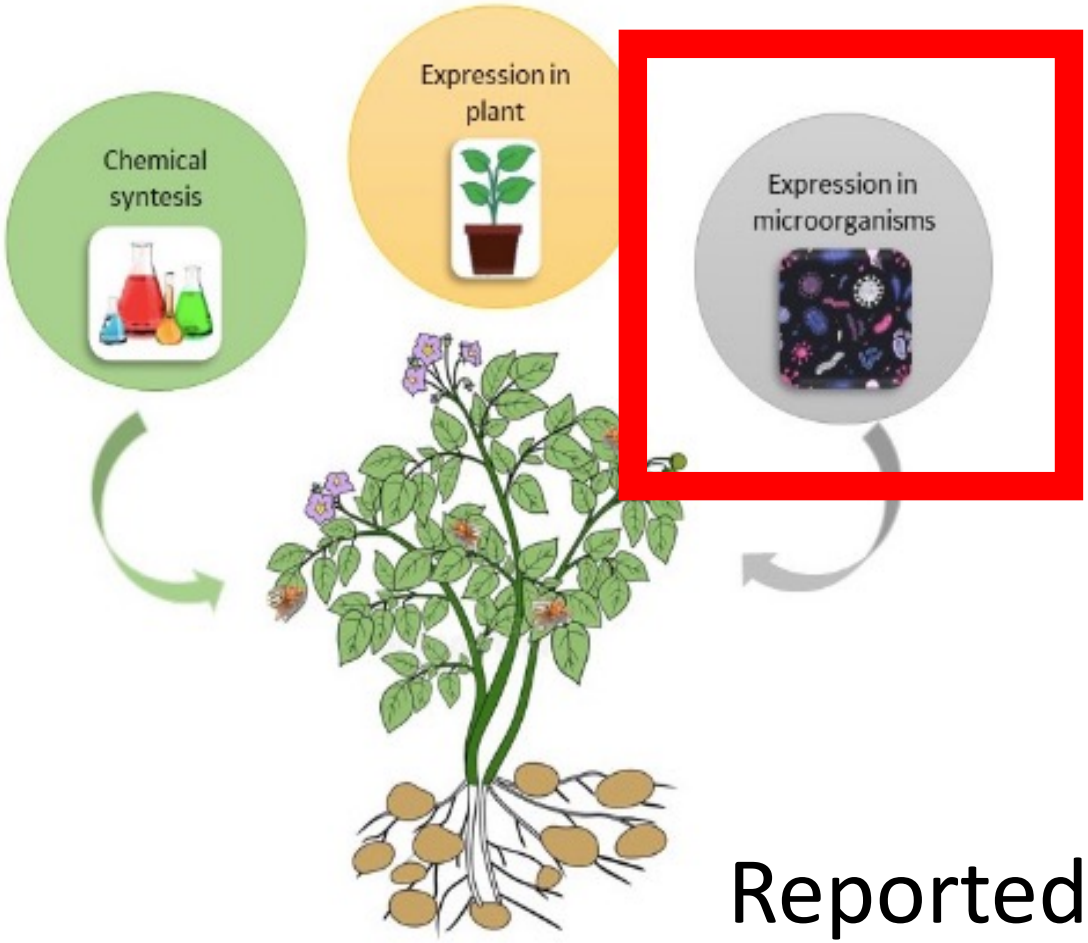

Use of yeast delivery system

Ease of production scale up

Method is very CPB specific

Can target >1 gene at a time

Reported to achieve 98% lethality against CPB larvae

RENAISSANCE BIOSCIENCE

Ultimate goal: Integrated Pest Management

Pesticide

Chemical insecticide

Biologicals

RNAi

Cultural

Crop rotation

Trap cropping

UAV scouting

Physical

Trenching

Mulch

Biological

Beneficials

Plant host resistance

NEW TECHNOLOGY IN RED

Questions? Comments?

<u>USDA-ARS Prosser</u>
Mr. Richard Quick
Mr. Esteban Calderon
Ms. Katelyn Greene
Mr. Moises Cohetzaltitla-Ponce
Dr. Roy Navarre
Ms. Launa Cimrhakl
Dr. Kylie Swisher-Grimm
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<u>University of Minnesota</u>
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<u>University of Wisconsin</u>
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<u>Washington State University</u>
Dr. Mark Pavek
Dr. Jake Blauer