RUTGERS

New Jersey Agricultural
Experiment Station

Biology and Management of the Annual Bluegrass Weevil

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Experiment Station

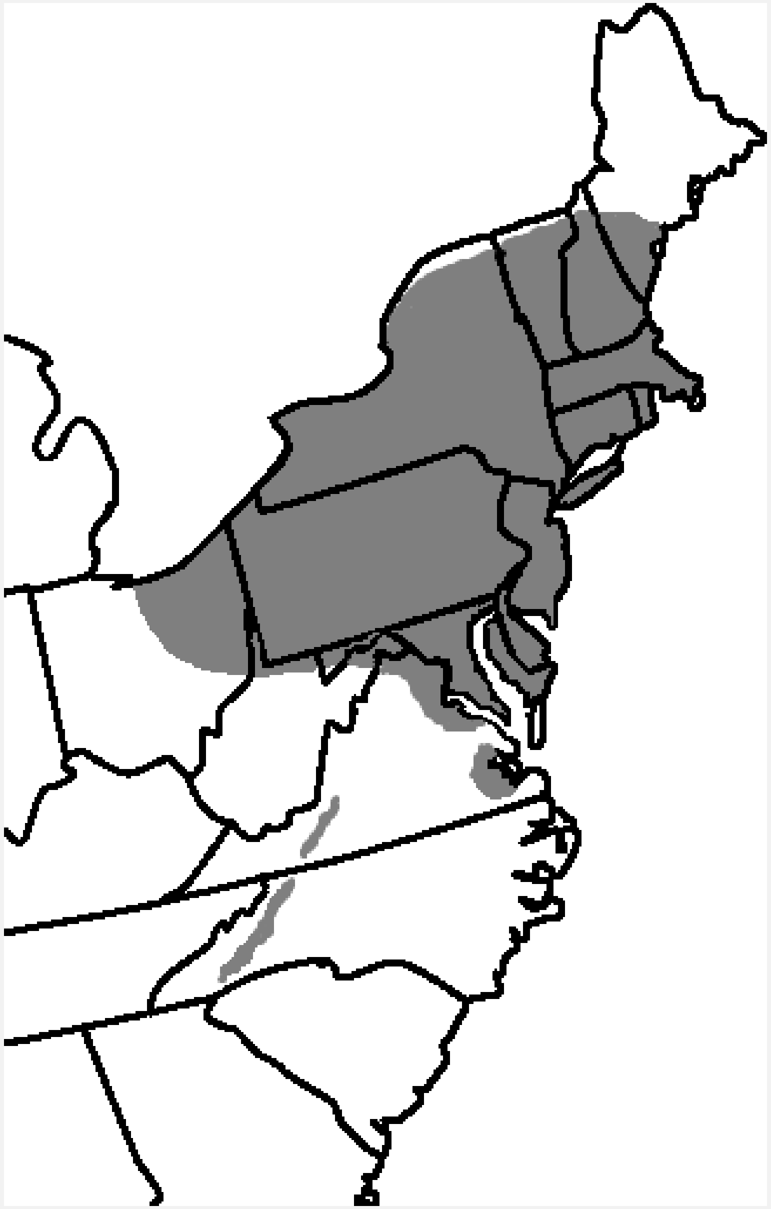
ABW Biology and Control

- **Biology, ecology, damage (3-24)**
- **Monitoring (25-37)**
- **Insecticide resistance (38-75)**
- **Sustainable management: non-resistant (76-92)**
- **Sustainable management: resistant (93-101)**
- **Biorationals (102-118)**

ABW Biology and Control

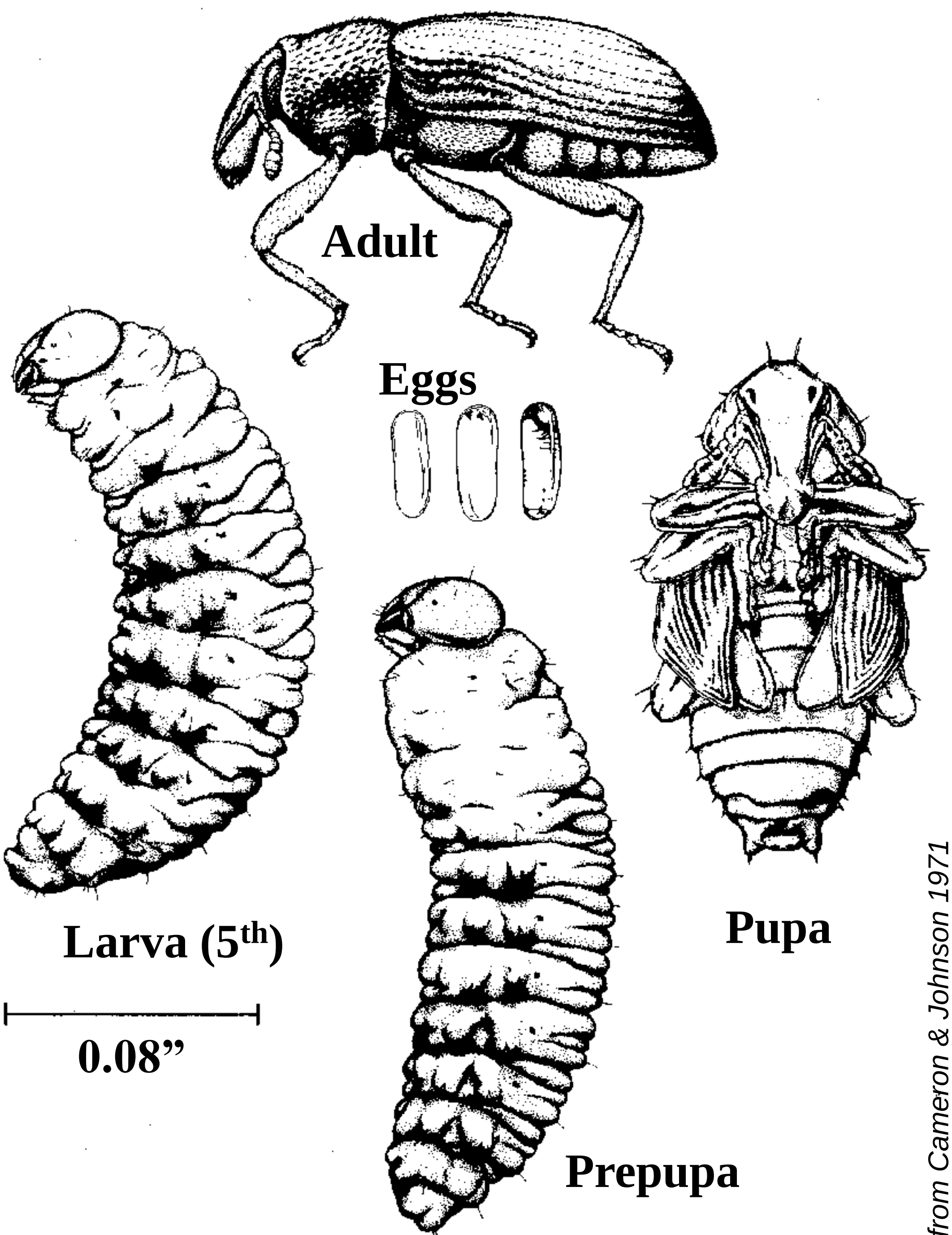
- **Biology, ecology, damage**
- Monitoring
- Insecticide resistance
- Sustainable management: non-resistant
- Sustainable management: resistant
- Biorationals

ABW



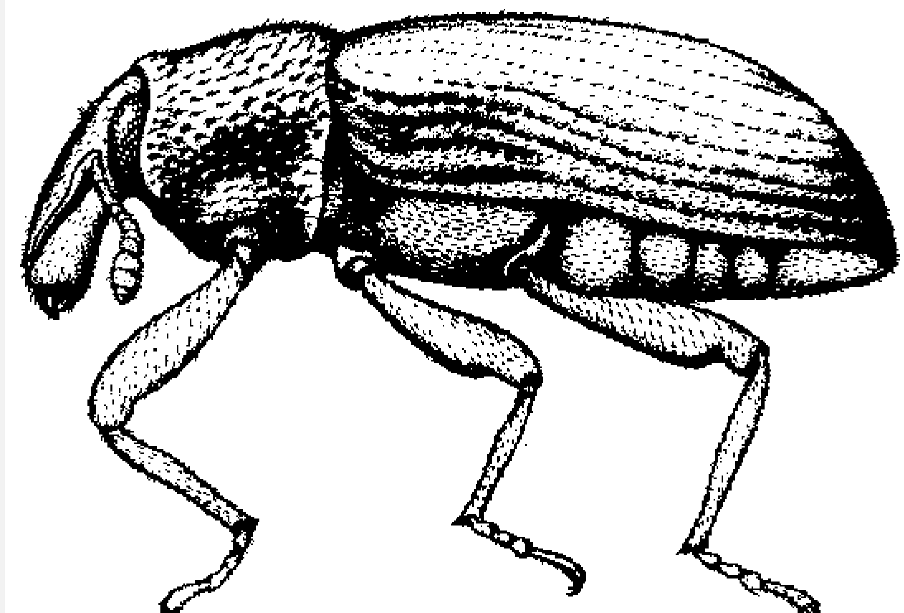
- Serious expanding pest of close-cut annual bluegrass
- Serious problems throughout NJ, NY, CT, PA, RI, MA, NH, VT, DE, MD.
- Also problems in parts of OH, ME, VA, ONT, QUE.

ABW Morphology



Adult

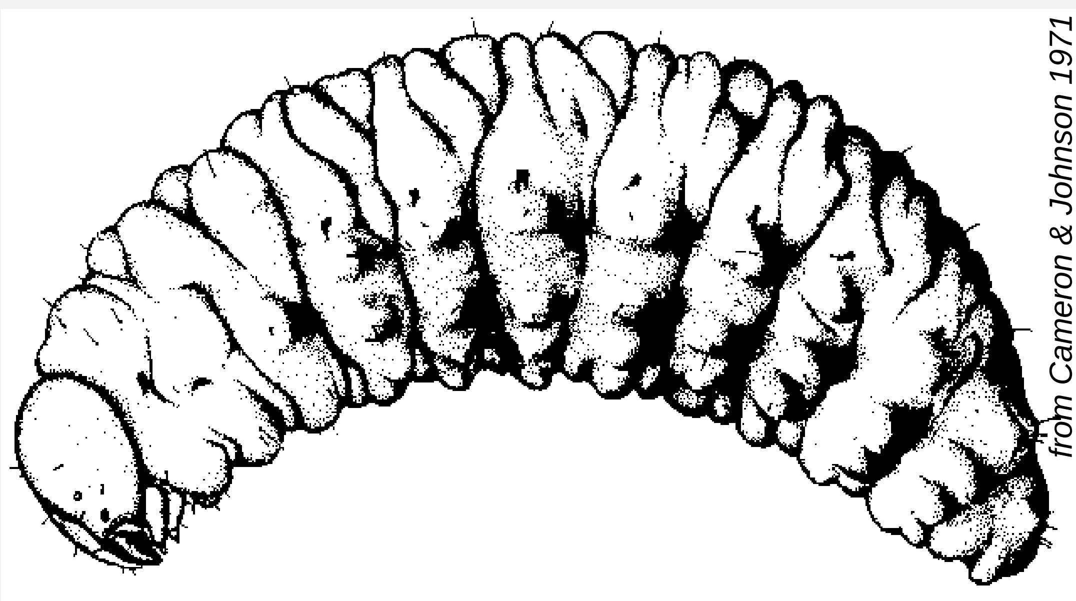
- Short, blunt snout with mouthparts at tip
- Elbowed antennae attached near snout tip
- Length of snout+head+thorax < elytra
- Body dark charcoal-gray, covered with fine yellowish hair and scales that wear off with age
- /8” – 5/32” long

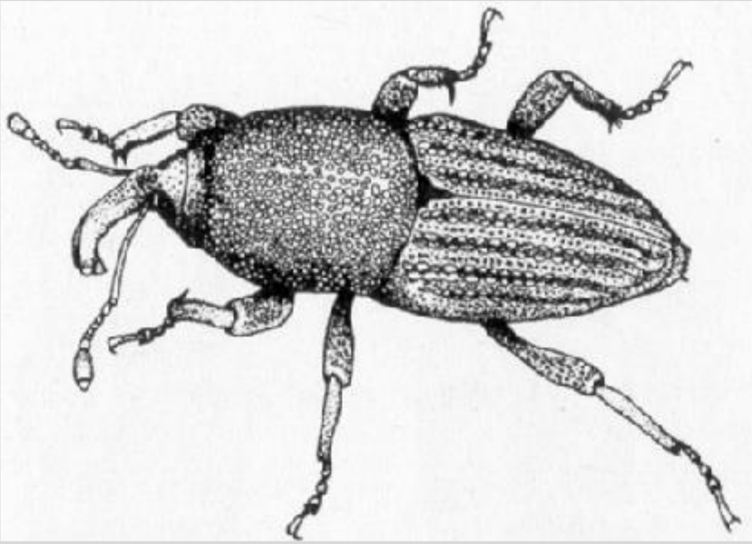


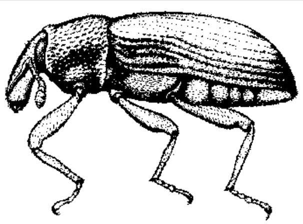
from Cameron & Johnson 1971

Larva

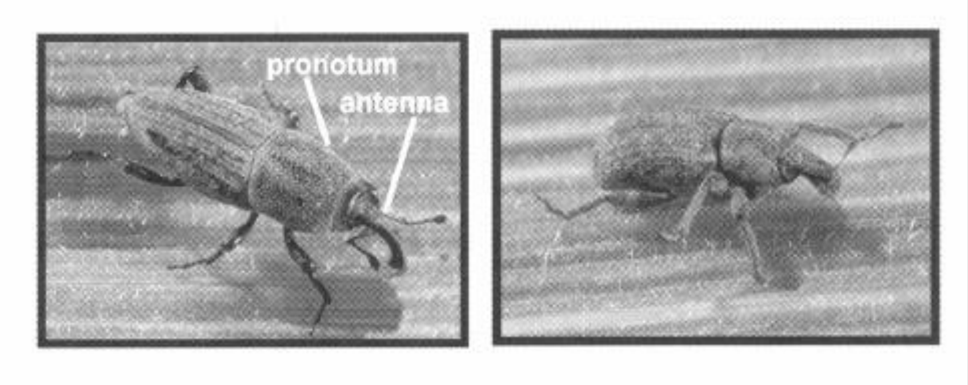
- Cream colored body, brown head
- Body somewhat curved, pointed at tail, legless
- 0.03 (L1) to 0.2” (L5) long



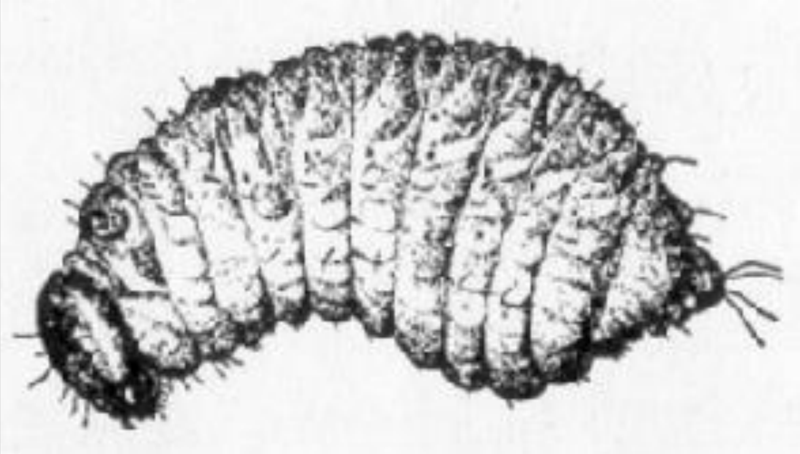


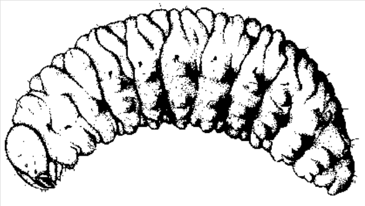


Billbug



Annual Bluegrass Weevil






Adult Overwintering
Adult extraction by submersion of substrate samples in warm water
Adults overwinter in the top 1-2”of soil/turf profile, under taller grass, under tree litter, around trees, even in roughs
B. McGraw

Adult Overwintering

- Overwinter up to 200’ from fairway and up to 30’ into the woods
- Most abundant near tree lines and around trees
- No beetles found within 15’ of fairway
- Pine litter not best site – prefer tall grass and mixed leaf litter

Adult spring migration to playing surfaces

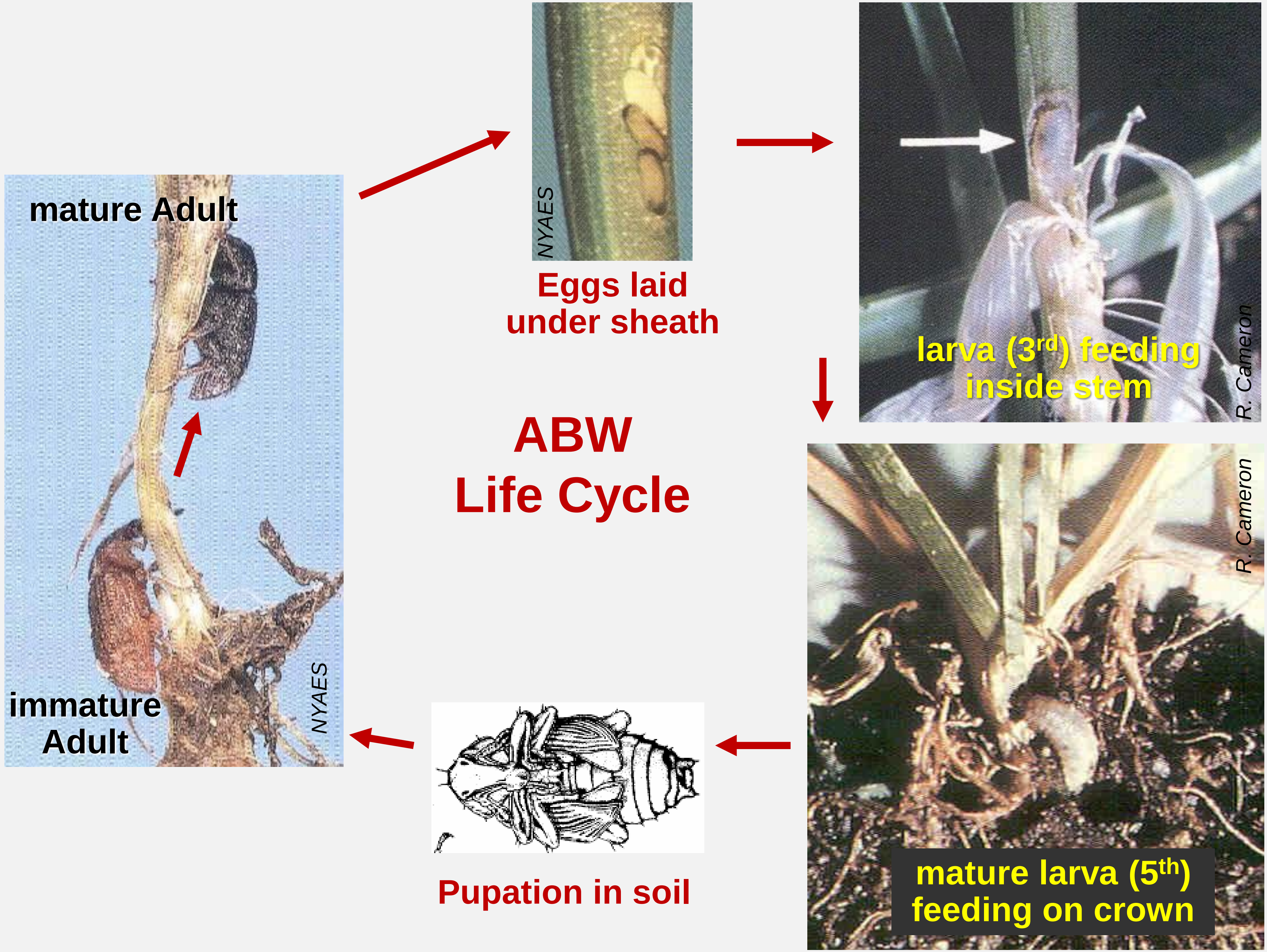
- arrival spread out over several weeks because:

→affected by variably spring temps

→converging from different overwintering sites

→more than 1 peak if cool temps interrupt migration

- primarily on foot


ABW
Life Cycle
mature Adult
immature
Adult
NYAES
NYAES
Eggs laid
under sheath
larva (3rd) feeding
inside stem
R. Cameron
R. Cameron
mature larva (5th)
feeding on crown
Pupation in soil

1st Signs of Larval Feeding Damage (late May)

- Usually starts at edges of fairways, greens, tees.
- Small, yellowish-brown spots
- Scattered dead spots grow together.
- Tunneled stems break off at crown.

B. McGraw

Extensive Larval Feeding Damage (early to -mid June)

- Worst damage early to mid-June (1st gen.).
- Usually less damage in late July/early August (2nd gen.).

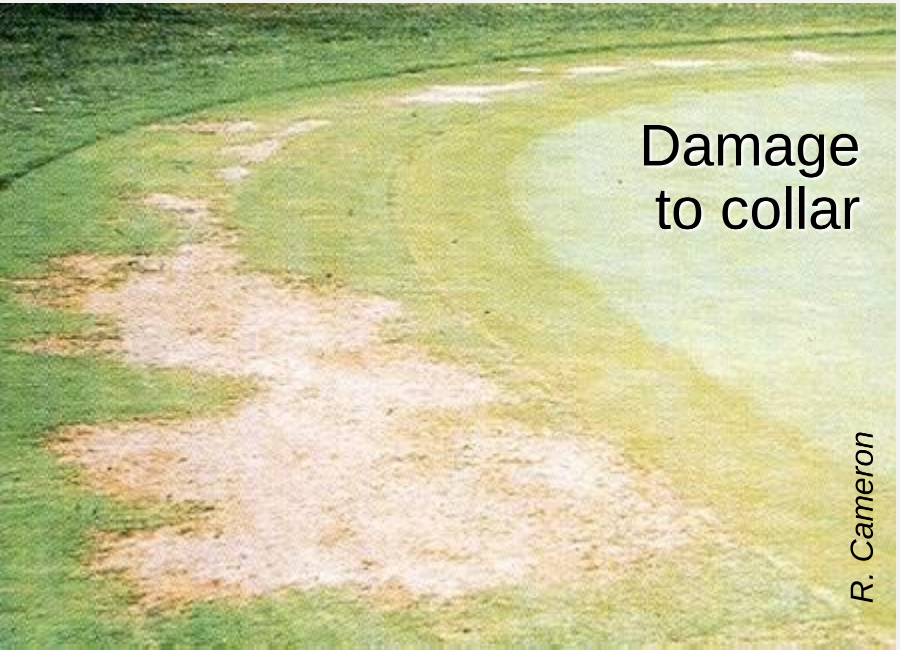
B. McGraw

ABW

Injury


Leaf notching by adults
NYAES

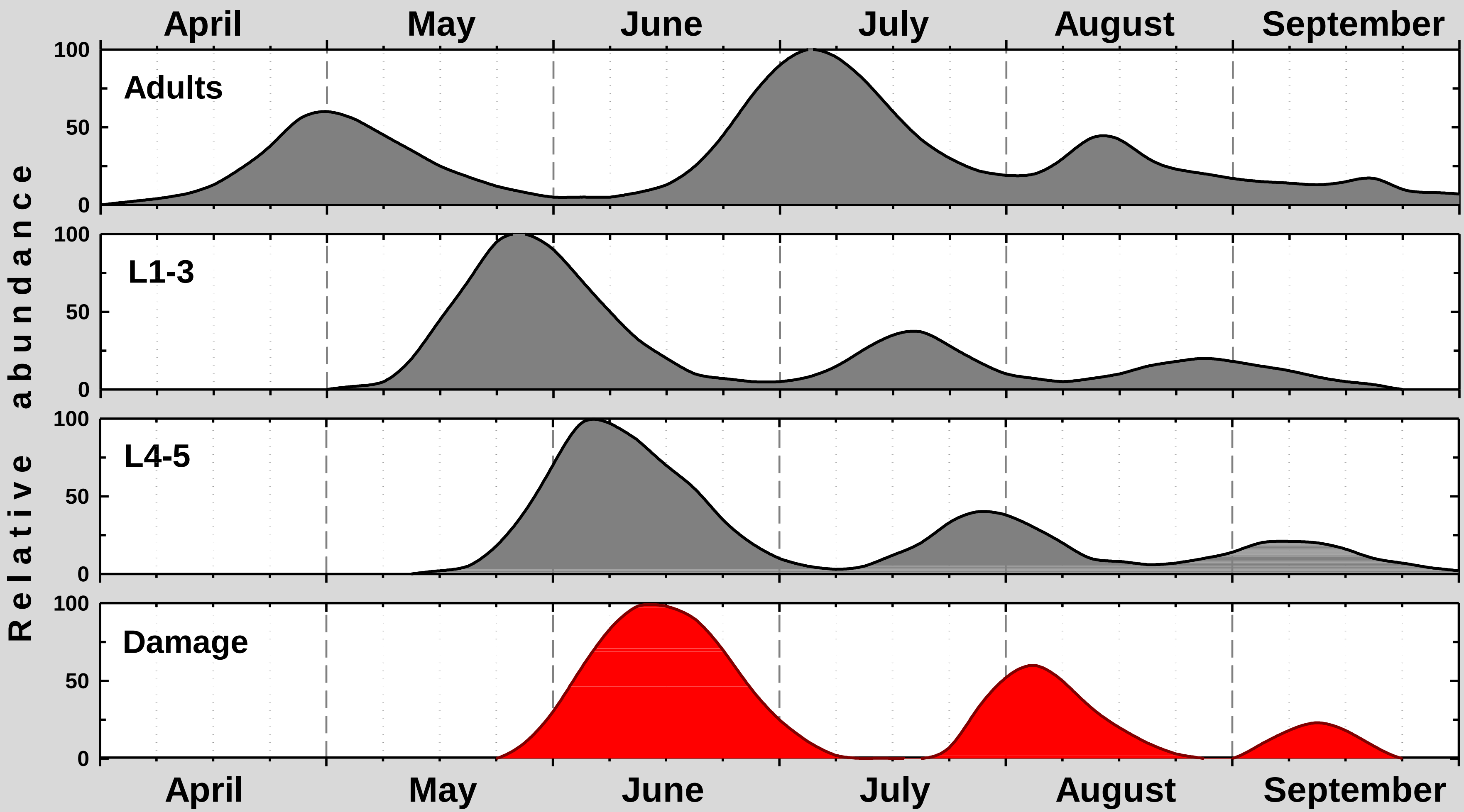

Early summer damage along edge of fairway
B. McGraw


Damage to collar
R. Cameron


Damaged Poa surrounded by undamaged bentgrass
H. Tashiro

ABW Seasonal Life-cycle

(average timing for NY metropolitan area)



*L1-3 = 1st thru 3rd larval stage; L4-5 = 4th thru 5th larval stage

From: Koppenhöfer et al. 2012

Host plant resistance for ABW management

- Low cost
- Highly compatible with other tactics
- Long lasting
- Environmentally sound

Host plant resistance components:

Tolerance: plant tolerates feeding better, but may support high pest density

Resistance: detrimental for pest development and reproduction → fewer/no pests

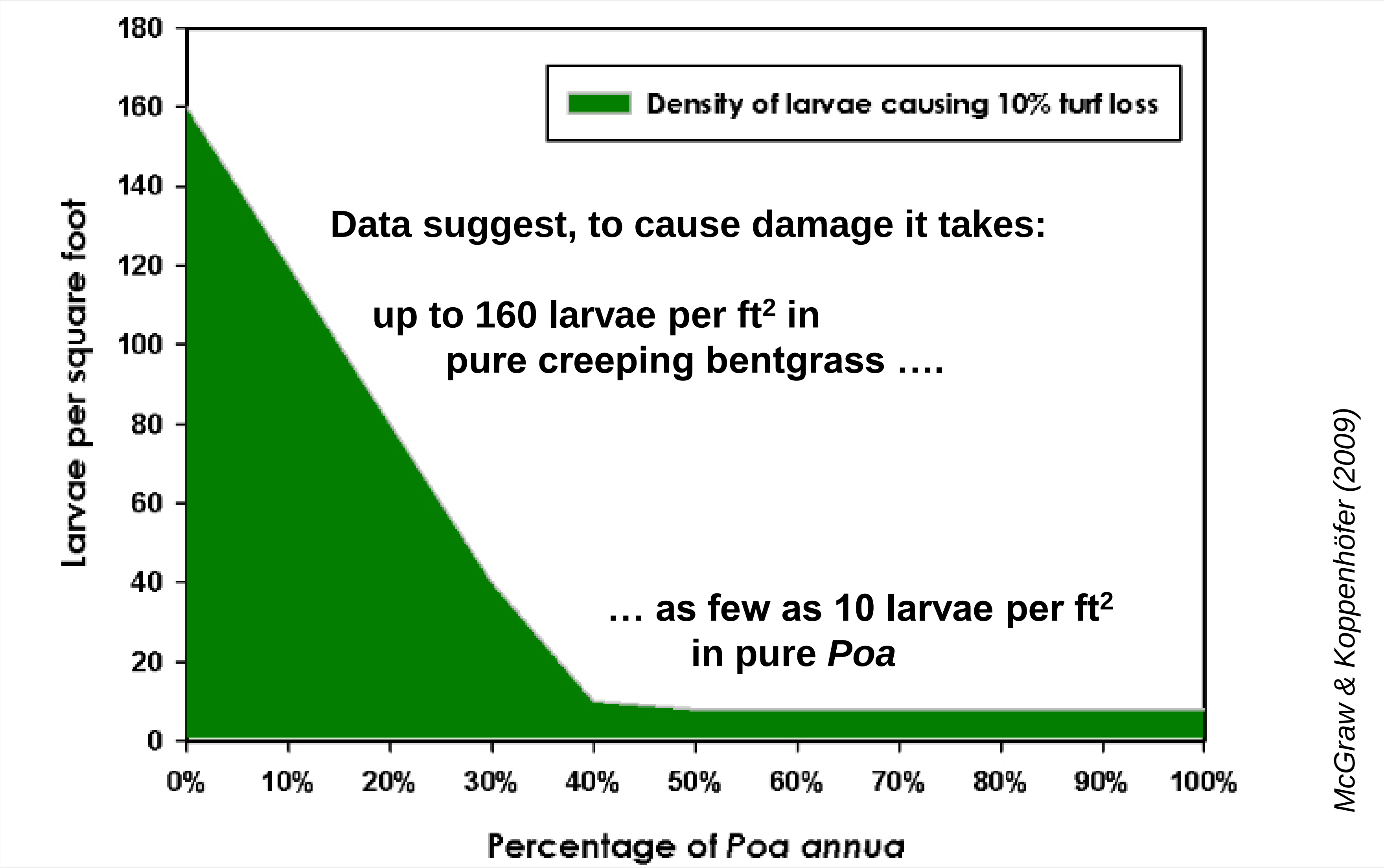
Host Plant Resistance to ABW

- Severe damage typically in areas with high *P. annua* percentage
- But damage to bentgrass possible

Limited previous experimental data suggest:

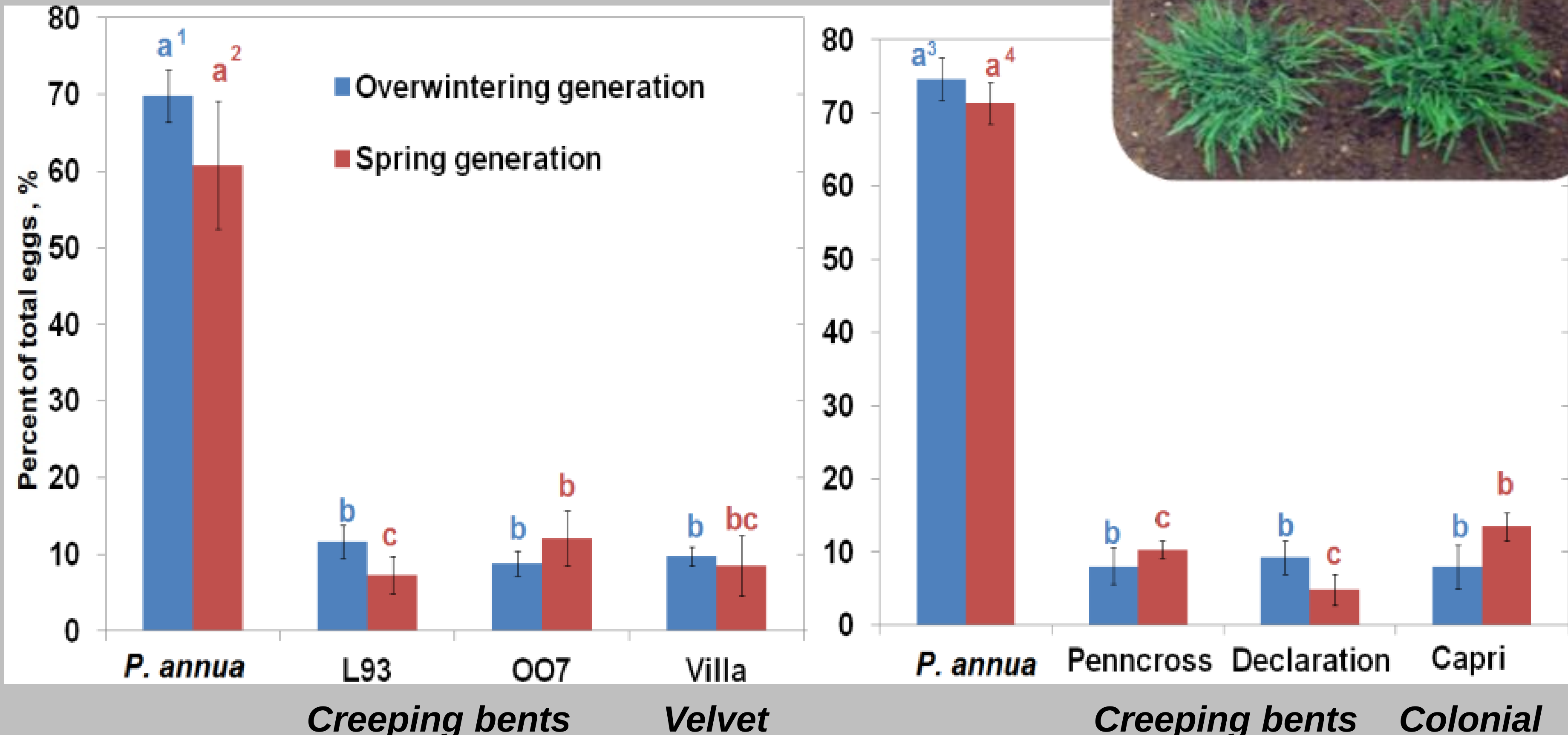
- Same larval density in *P. annua* and CBG (Rothwell 2003)
- No effect of host species on spring adult and larval distribution (McGraw & Koppenhöfer 2010)
- Higher ABW tolerance of pure CBG vs. mixed stands of CBG + *P. annua* (McGraw & Koppenhöfer 2009)

Larval density and damage in mixed *Poa* – creeping bentgrass stands



Egg-laying - Choice field tests

10 females + 10 males for **1 wk**



→ *P. annua* preferred for oviposition.

→ No clear differences among bentgrasses

Kostromytska & Koppenhöfer (2014)

Egg-laying + Larval Development

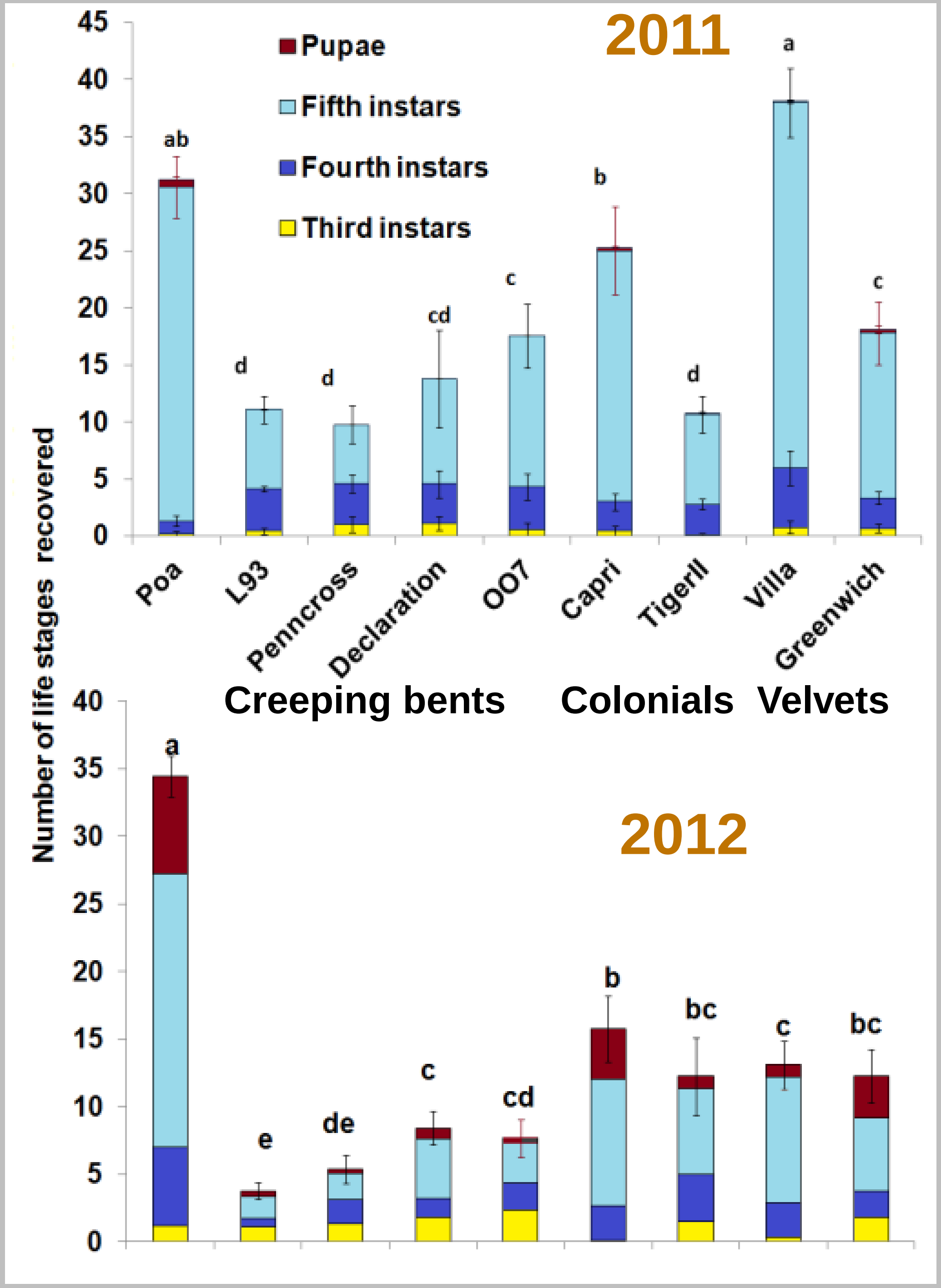
No-choice greenhouse test

5 fem. + 5 males for 1 wk

→ Stages after 5 wk

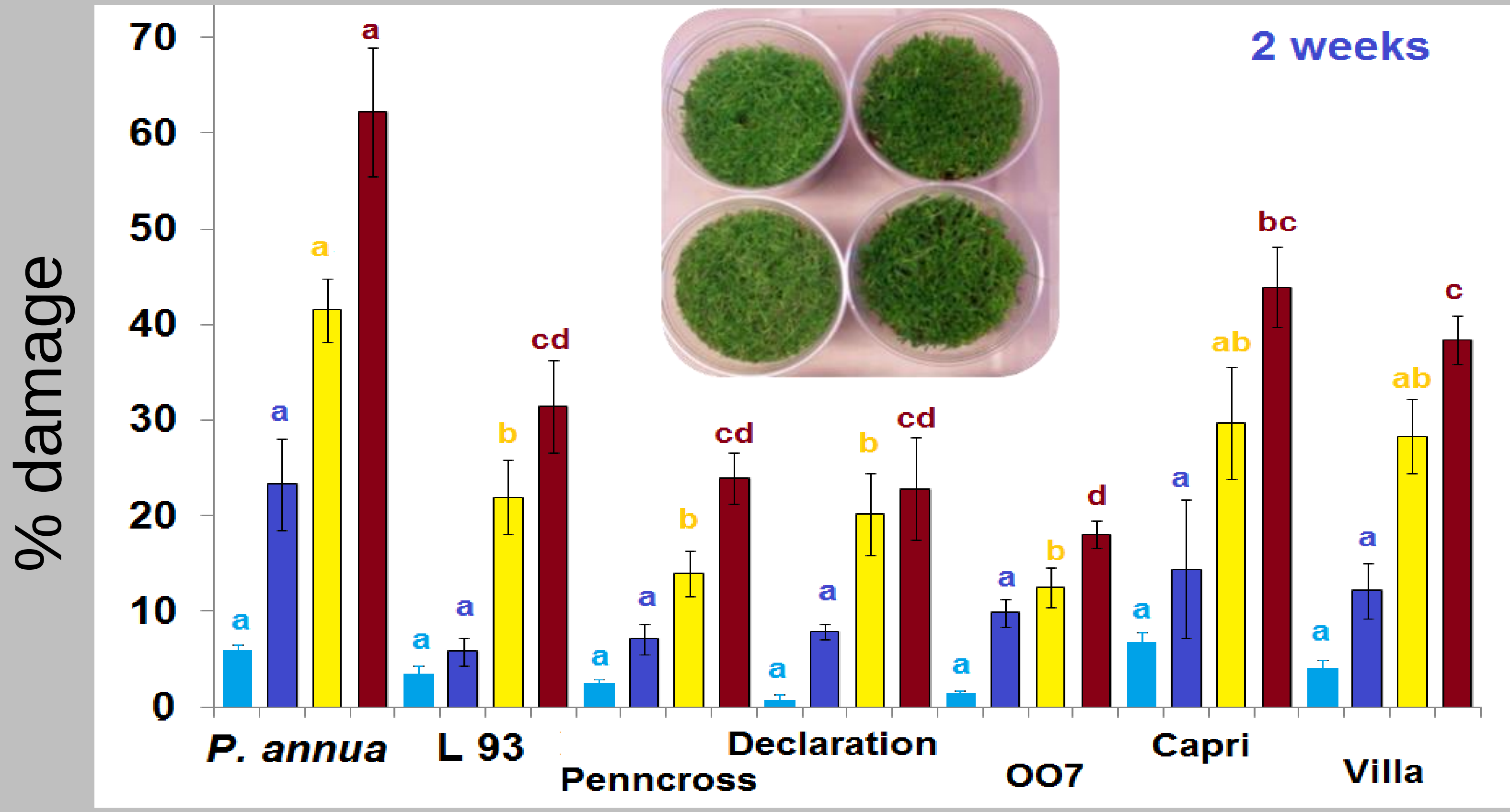
- More stages in *P. annua* than in bentgrasses
- Creeping bentgrasses have the fewest larvae.
- BUT: ABW fully develops in all bentgrasses

Kostromytska & Koppenhöfer (2014)



Tolerance to larval feeding - Greenhouse tests

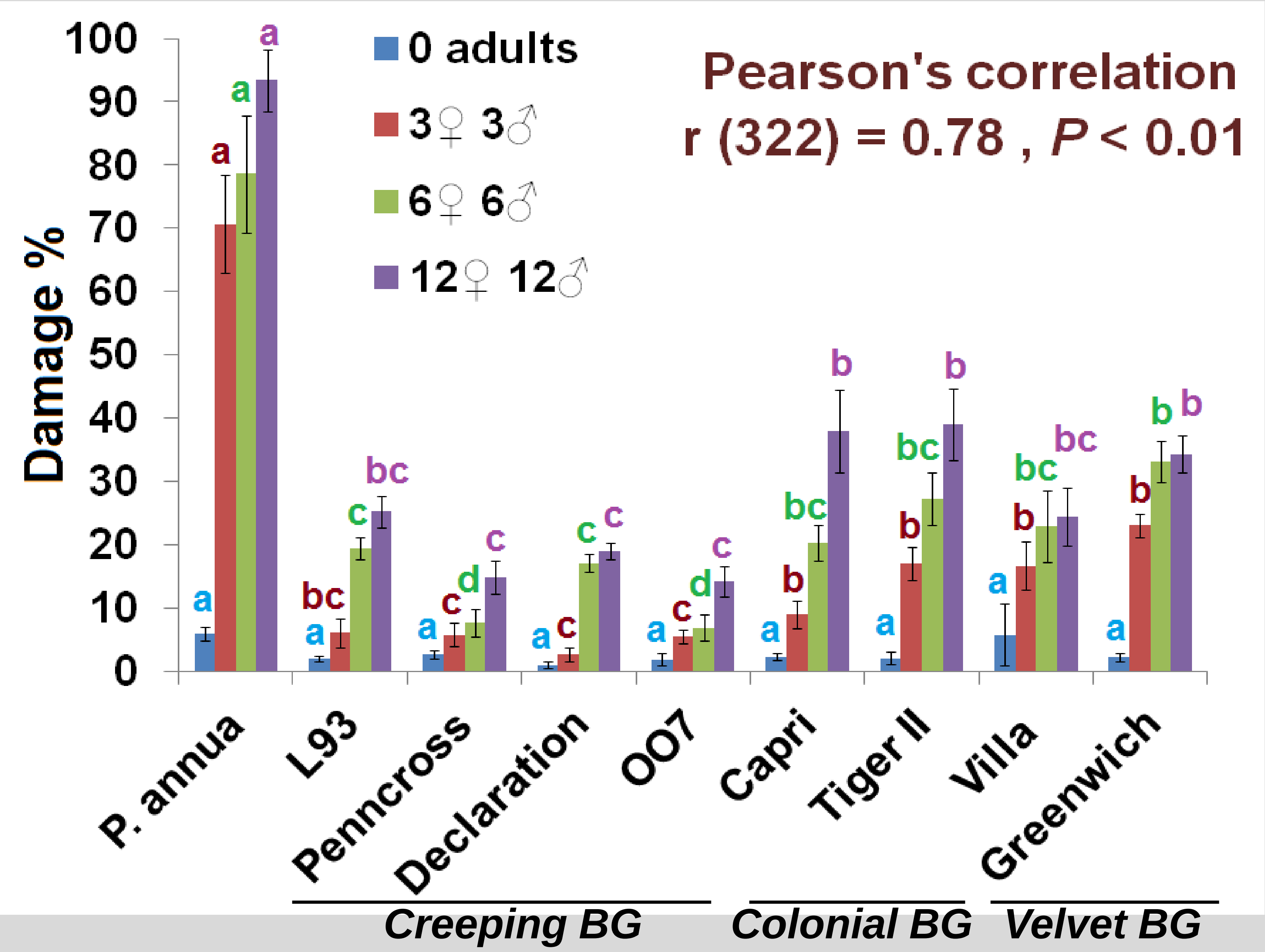
3rd-4th instars introduced (0, 71, 142, 284 / ft^2)



Kostromytska & Koppenhöfer (2016)

- *P. annua* most susceptible
- ‘Capri’ (Colonial), ‘Villa’ (Velvet) most susceptible bentgrasses
- No significant difference among creeping bentgrasses

Effect of grass cultivar and adult density on grass damage by progeny larvae (greenhouse)



Host Plants – Summary:

- *Poa annua* preferred for egg laying, better for larval development, and least tolerant grass.

- Creeping bentgrasses can be damaged but much less likely, much less intensive, and can recover better.

→ **Best preventive control for ABW problems: Keep *P. annua* percentage as low as possible wherever possible using cultural practices and herbicides !!!**

ABW Biology and Control

- Biology, ecology, damage
- **Monitoring**
- Insecticide resistance
- Sustainable management: non-resistant
- Sustainable management: resistant
- Biorationals

Plant Phenology for ABW

- **Forsythia full bloom** → overwintering adults become active
- Migration from overwintering sites to playing surfaces has started.
- Adult densities on playing surfaces increase during full bloom.

Plant Phenology for ABW

- **Forsythia ½ gold** : **½ green**
- **Eastern redbud** early bloom

→ peak adult densities on playing surfaces

→ best time to spray vs. overwintered adults

- But: blooming variable
  → Don’t rely on just 1 or 2 plants.

Plant Phenology for ABW

- **Flowering dogwood** full bloom
- **Eastern redbud** full bloom

→ egg-laying has begun

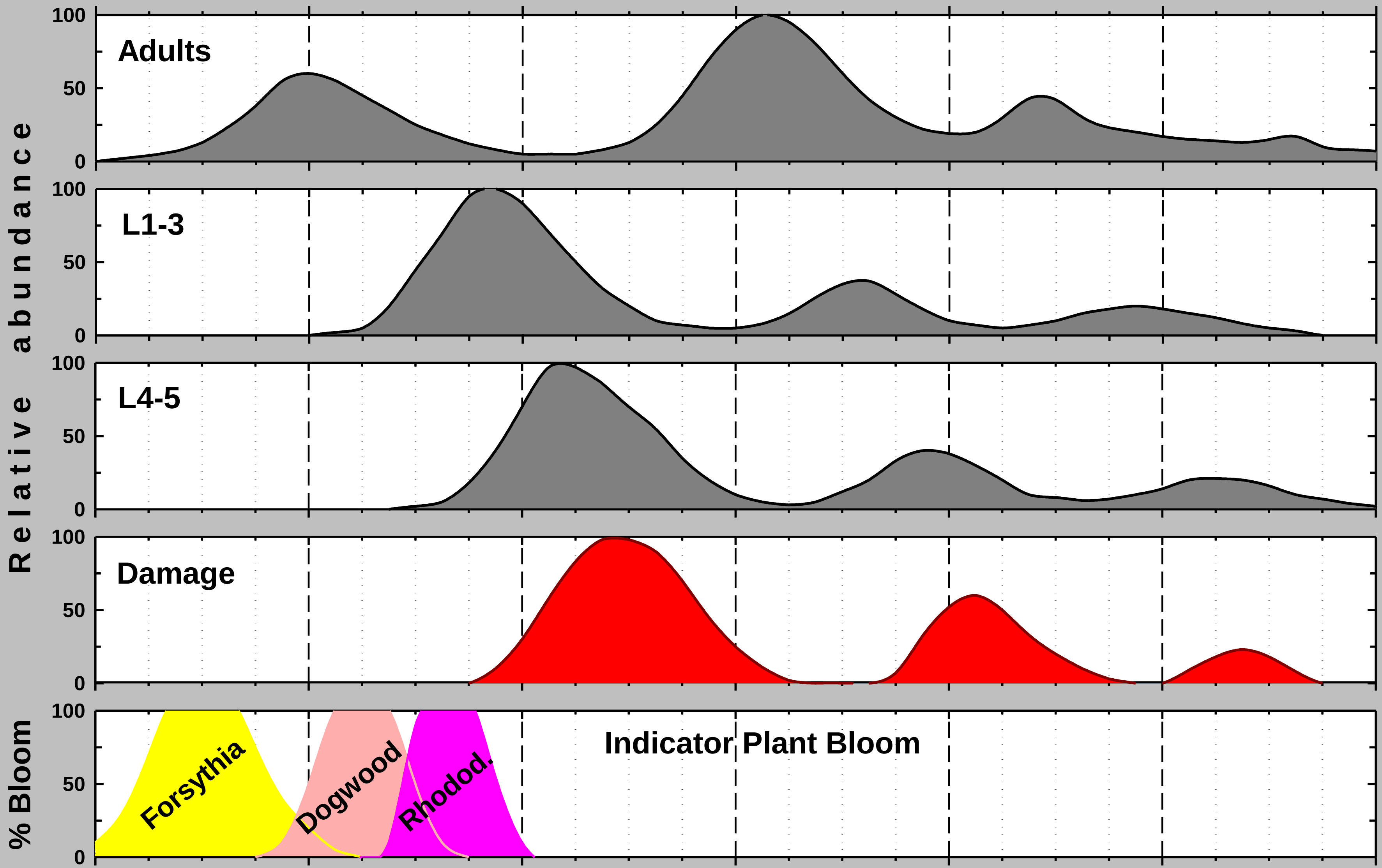
→ adulticides ineffective

Plant Phenology for ABW

- **Catawba Rhododendron** hybrid full bloom
  → larvae start appearing in soil
  → curative larvicides.

Phenological Indicator Plants for ABW

(average timing for NY metropolitan area)



*L1-3 = 1st thru 3rd larval stage; L4-5 = 4th thru 5th larval stage

From: Koppenhöfer et al. 2012

Degree-Day Models

- Predict insect activities and fine-tune treatment timing.
- Baseline developmental temperature for most insects 50°F.
- Calculate degree-day (GDD) units for each day:

$$\frac{(\text{min.temp.} + \text{max.temp.})}{2} - \text{baseline temp}$$

- Add up average GDD units for each day → GDD accumulation
- No values < 0!

Degree-Day Accumulation (base 50 = GDD_{50})

Date	Max Temp	Min Temp	Total	Ave	Minus 50 for baseline	DD Accumu-lation
4/13	58	40	98	49	0	0
4/14	66	42	108	54	4	4
4/15	70	46	116	58	8	12
4/16	75	49	124	62	12	24
4/17	71	47	118	59	9	33

Degree-Day Recording

- For best regular updates:
  - -Use own weather station data to calculate GDDs.
  - -Use weather/GDD trackers, ideally more than 1 per GC.

Degree-Day Correlations for NJ

Observation	GDD_{50}	GDD_{50} Range
Forsythia full bloom	46	23–69
Forsythia 50:50	158	113–210
Dogwood full bloom	188	139–280
L1.5	298	265–291
L2.0	331	264–338
Rhodo full bloom	389	306–444
L2.5	396	390–425
L3.0	486	413–560
L3.5	540	409–553
L4.0	636	618–746

Linear Pitfall Traps to monitor adult movement

(not good estimate of adult densities)

Monitoring Adults - Grass clippings

- Many adults picked up by mowers
- Extraction: ~15% on green but < 1% on fairways
- Adult numbers in standard samples should be correlated to population built-up
- BEWARE: 70% of adults survive mowing undamaged → discard clippings with significant adult numbers away from playing.

Monitoring Adults
Vacuuming

- Inverted leaf blower to suck adults into an inserted sieve basket
- Between Forsythia full bloom and ½ gold : ½ green
- Extraction: ~30% on green, ~5% on fairways

→number of adults sucked up indicator of ensuing larval populations

Vacuum sampling adults :
Standardize your sampling plan (1-2x/week)
→ count ABW and chart numbers

<u>What I do:</u>
5 vac samples (20 sec. ea) from 5 collars 1x per week at 11 am
= 40 MINS

B. McGraw

Monitoring adults: Soap flush

- 1 fl oz. lemon scented liquid dishwashing detergent per gal of water (0.8%)
- Spread 1 pt (~500 ml) solution per 1’x1’ area at 0 minutes and again at 5 minutes.
- Collect adults after ~5, 10, 15 (20) minutes
- Multiple samples per area
- Recovers > 75% of adults
- Water afterwards to avoid SCALD!!!

Monitoring – All Stages

- In spring, start with Rhododendron full bloom
- Cut turf cores with turf plugger (2.3” diam) or knife (1-2” deep).
- Break up soil and thatch on a tray and count insects.

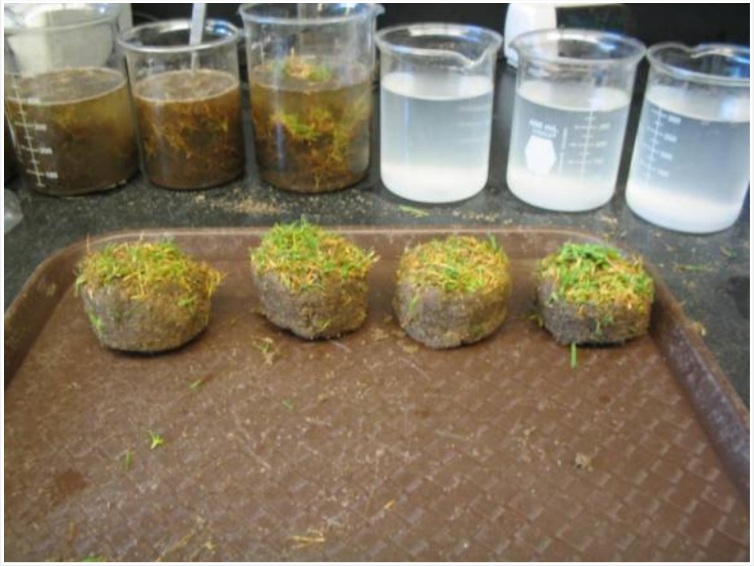
  For more detail: Submerge material in lukewarm water → remaining pupae, larvae, adults float up in 5-10 min.


B. McGraw

Adequately irrigated turf can tolerate 30-50 larvae/ft^2

Monitoring – All Stages
More precise method

- Break 2.5” diam cores into 3-4 pieces
- Submerge in lukewarm water saturated with salt for 1 hr.
- Stir after 1, 20, and 40 min.
- Collect and count stages floating to the surface



ABW Biology and Control

- Biology, ecology, damage
- Monitoring
- **Insecticide resistance**
- Sustainable management: non-resistant
- Sustainable management: resistant
- Biorationals

ABW Resistance to Insecticides

- Many GCs apply >3 treatments per season, up to 10 per season !!!

→ suggests resistance to insecticides.

- **Many resistant populations detected !**

- Likely that most GCs with > 5 years of intensive insecticide use vs. ABW have some level of resistance!

ABW Survey 12/2014–2/2015

Region	No. of responses	ABW applic. / year			Resistance suspected (%)
		Avg.	> 5 (%)	> 9 (%)	
All Regions	**291**	**3.9**	**18**	**6**	**19**
North.Periph.	13	2.2	0	0	0
MA	33	4.4	13	10	0
CT	**25**	**4.2**	**20**	**12**	**48**
NY	**56**	**4.1**	**18**	**14**	**29**
LI	**20**	**5.5**	**30**	**20**	**55**
Upstate	**26**	**2.3**	**0**	**0**	**8**
NJ	**32**	**4.4**	**23**	**0**	**28**
PA	**74**	4.2	24	1	22
DE-MD-VA	42	3.6	17	0	5
South.Periph.	16	2.9	0	0	0

(*McGraw & Koppenhöfer 2017*)

Resistance to Insecticides

- Resistance result of artificial selection pressure in favor of genes that convey ability to survive toxin exposure

- Genes controlling resistance mechanisms already present before exposure in 0.01–1% of population

- In resistant populations, frequency of resistance genes up to 97%.

Model assuming simple genetics of Resistance

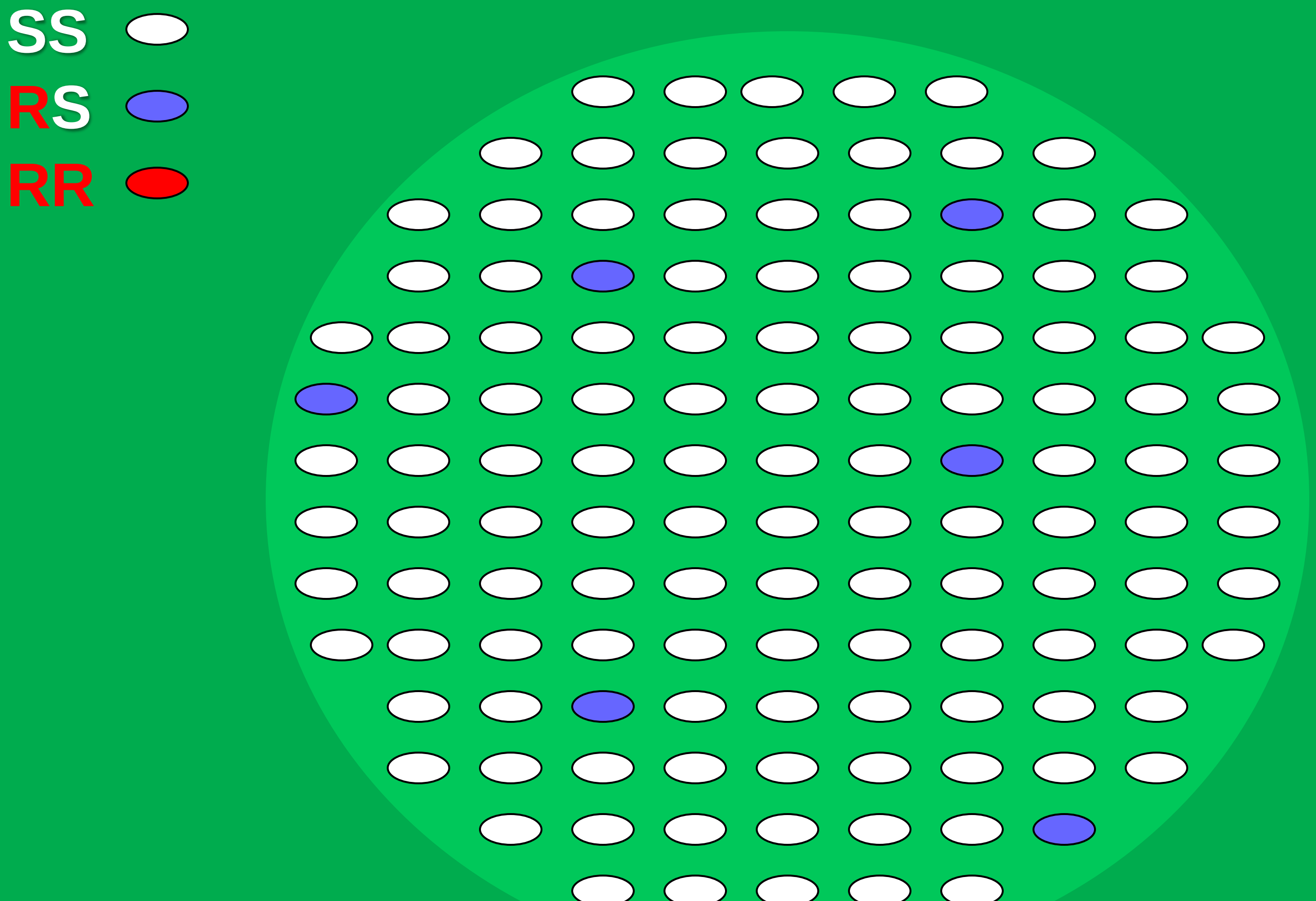
- S = original gene version → susceptible
- R = mutated gene version → resistant
- Insects have 2 copies of each gene that controls a resistance mechanism

→ SS = individual fully susceptible

→ RR = individual fully resistant

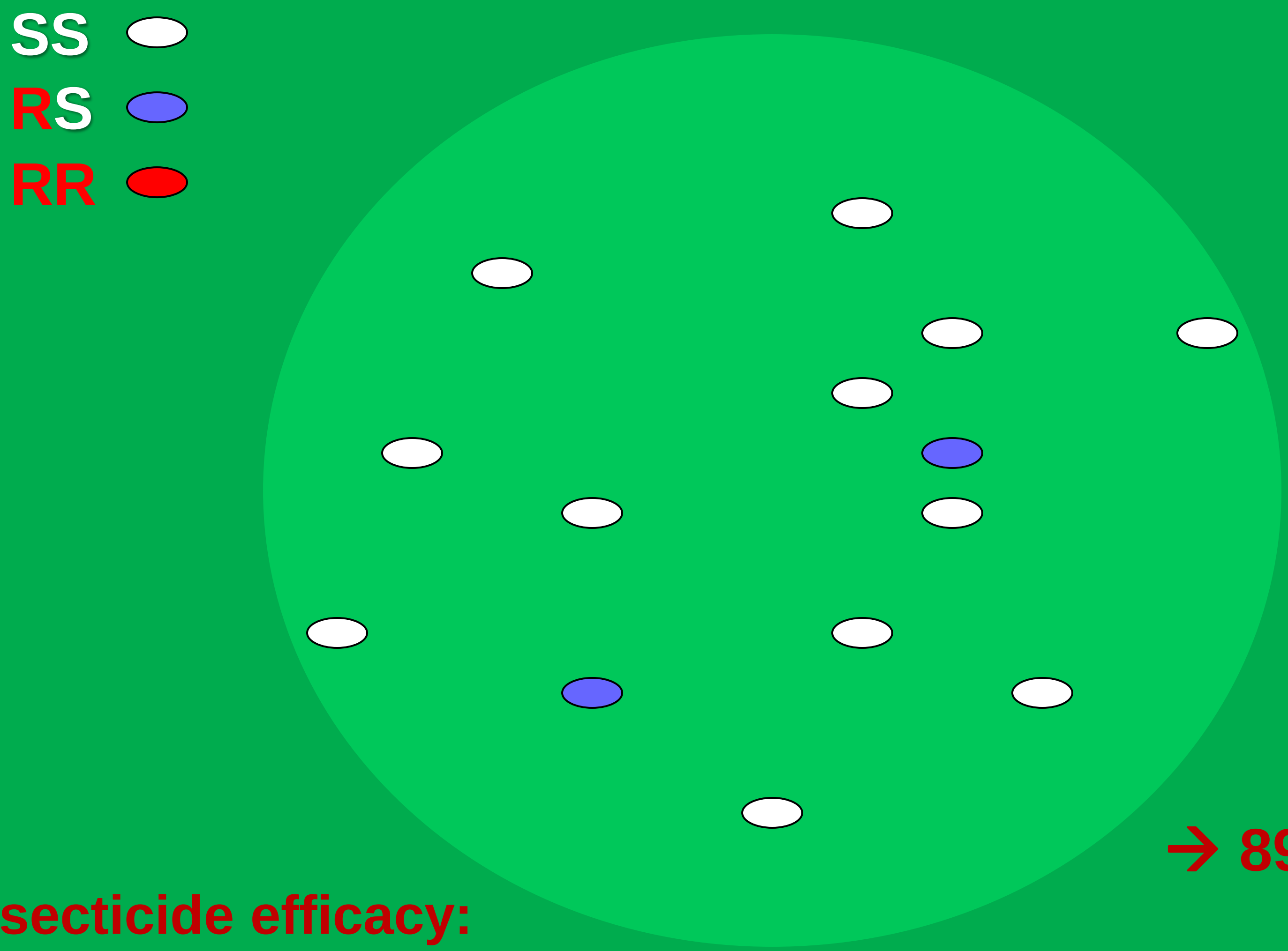
→ RS = intermediate resistance level

Simple Model of Resistance Development
1st Generation: before application



Insecticide efficacy:
SS = 90%; RS = 60%; RR = 0%

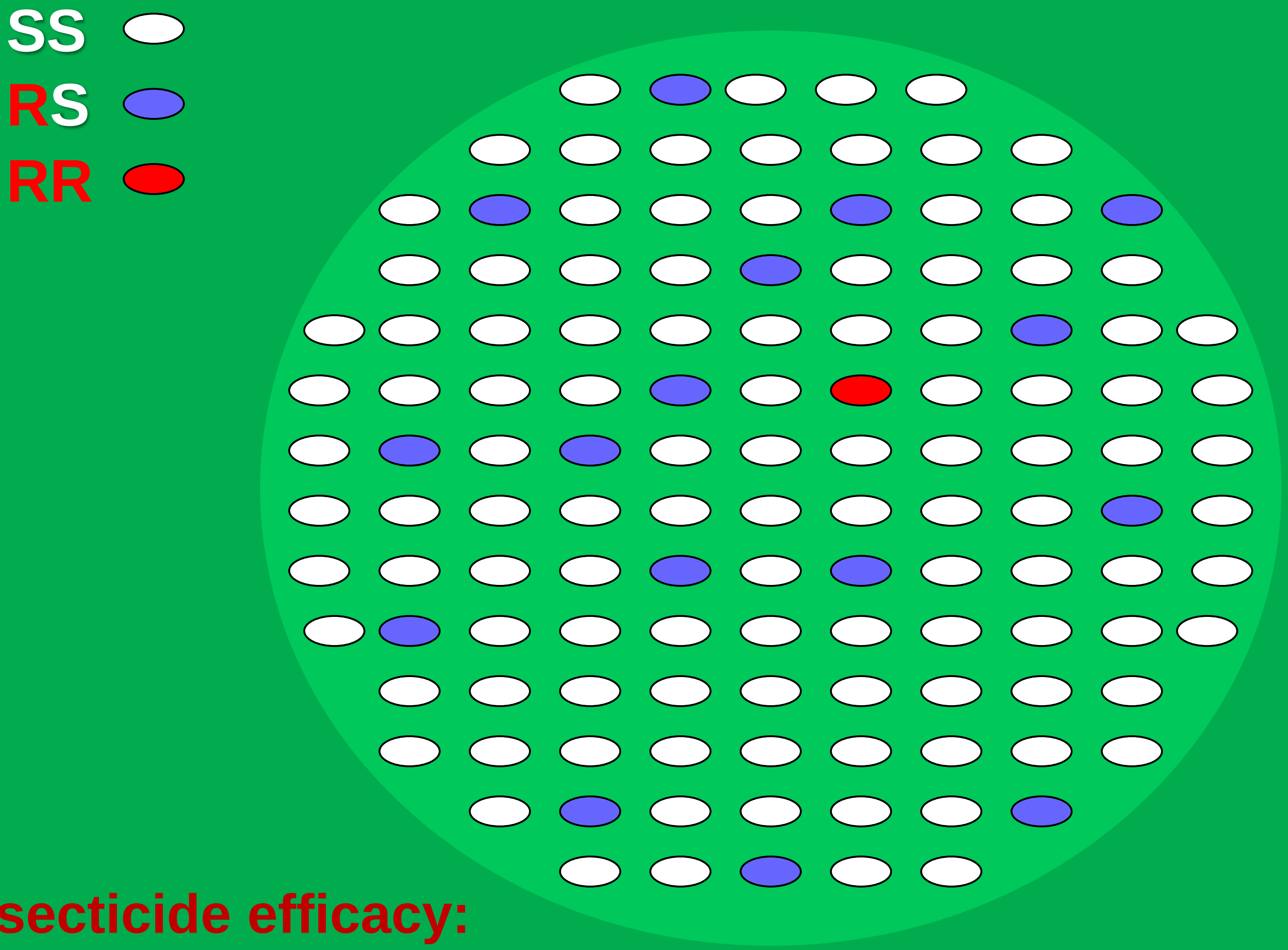
Simple Model of Resistance Development
1st Generation: after application



→ 89% control

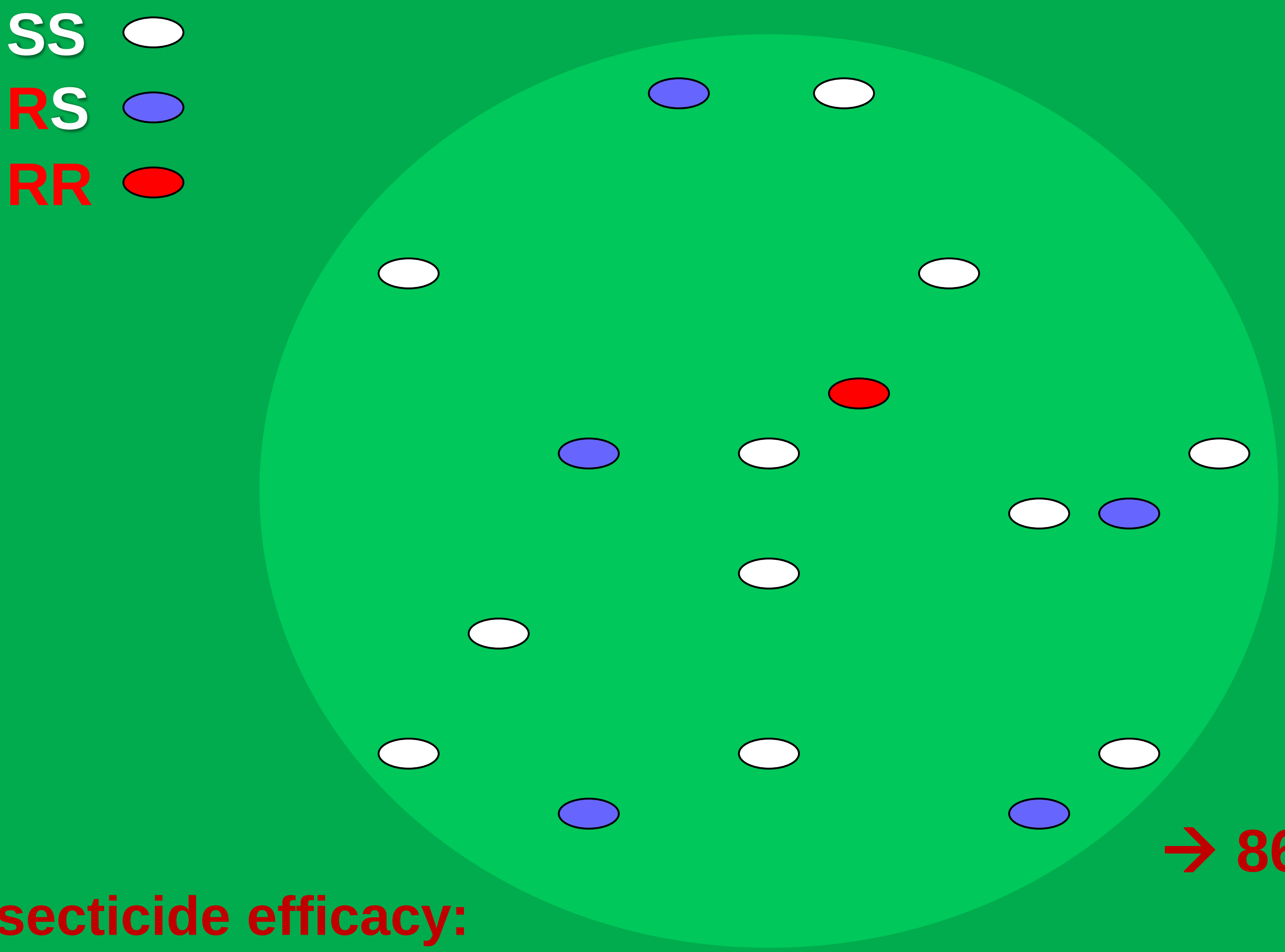
Insecticide efficacy:
SS = 90%; RS = 60%; RR = 0%

Simple Model of Resistance Development
2nd Generation: before application



Insecticide efficacy:
SS = 90%; RS = 60%; RR = 0%

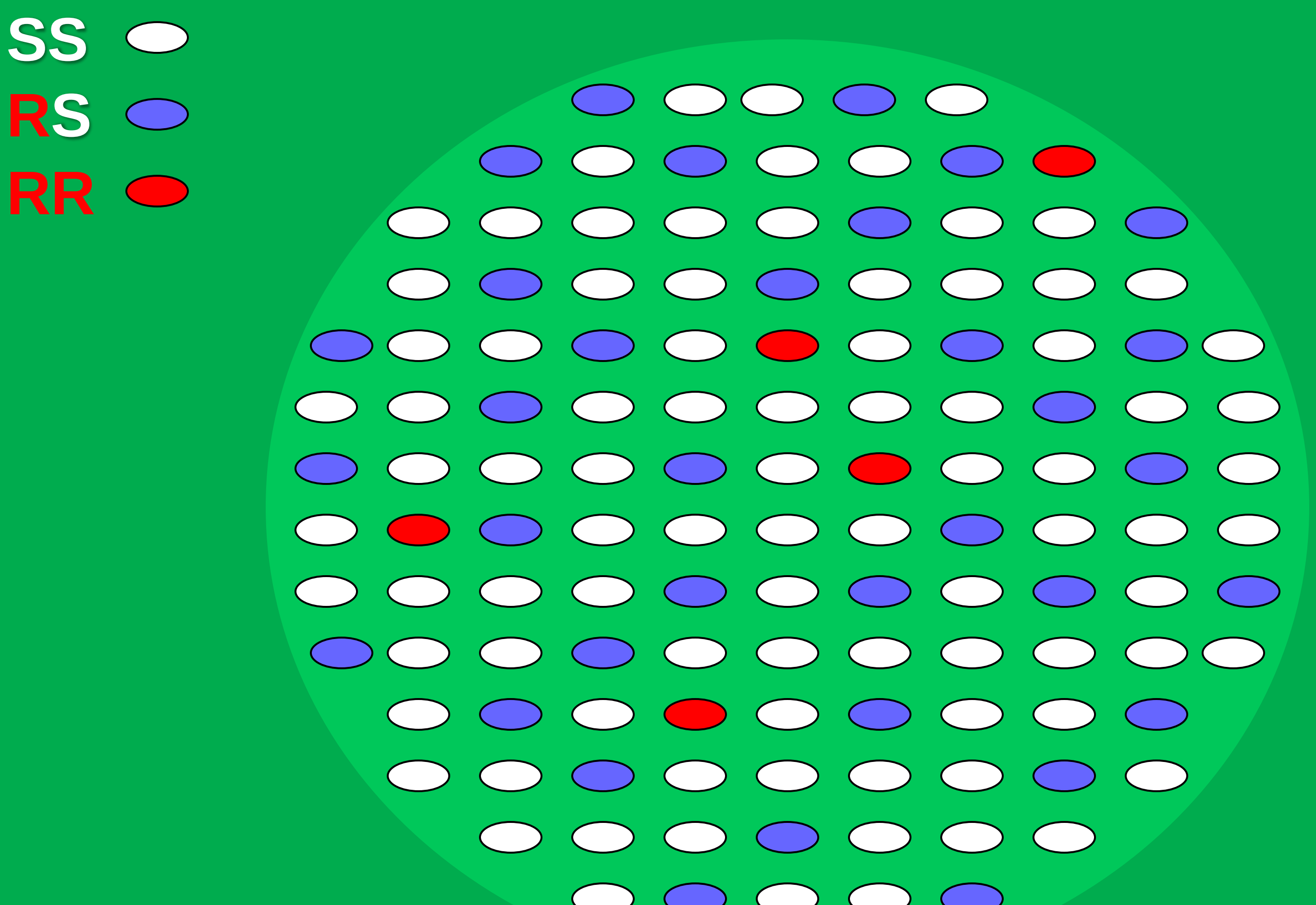
Simple Model of Resistance Development
2nd Generation: after application



→ 86% control

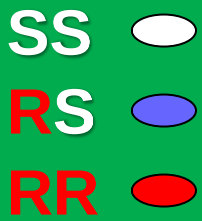
Insecticide efficacy:
SS = 90%; RS = 60%; RR = 0%

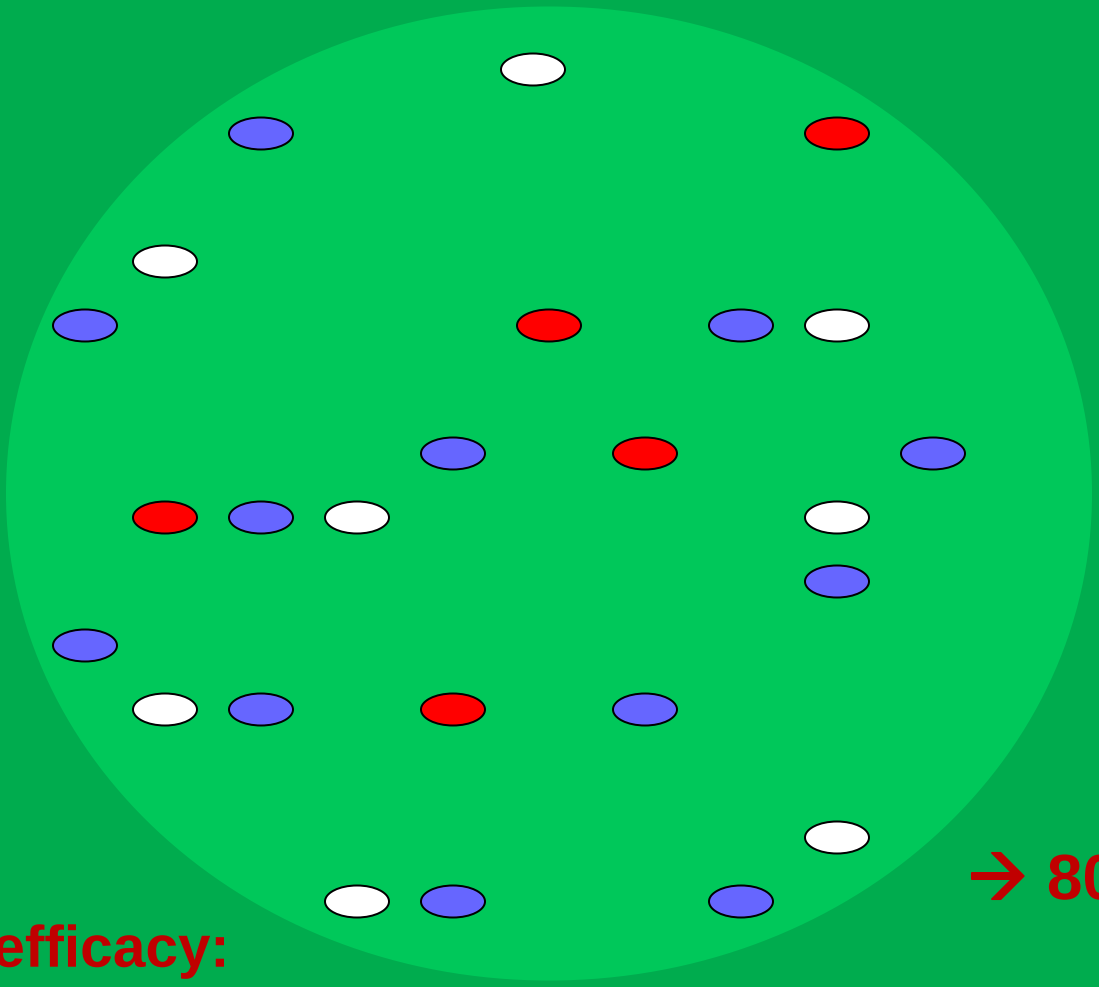
Simple Model of Resistance Development
3rd Generation: before application



Insecticide efficacy:
SS = 90%; RS = 60%; RR = 0%

Simple Model of Resistance Development
3rd Generation: after application





→ 80% control

Insecticide efficacy:
SS = 90%; RS = 60%; RR = 0%

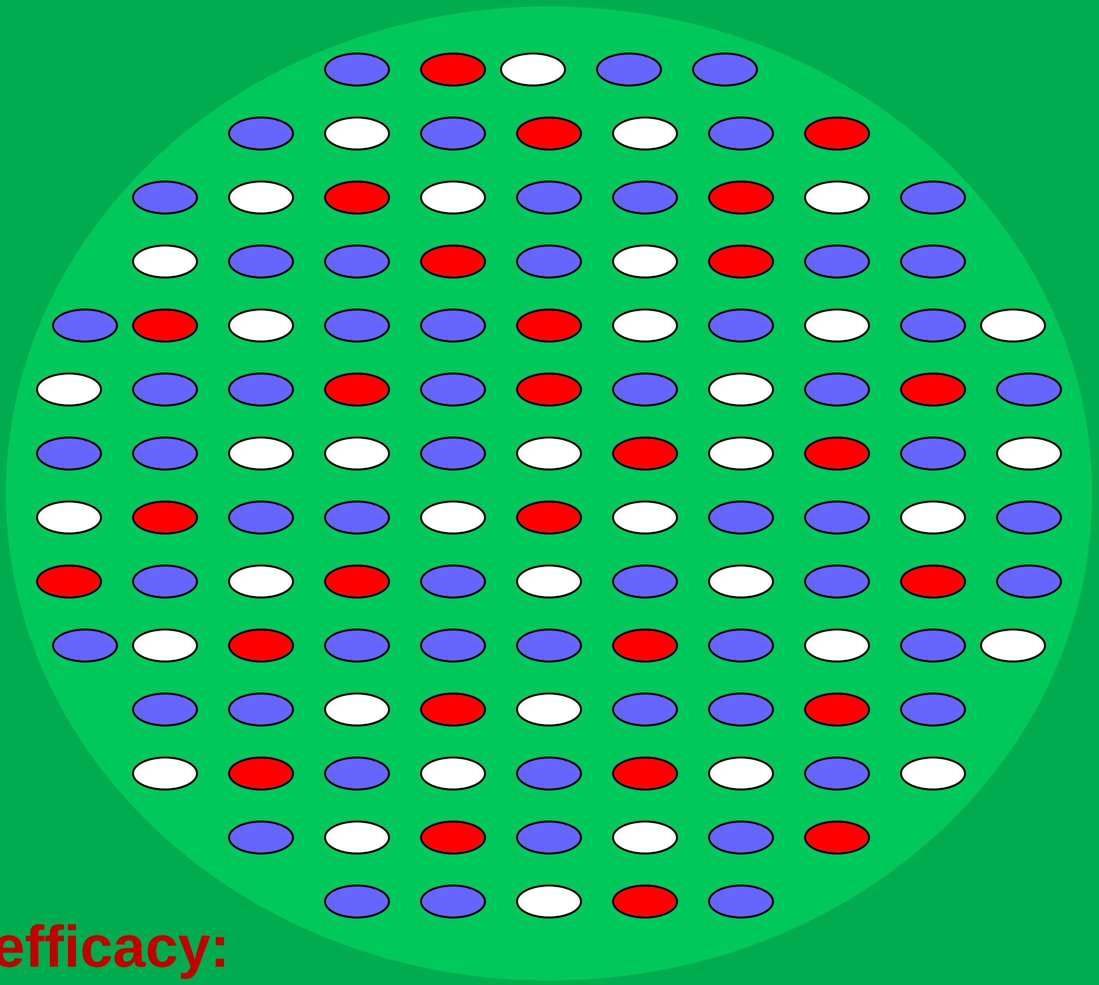
Simple Model of Resistance Development

4th Generation: before application

SS

RS

RR

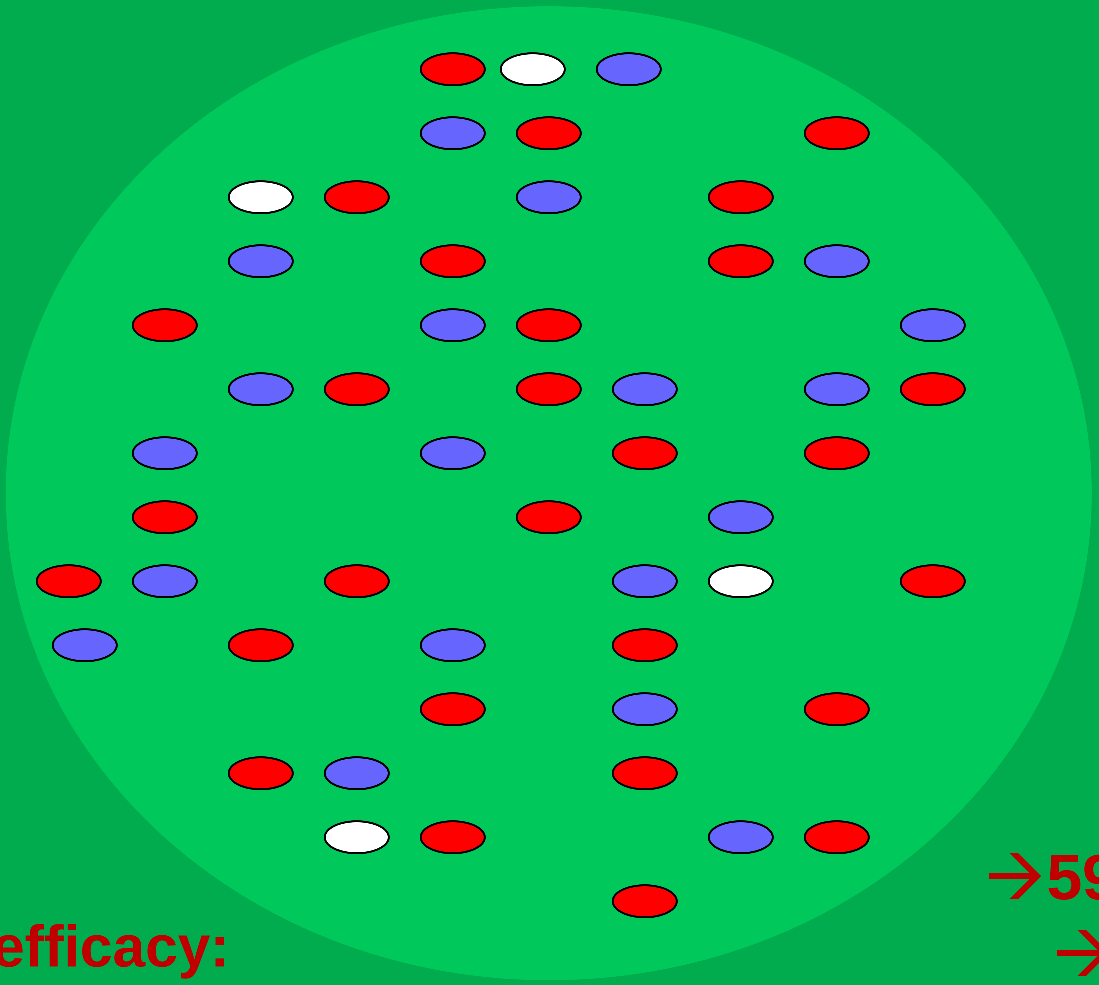


Insecticide efficacy:

SS = 90%; RS = 60%; RR = 0%

Simple Model of Resistance Development
4th Generation: after application

SS
RS
RR

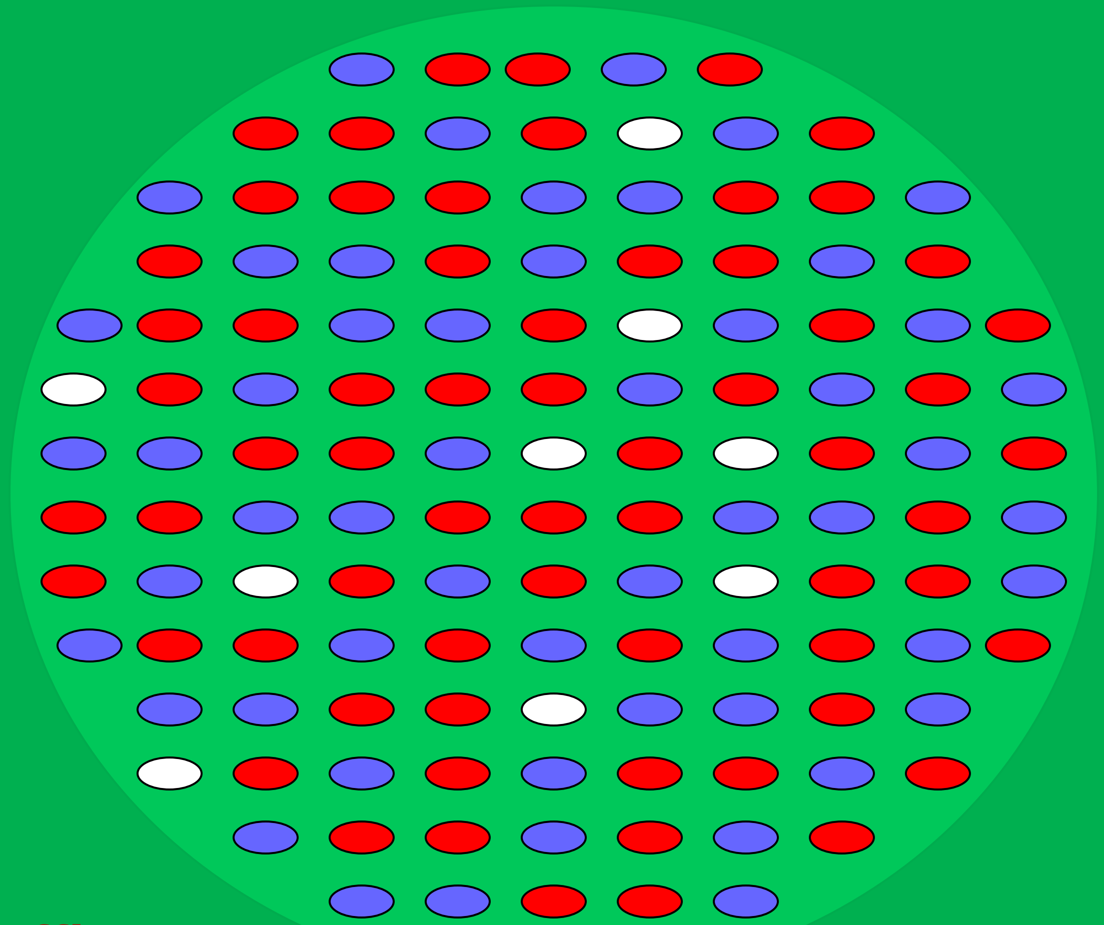


Insecticide efficacy:
SS = 90%; RS = 60%; RR = 0%

→59% control
→Problem !

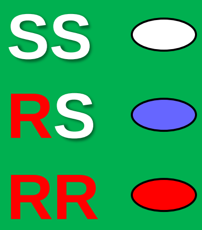
Simple Model of Resistance Development
5th Generation: before application

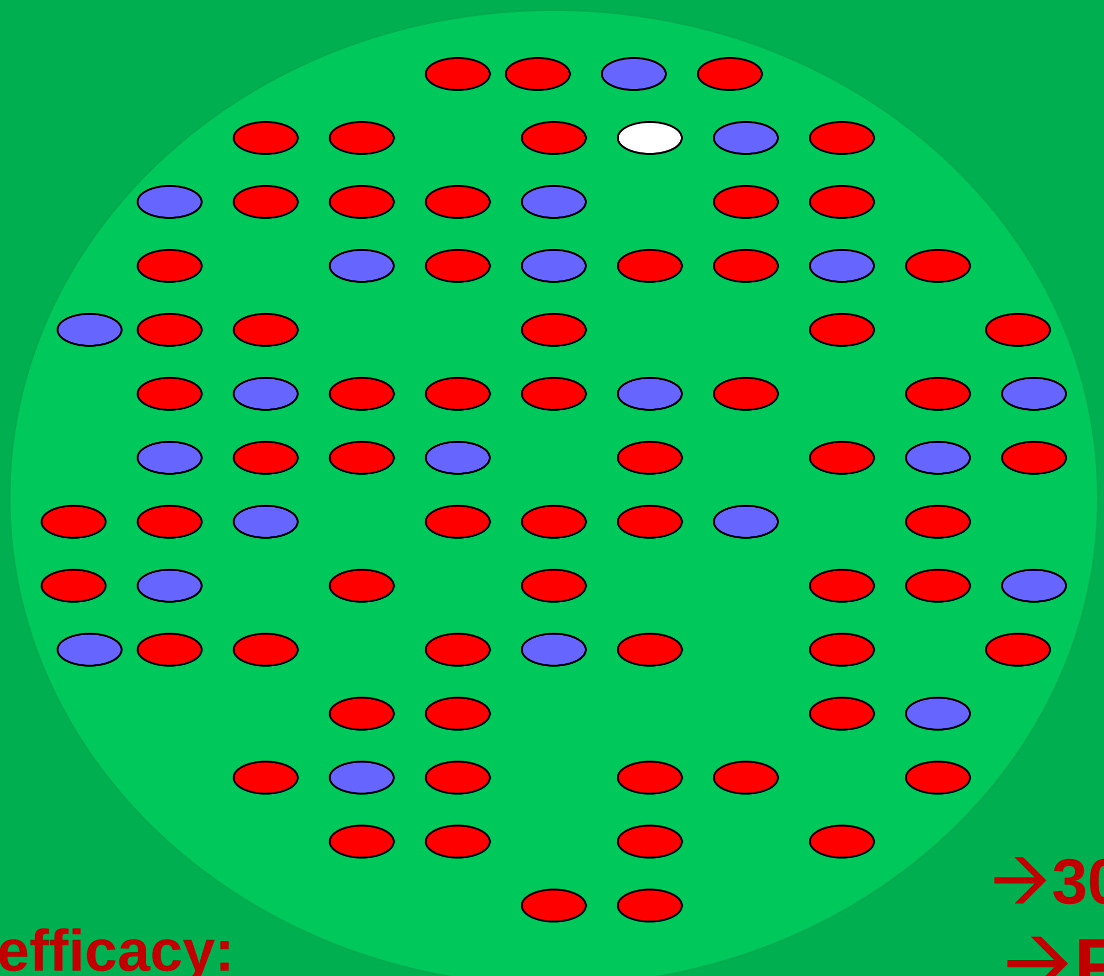
SS
RS
RR



Insecticide efficacy:
SS = 90%; RS = 60%; RR = 0%

Simple Model of Resistance Development
5th Generation: after application





→30% control
→Failure !!!

Insecticide efficacy:
SS = 90%; RS = 60%; RR = 0%

Rate of Resistance Development

Likely begins with 1st application but at first slow → unnoticed for several years.

Rate depends on:

- R allele dominance: more dominant → faster
- Generation turnover: takes10-15 generations
- Population mobility: influx of SS slows rate
- AI persistence: more persistent → faster
- Selection pressure: greater → faster

Insecticide Resistance Mechanisms

- **Behavioral**: ability to avoid lethal toxin dose (increased sensitivity/irritability)
- **Reduced cuticular penetration**
- **Target site insensitivity**: reduced affinity of receptor sites to AI
- **Increased detoxification** (metabolic): overexpression or amplification of genes coding detoxifying enzymes

Resistance Interactions

- **Cross-resistance**: resistance to one AI automatically makes resistant to another (even without exposure).
- **Multiple resistance**: different mechanisms for each of several affected insecticides
- Resistance factors normally don’t occur alone

→ Different factors may interact synergistically.

Resistance Management Strategies

1. Use of resistant natural enemies:

- **Not available for any turfgrass pest**

Resistance Management Strategies

2. Use of new, unaffected MoA:

- Increasingly difficult to find and develop new MoAs.
- Not much in pipeline.

→ **Don't count on the next silver bullet !**

Resistance Management Strategies

3. Use of synergists:

- If increased detoxification involved, certain compounds can interfere with detoxifying enzymes.
- E.g., piperonyl butoxide (PBO) interferes with major detoxifying system in ABW.
- **But too unstable in sunlight for outdoor applications**

Resistance Management Strategies

4. Use of insecticide mixtures:

- Concept: extremely unlikely that resistance mechanisms for both AIs present in same individual
- But !!!: Resistance to both AIs has in some cases developed rapidly.
- **Cross-resistance possible**
- **Especially risky if pest already resistant to one of the AIs**

Resistance Management Strategies

5. Reducing R gene frequency:

- Use short persistence insecticides
- Leave refugia for SS (no wall-to-wall apps)
- Treat only most susceptible life stage

Resistance Management Strategies

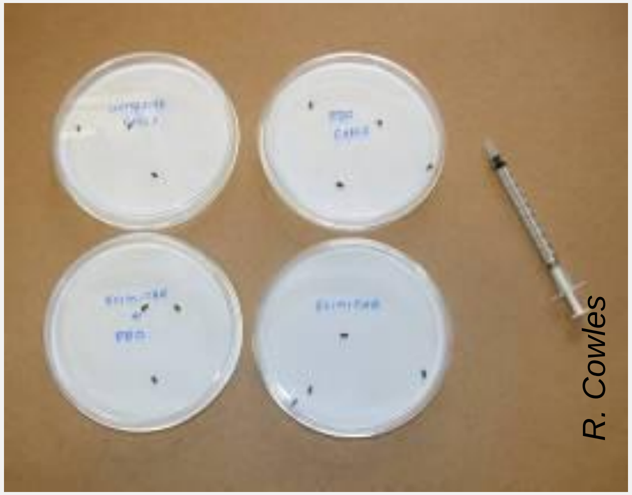
6. MoA rotation:

- **Do not use same MoA more than once per generation**
- **Do not use same MoA vs. consecutive generations.**
- Same MoA should skip several generations, the more the better.
- May lead to reduction of R, but only if fitness cost involved with R

Resistance Management Strategies

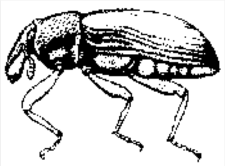
7. Field monitoring of resistance:

- By the time resistance obvious through failures, R frequency too high for implementation of effective and simple resistance management → more drastic changes required.
- Petri dish test detects ABW resistance but not sensitive enough to determine level of resistance
- More sensitive tools in development



R. Cowles

Resistance in ABW

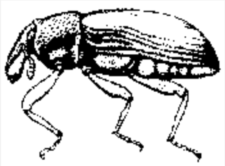


- On GCs with history of intensive insecticide use, particularly of pyrethroids
- Resistance seems primarily based on increased enzymatic detoxification.
- **Continued intensive insecticide use**

  → involvement of up to 3 detox. systems

  → up to 343x rate required to kill in lab tests !!!

Resistance in ABW



- **Increased detoxification particularly problematic because not very specific**

  → Cross-resistance very common !!

  → In extreme cases most available AIs affected !!!

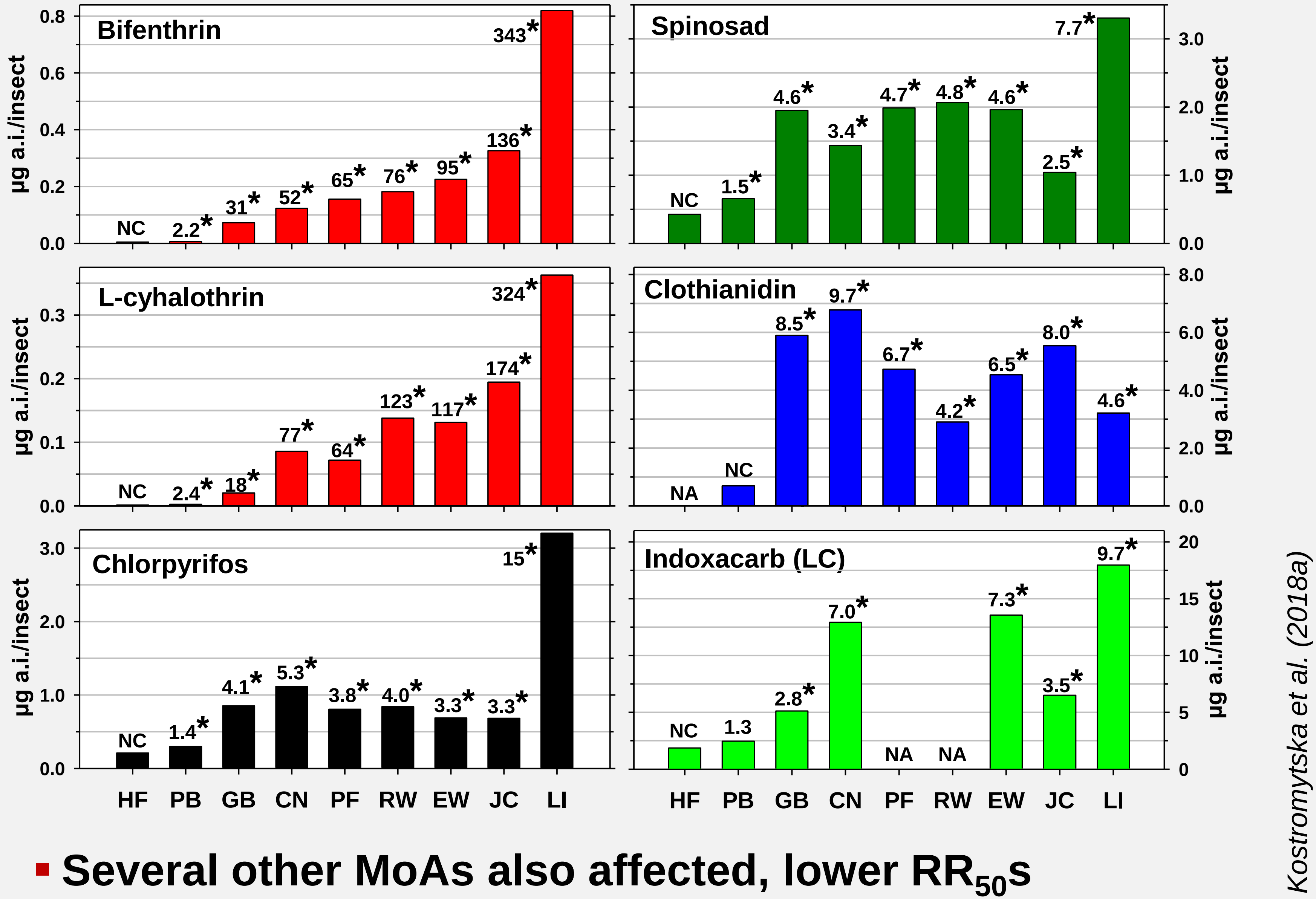
  →MoA rotation no guarantee for resistance delay

- **Limited resistance to chlorpyrifos (up to 20x) already observed**.

Baseline susceptibility and cross resistance

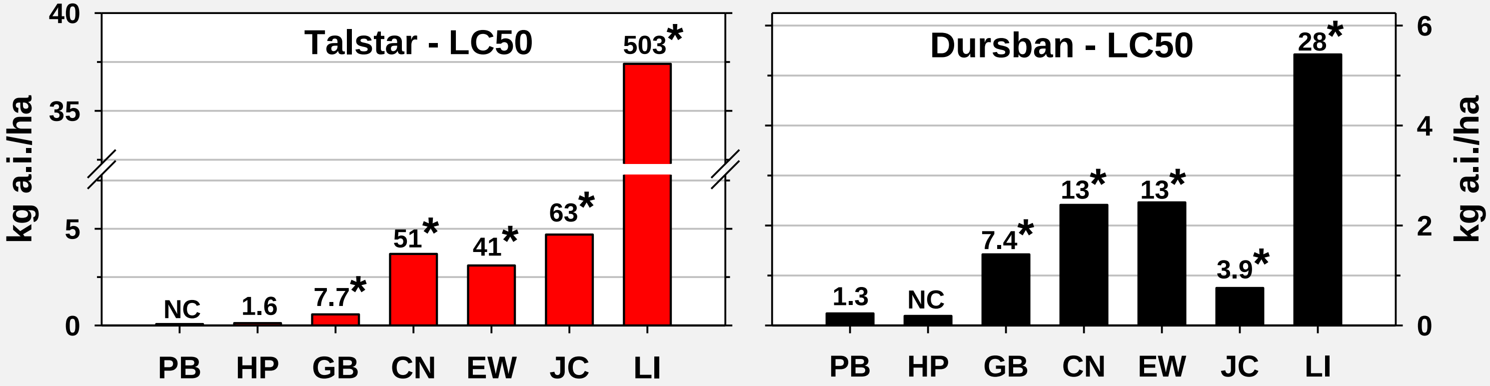
- **Topical bioassay to determine LDs (≤ 72 h) for important AIs.**

Topical Assay LD_{50} / RR_{50} @ 72 h



- Several other MoAs also affected, lower RR_{50}s

Greenhouse Assay LC_{50} / RR_{50} @ 72 h



- **RR_{50}s similar in greenhouse**

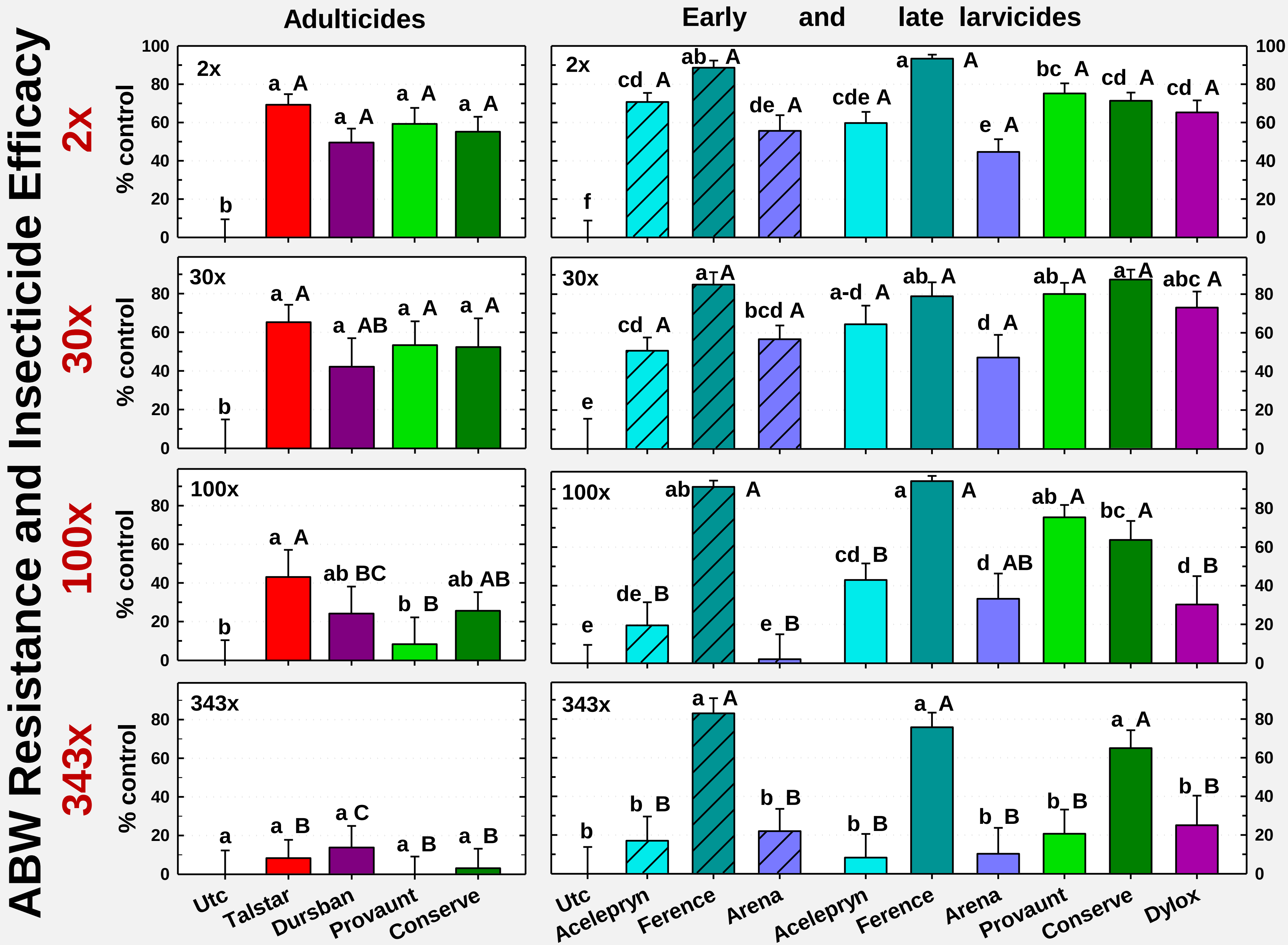
Kostromytska et al. (2018a)

Field efficacy vs. ABW populations with different resistance levels

Field efficacy vs. ABW populations with different levels of resistance

Insecti-cide class	AI	Trade name	Rate (lb ai/ac)	Targets Ad / L1 / L3		
				Ad	L1	L3
Pyrethroid	Bifenthrin	Talstar	0.100	X		
Organo-phosphate	Chlorpyrifos	Dursban	1.000	X		
	Trichlorfon	Dylox	6.000			X
Spinosyn	Spinosad	Conserve	0.400	X		X
Oxadiazine	Indoxacarb	Provaunt	0.225	X		X
Anthranilic diamide	Chlorantraniliprole	Acelepryn	0.156		X	X
	Cyantraniliprole	Ference	0.156		X	X
Neonicotin.	Clothianidin	Arena	0.247		X	X

Koppenhöfer et al. (2018)



Koppenhöfer et al. (2018)

Resistance - Recommendations

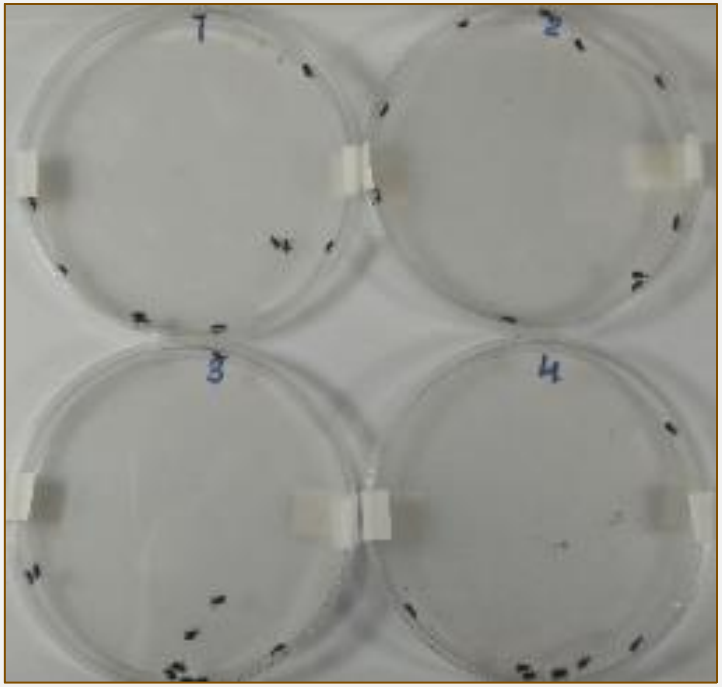
- Reduce synthetic insecticide use.
- Shift control measure more towards larvae.
- RR_{50} > 50: concentrate on larvae using Ference (L1-4), Conserve/MatchPoint (L3-4), Provaunt (L3-4) (and Dylox [L3-4]).
- RR_{50} > 100: Ference (L1-4), Conserve/ MatchPoint (L3-4) (and Provaunt [L3-4]).
- RR_{50} > 100: rotate with biorationals!

Koppenhöfer et al. (2018)

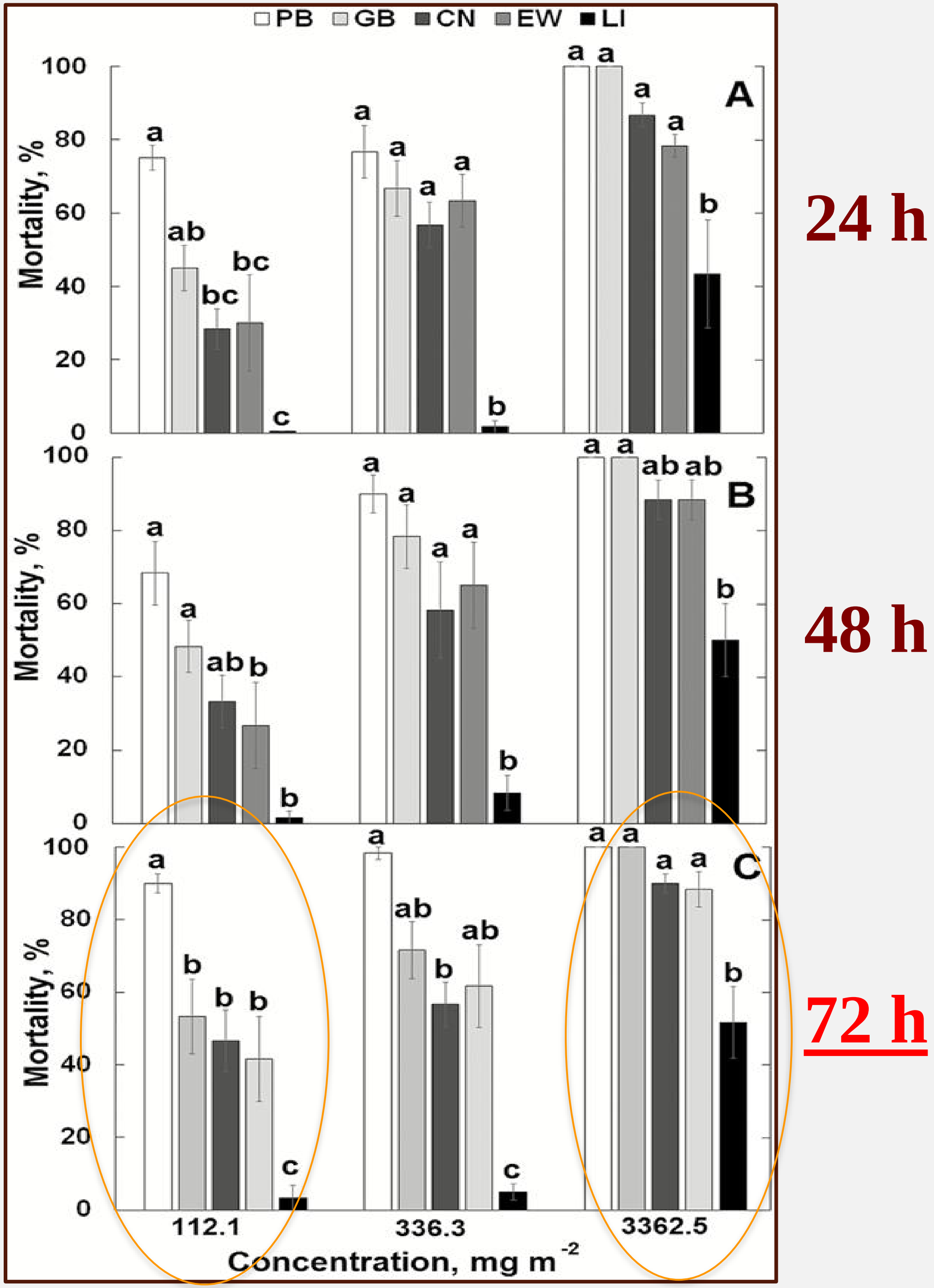
Petri dish Validation Assay

9 cm dish, 1 filter paper
1 ml solution, 10 adults

Bifenthrin (Talstar)



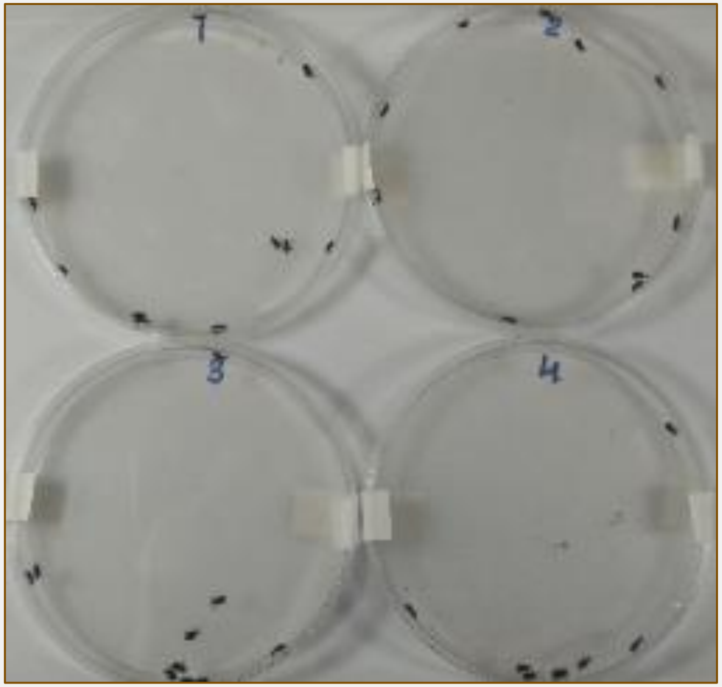
Kostromytska et al. (2018b)



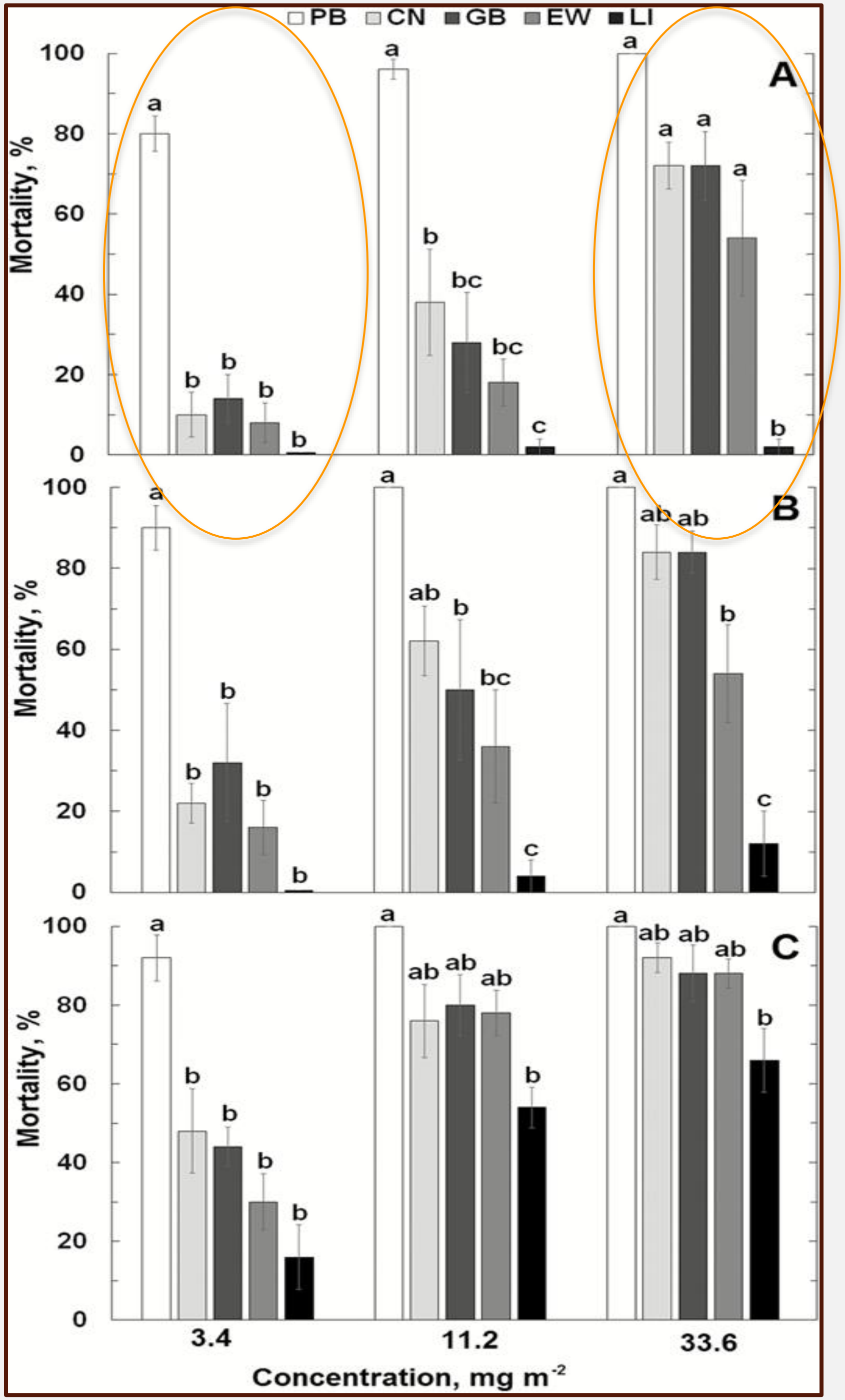
Petri dish Validation Assay

9 cm dish, 1 filter paper
1 ml solution, 10 adults

Chlorpyrifos



Kostromytska et al. (2018b)



24 h

48 h

72 h

Resistance Level Assay - Conclusions

- Petri dish assay easy option for ABW resistance detection and monitoring
  - Sufficient discriminating power
  - Easy to set up and conduct
- One rate to separate susceptible and resistant population
- Two rates to estimate resistance level

Don’t breed your own Super Weevil !!!

1. DON’T do repeated applications with the same insecticide class (e.g. pyrethroids, OPs).

2. DON’T exceed label rates.

3. DON’T do ‘wall-to-wall’ applications.

4. Spray as little as possible by practicing good Integrated Turf Management

Rutgers New Jersey Agricultural Experiment Station

ABW Biology and Control

- Biology, ecology, damage
- Monitoring
- Insecticide resistance
- **Sustainable management: non-resistant ABW**
- Sustainable management: resistant
- Biorationals

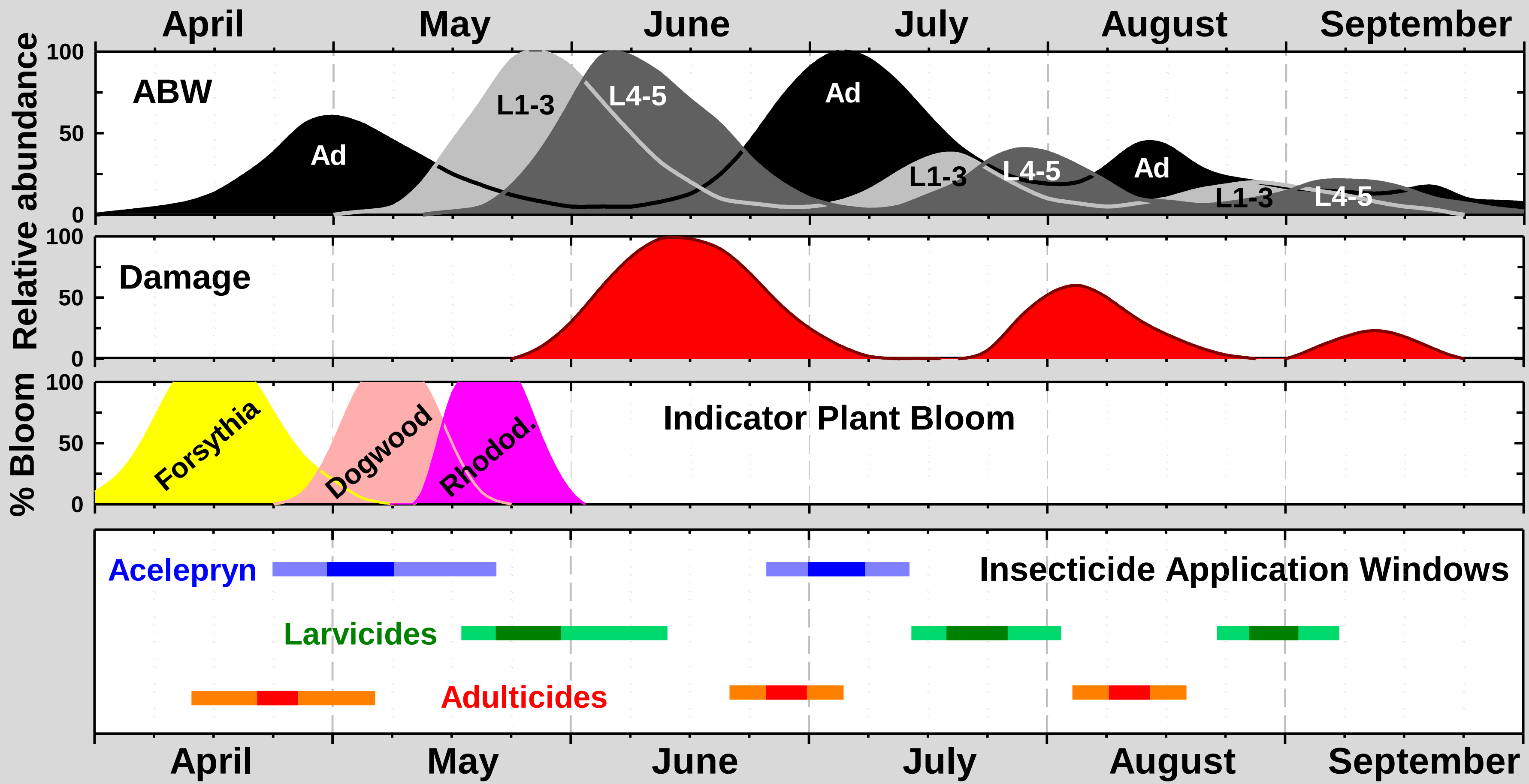

Most Successful Programs:
1. Include monitoring to make decisions
2. Minimize sprays – in time & space
3. Get good 1st generation control of larvae
B. McGraw

To Get Good Control…
Monitoring is Essential !!

- *Forsythia* still a good predictor
  - – Start of migration (FULL BLOOM)
  - – Peak densities = ½ Gold, ½ Green
- Combine with insect counts
  - – Soapy flushes, vac sampling, pitfall traps

B. McGraw

Ideal Timing of ABW Applications
(Timing for NY metropolitan area)



*Ad = adult; L1-3 = 1st – 3rd larval stage; L4-5 = 4th – 5th larval stage
Larvicides: Conserve, Provaunt, Dylox
*Adulticides: Pyrethroids, chlorpyrifos, Conserve, Provaunt

Koppenhöfer et al. 2012

Why 1st Generation Control is Important

- Overwintering adults can lay many eggs over many weeks
  - Avg. 60 to 90 eggs/female
  - Over up to 15 weeks
- Overlap in stages decrease effectiveness of controls
  - Larvae protected in stem
  - Pupae not susceptible

Does it make sense to apply adulticides before adult densities peak on playing surface?

- NY: 3-year study:
  - Few adults feed on migration
  - Adults don’t lay eggs before peak densities reached
- Our recommendation: Wait for peak adult densities!

Problems with pre-peak applications

- unnecessary kill of beneficials
- increased exposure of adult ABW to sublethal insecticide concentrations

→ less control

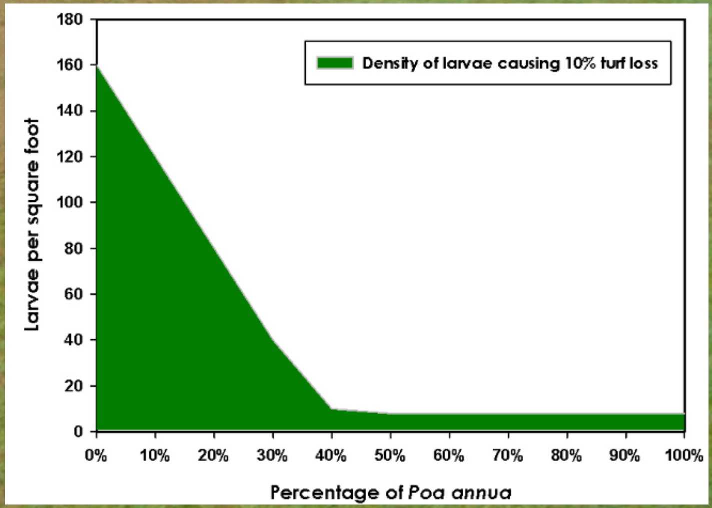
→ additional applications

→ faster resistance development !!

Sustainable ABW Management

Most effective and sustainable option:

- Work to **reduce *Poa*** as much as possible wherever possible.
- Start on fairways.

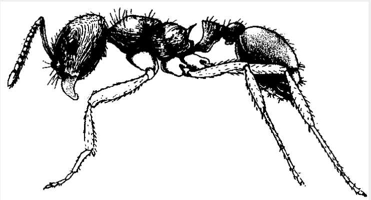
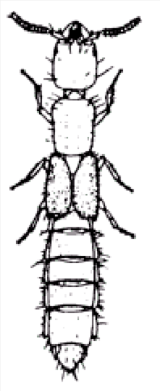
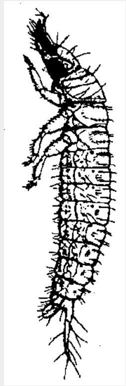


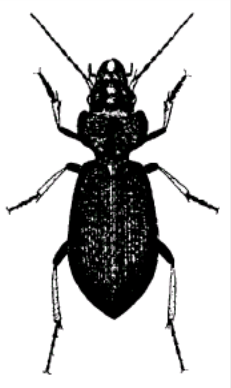
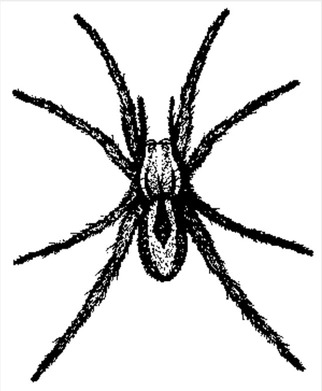
Sustainable ABW Management

- **<u>Minimize adult treatments</u>**
- **<u>Concentrate on larvae</u>**

→ Allows more precise monitoring → more targeted treatments → less R selection

→ Softer on natural enemies → rebuild safety net of biological control → less R selection

Managing non-resistant ABW
while reducing risk for resistance development

- Tailor applications to pest pressure.
- You cannot eradicate ABW!
- Excessive insecticide use may release ABW (and other pests) from suppression by natural enemies and can lead to resistant populations.

→ Don't follow a 'program' blindly.

→ Monitor populations throughout season

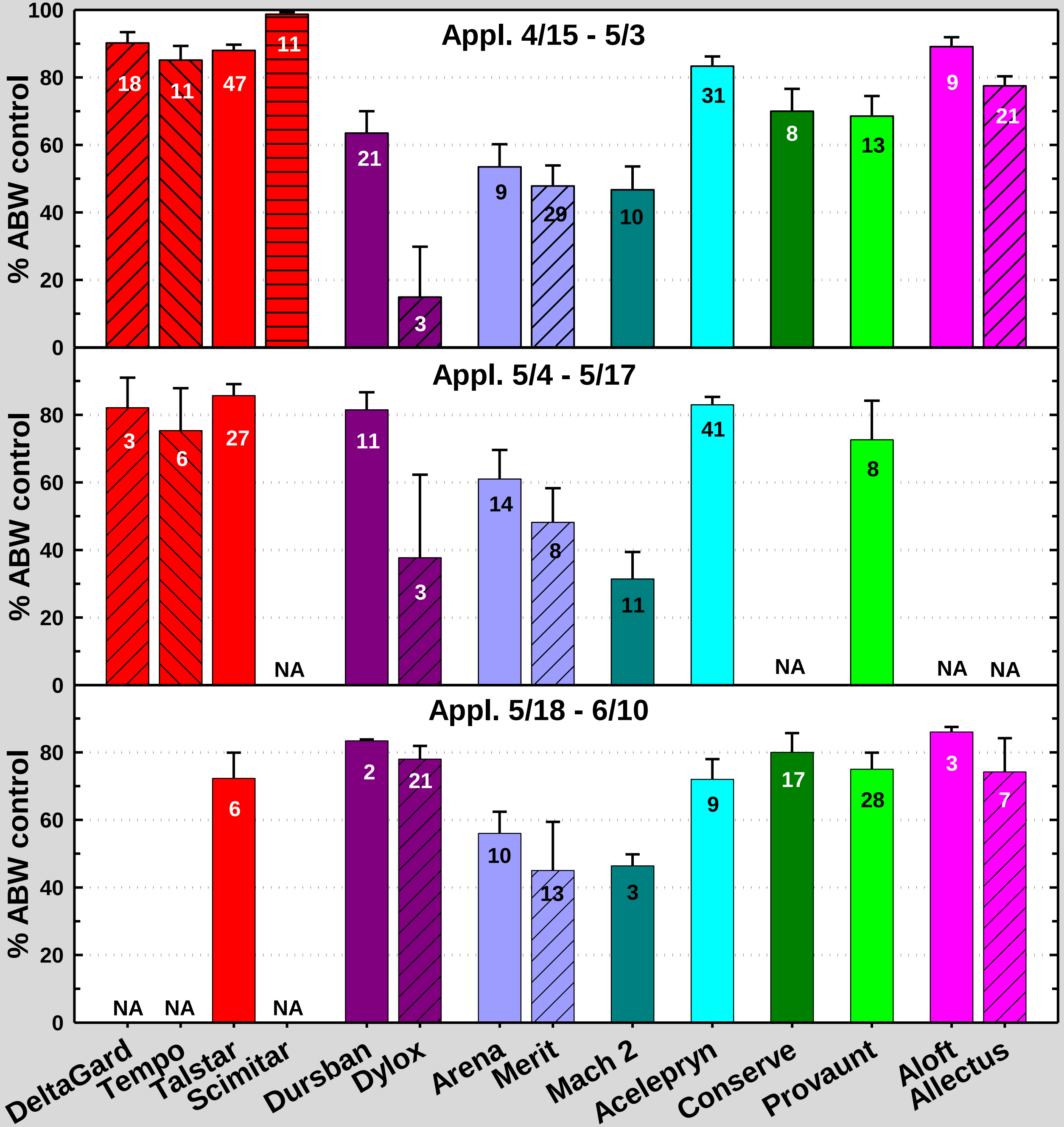
→ Applications only when/where needed.

Risk assessment

Determine risk for ABW damage based on:

- Percentage *Poa annua* in turf area
  → *P. annua* particularly susceptible
- History of ABW problems
  → tend to show up in same areas.
- Monitoring
  → base treatment decisions on observed larval and/or adult densities.

Insecticide Efficacy vs. ABW



DeltaGard (deltamethr.)
Tempo (cyfluthrin)
Talstar (bifenthrin)
Scimitar (λ-cyhalothr.)

Dursban (chlorpyrifos)
Dylox (trichlorfon)

Arena (clothianidin)
Merit (imidacloprid)

Mach 2 (halofenozide)

Acelepryn (chlorantraniliprole)

Conserve (spinosad)

Provaunt (indoxacarb)

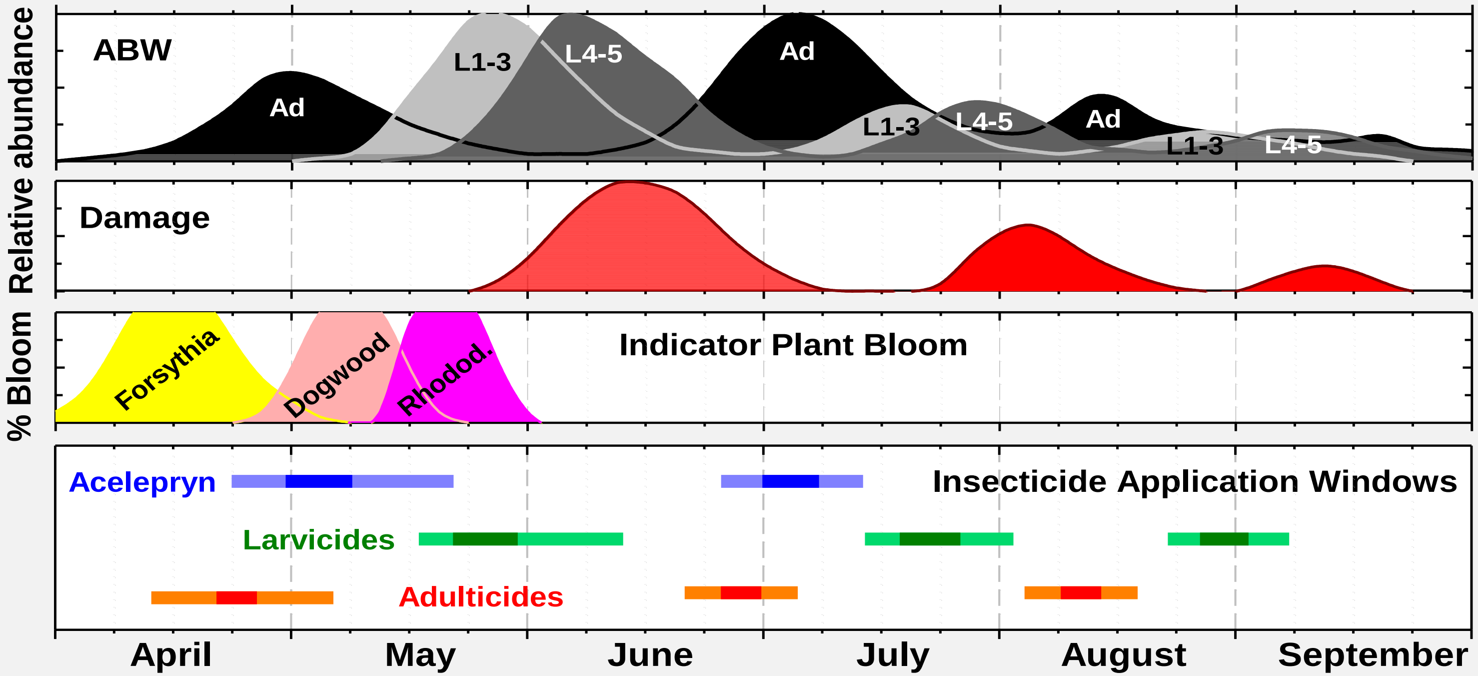
Aloft (clothia.+bifen.)
Allectus (imida.+bifen.)

Koppenhöfer et al. 2012

ABW +/- preventive white grub management

- If no preventive white grub (WG) management or if limited overlap in space → manage separately.
- If large areas receiving preventive white grub treatments also at risk from ABW → coordinate management to reduce treatments.

Managing non-resistant ABW

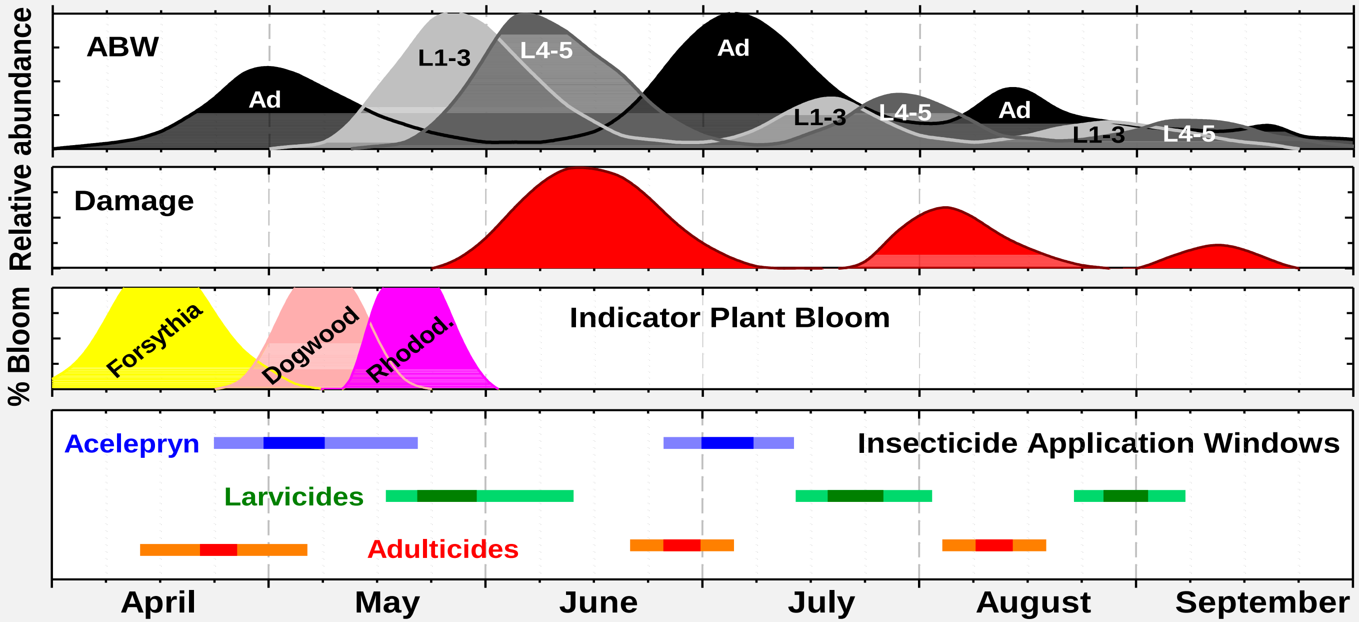


1. ABW management only & low ABW risk:

- Monitor for larvae (full to late bloom Rhodod.).

- If significant densities → larvicide.

Managing non-resistant ABW



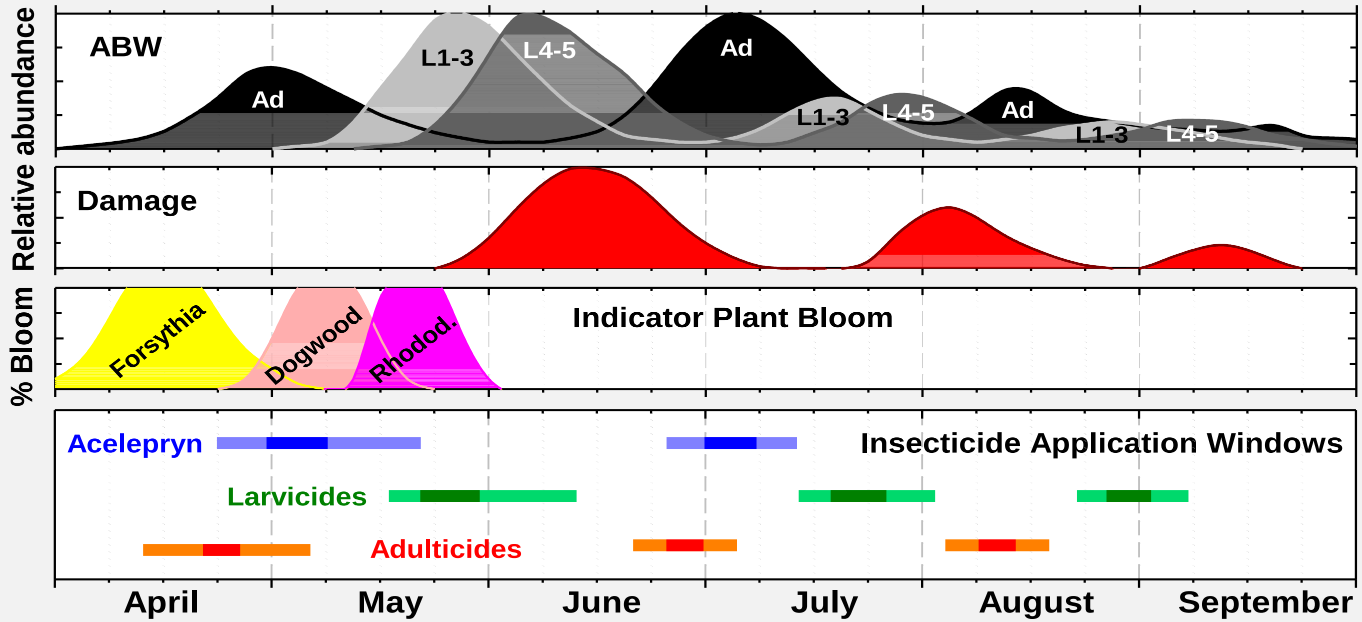
2. ABW management only & <u>higher</u> ABW risk:

- Monitor for adults (until forsythia ½ gold : ½ green).

- If significant densities → Acelepryn / Ference / Tetrino (late bl. dogwood/eastern red bud).

- In areas with particularly high risk, monitor for larvae and apply another larvicide if necessary.

Managing <u>non-resistant</u> ABW (Not LI-NY)



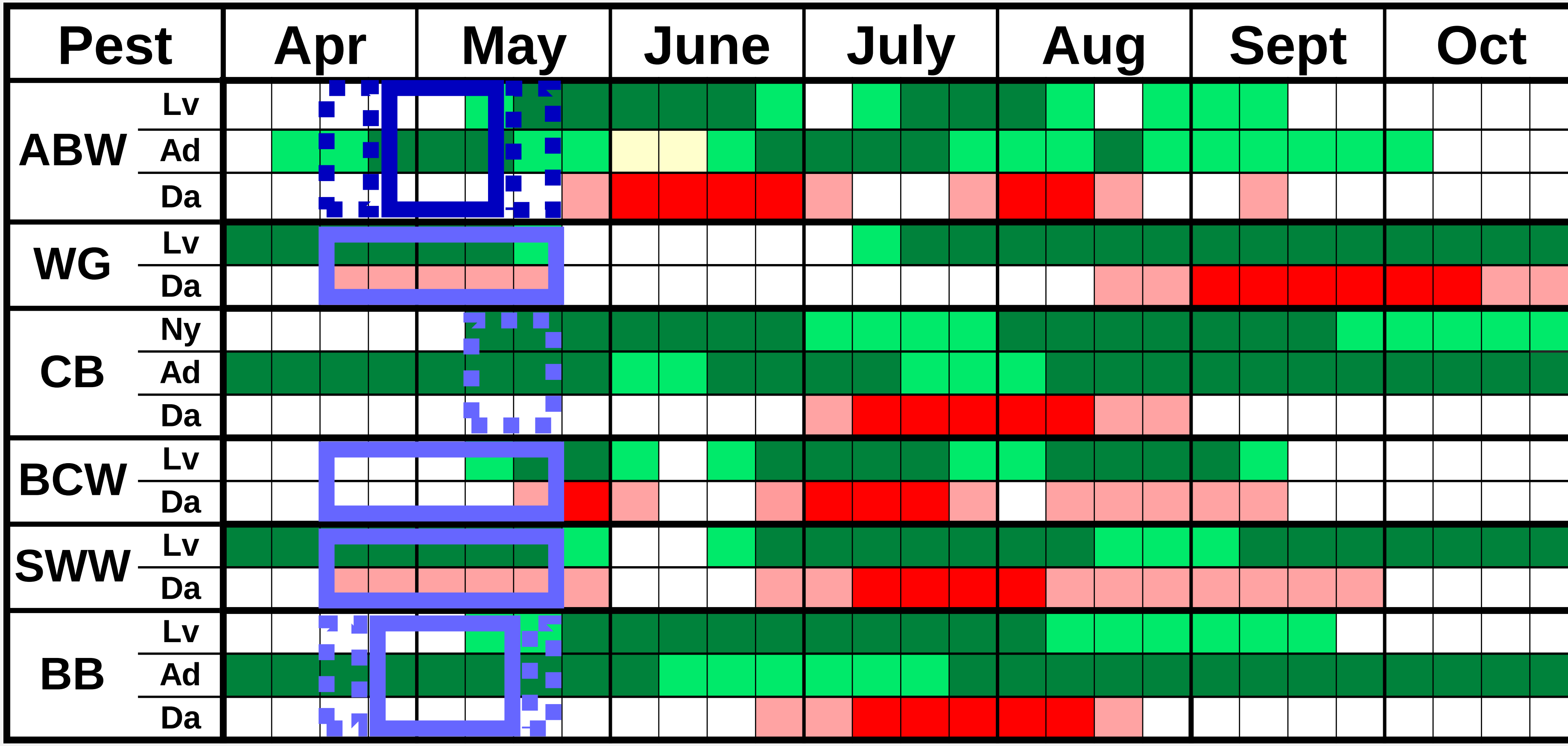
3. ABW & preventive WG management <u>combined</u>:

- Apply Acelepryn (at onset full bl. dogwood): 0.1 lb ai/ac for WG + 0.06-0.1 lb ai/ac for ABW areas

- Areas with very high ABW risk, monitor for larvae and, if necessary, apply another larvicide.

- Rotate every ~3rd year: neonicotinoid for WG → ABW separately.

Multi target - Key pest: *ABW*



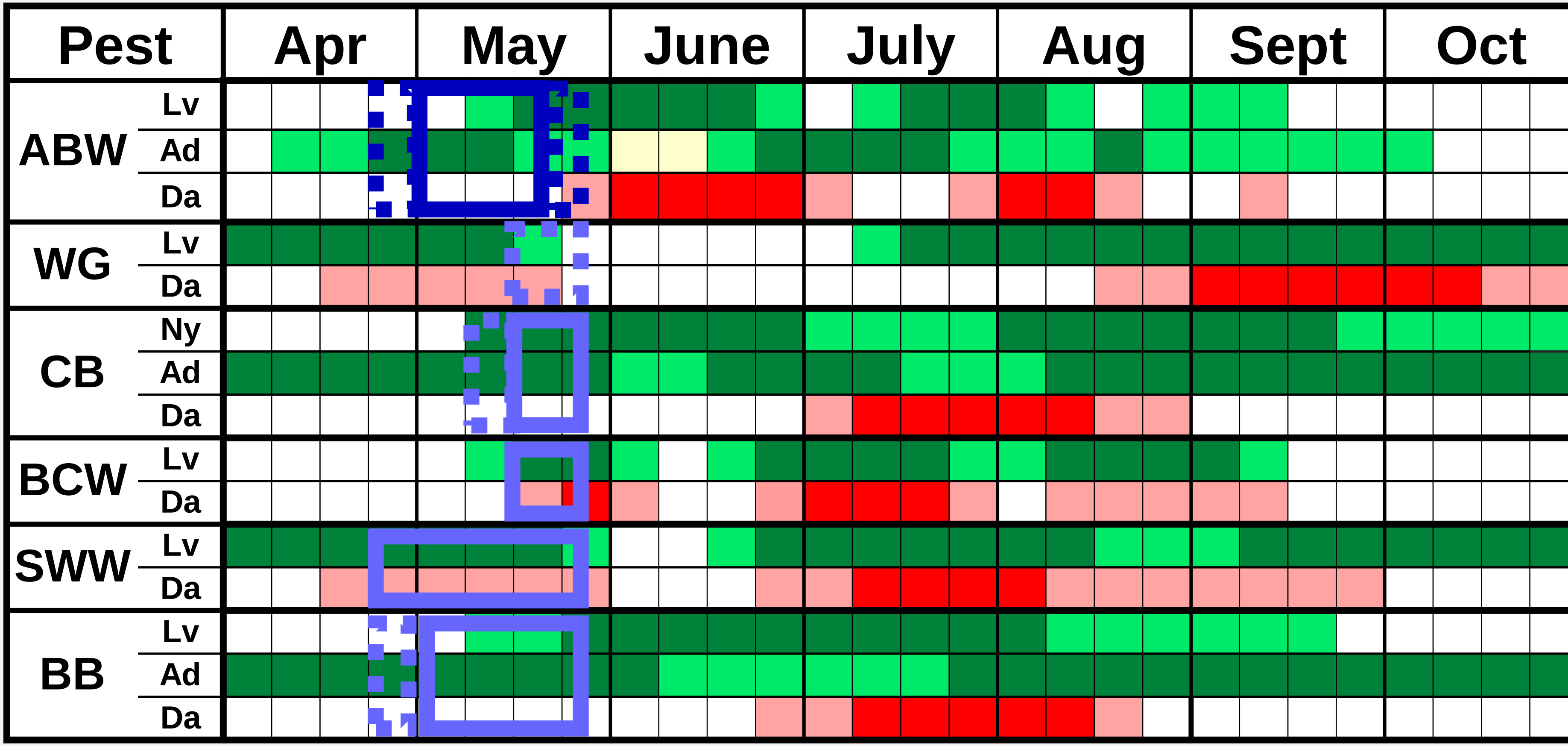
- Acelepryn: ABW control @ 0.16 lb ai/ac

→up to 0.26 lb ai/ac for early and late applications

→also WG, SWW, BCW, BB control

→CB only suppression

Multi target - Key pest: *ABW*



- <u>Tetrino</u>: ABW control @ 0.045-0.09 lb ai/ac

→ 0.09 lb ai/ac for early and late applications

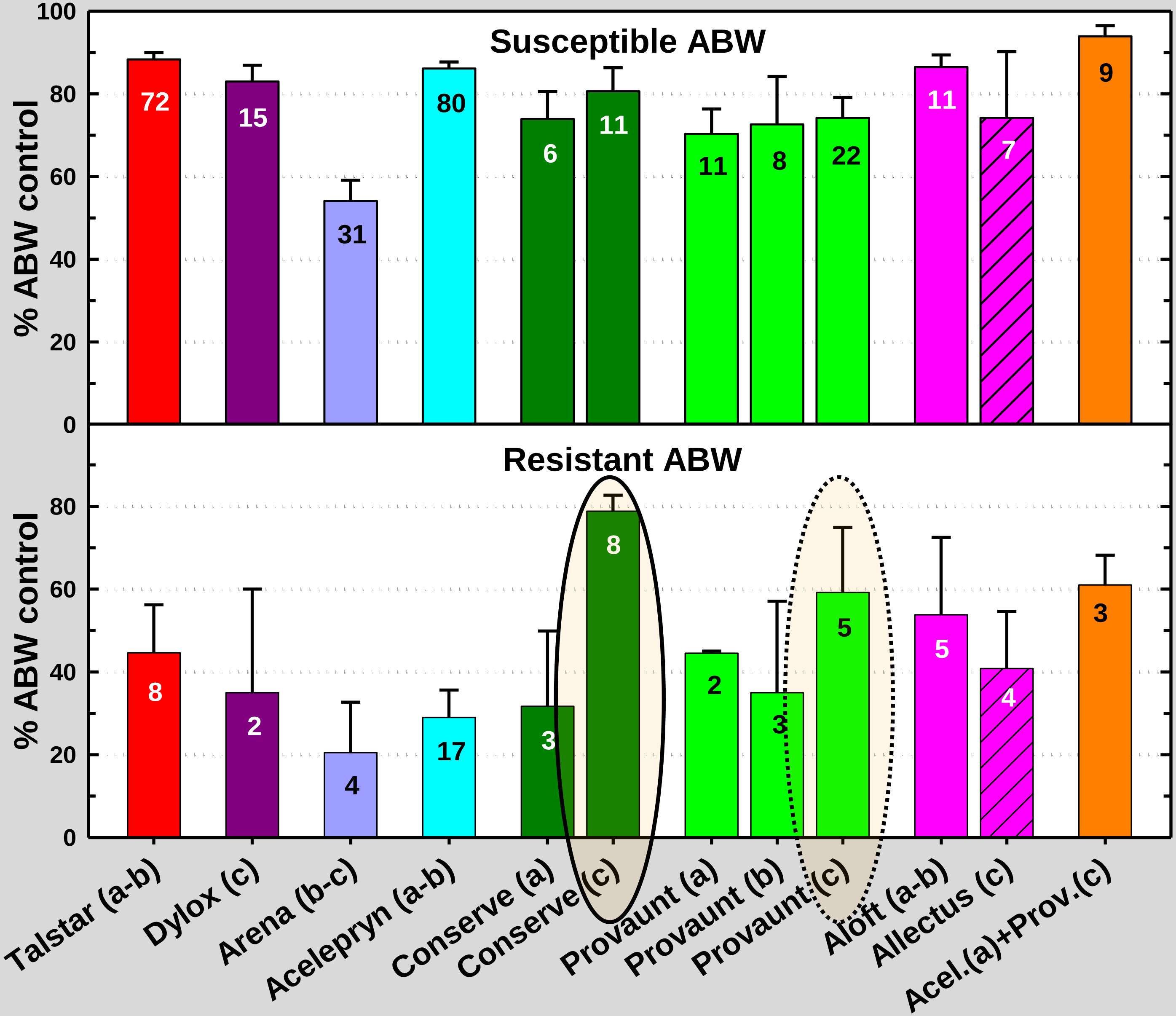
→ also CB, BCW, SWW, BB control

→ WG suppression (too early)

ABW Biology and Control

- Biology, ecology, damage
- Monitoring
- Insecticide resistance
- Sustainable management: non-resistant
- **Sustainable management: resistant ABW**
- Biorationals

ABW Resistance and Insecticide Efficacy



*a, b, c = ~4/15-5/3, ~5/4-17, ~5/18-6/10 application timing; NY Met. area

Koppenhöfer et al. 2012

Managing <u>resistant</u> ABW

- Chlorpyrifos less effective than pyrethroids vs. adults!!!
- Depending on degree of resistance, only effective compounds: MatchPoint and Ference vs. larvae (≥ 80% control).
- <u>BUT</u>: MatchPoint and Ference overuse likely to lead to resistance, too!!!
- **If you see something clearly not working: stop wasting time and money on it !!!**
- **NO MORE PYRETHROIDS !!!**

Managing resistant ABW – Strategy

- 1st year spring: MatchPoint or Ference to all playing surfaces with ABW damage history.

→ Ference full bloom dogwood thru late bloom rhododendron.

→ MatchPoint full to late bloom rhodo.

→ Water in: Ference / MatchPoint soon with 0.1”.

→ During summer apply only if high larval densities or onset of damage (monitor!!!)

→ Rotate MoAs

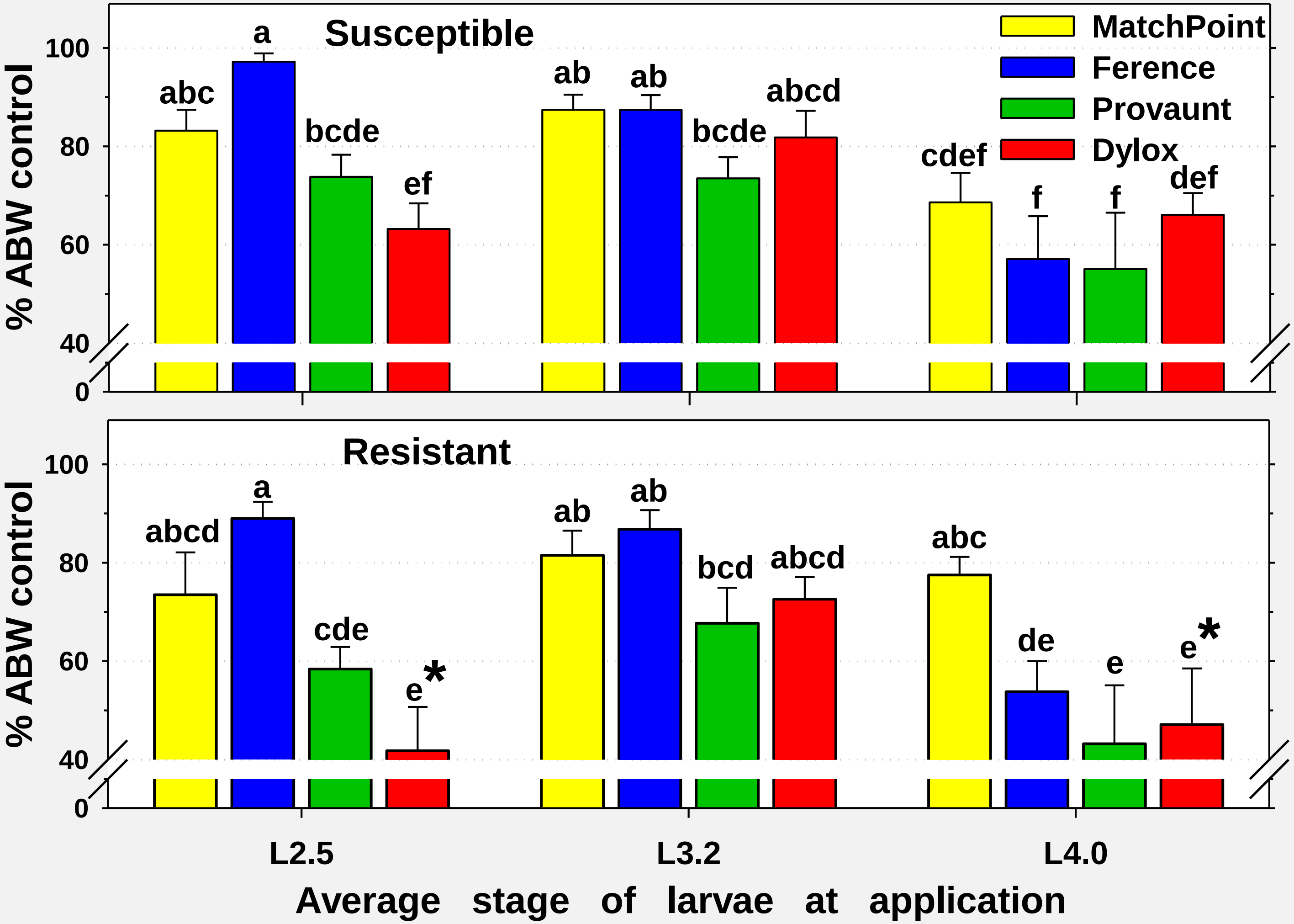
Managing resistant ABW – Strategy

- In following years, start reducing applications.
- Base treatments on monitoring.
- Start reducing treatments on fairways
- Then work your way up to higher profile areas.
- Rotate MatchPoint and Ference w/ Provaunt (test if still effective).
- In areas with moderate larval densities (< 70/ft^2) rotate with biorationals.

How late do larvicides work?
Why apply later?

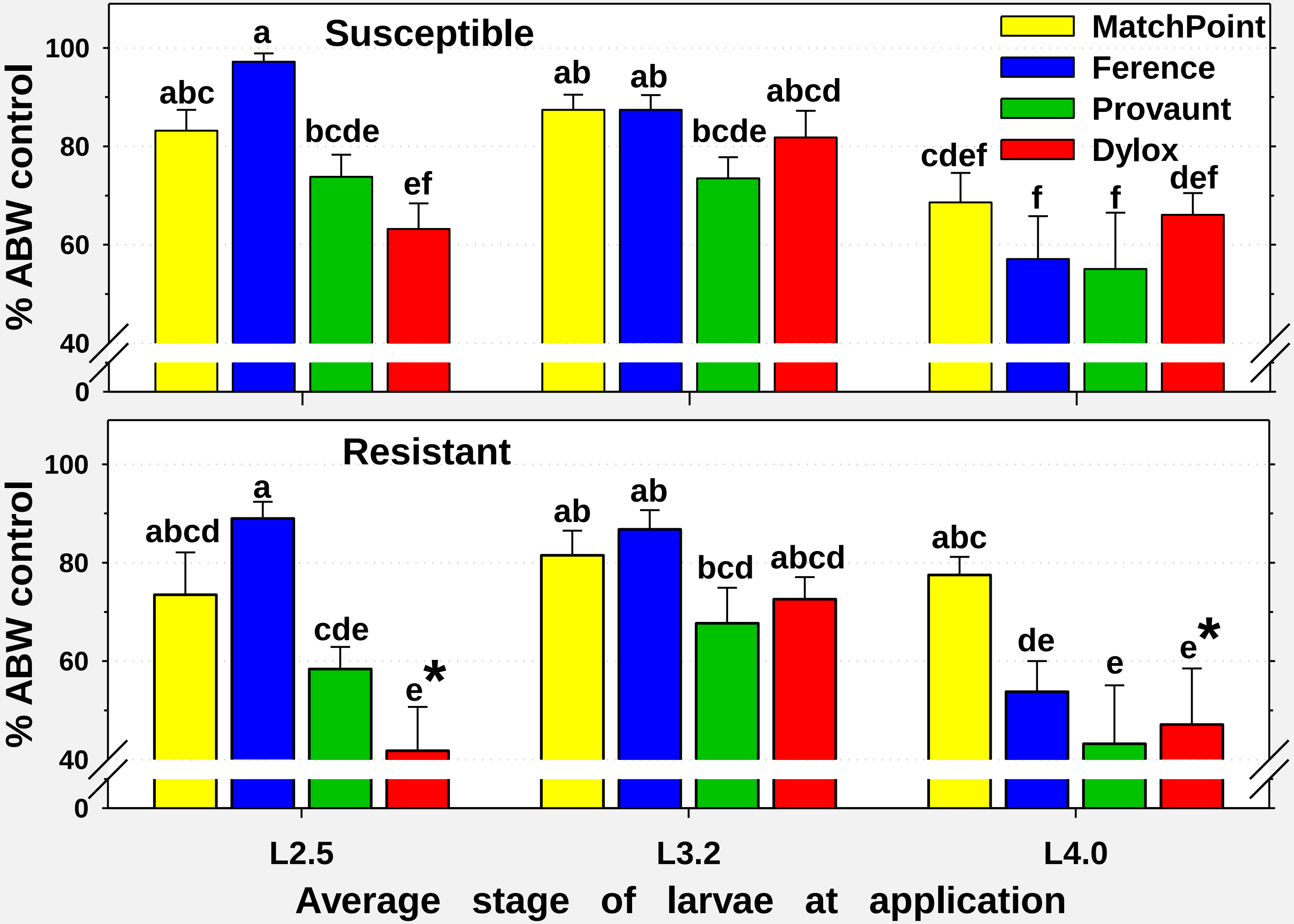
- Acelepryn, Ference efficacy: late bloom dogwood (L1.0) = start full bloom rhododendron (L2.5)
- Assessment of damage potential becomes easier and more precise.
- Late applications, if effective, cover a greater part of the population
- Sometimes infestations are missed until larvae large.

ABW larval stage average on insecticide efficacy – Field (2 years)



- L2.5: beginning full bloom Rhododedron
- L3.2: ~ 1 wk into full bl. Rhodo.
- L4.0: just past bloom; ~ 2 wk after beginning

ABW larval stage average on insecticide efficacy – Field (2 years)



- MatchPoint: L2.5, L3.2 ≥ L4.0
- Ference, Provaunt: L2.5, L3.2 > L4.0
- Dylox: L2.5 < L.3.2 > L4.0

Timing- Summary / Recommendations

- Ference, Acelepryn: L1.0 = L2.5.
- Ference, MatchPoint, Provaunt: L2.5 = L3.2
- Dylox: L3.2 > L2.5
- L4.0 generally lower but MatchPoint best

→ Concentrate on larvae

→ Assess damage potential at start of or during full bloom rhododendron

→ If necessary, apply asap

→ → Less applications, less resistance development

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ABW Biology and Control

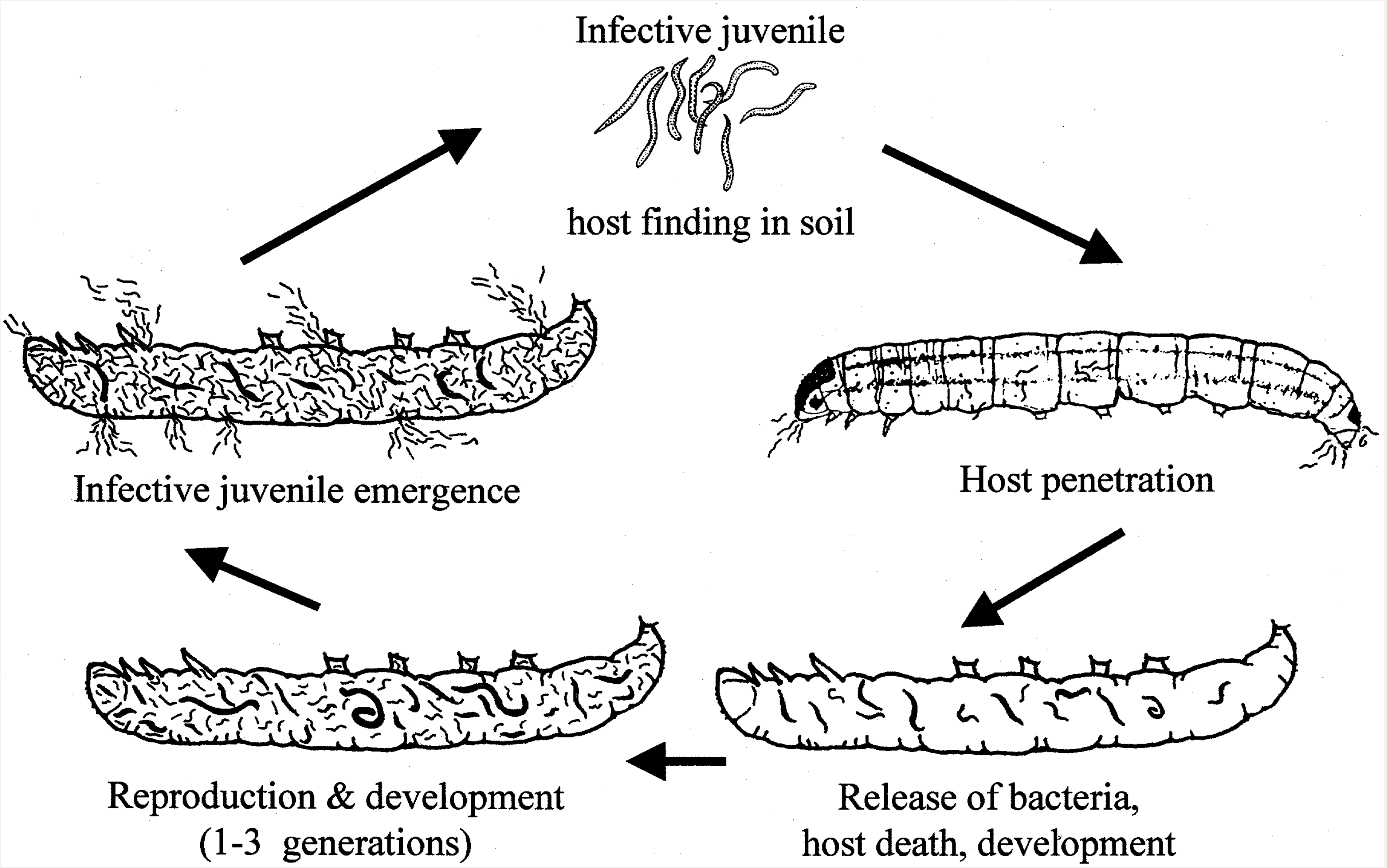
- Biology, ecology, damage
- Monitoring
- Insecticide resistance
- Sustainable management: non-resistant
- Sustainable management: resistant
- **Biorationals**

Entomopathogenic nematodes (EPN)

- obligate lethal parasites of insects
- mutualistic association with bacteria
- > 26 *Heterorhabditis* & 100 *Steinernema* spp.
- host searching capacity
- host range +/- broad
- ease of production
- recycling capacity


Infective juvenile nematodes

Entomopathogenic nematode life cycle



EPN Infections

Nematode products for US turf market

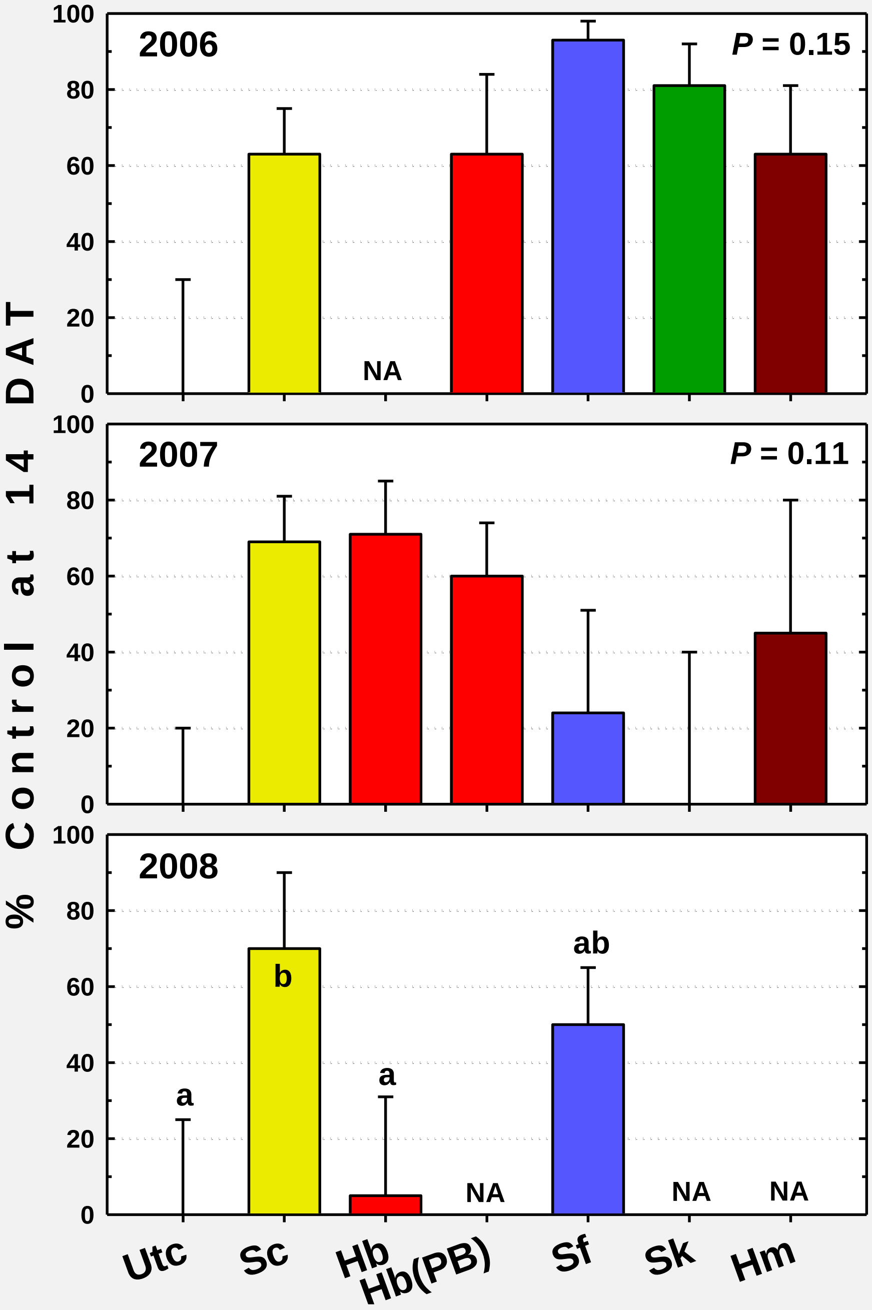
Nematode	Targets[1]	Product (Producer)
Steinernema carpocapsae	BCW, SWW, AW, BB, Fleas	Millenium (BASF), Capsanem (Koppert), Ecomask (BioLogic)
Heterorhabditis bacteriophora	WG, BB	Nemasys G (BASF), Terranem NAm (Koppert), Heteromask (BioLogic)

[1]BCW = black cutworm; SWW = sod webworm; AW = armyworm
BB = billbugs; WG = white grubs; MC = mole crickets

EPN vs. ABW larvae
- Fairway trials

vs. spring gen. L3-L5
2.5 b IJs/ha

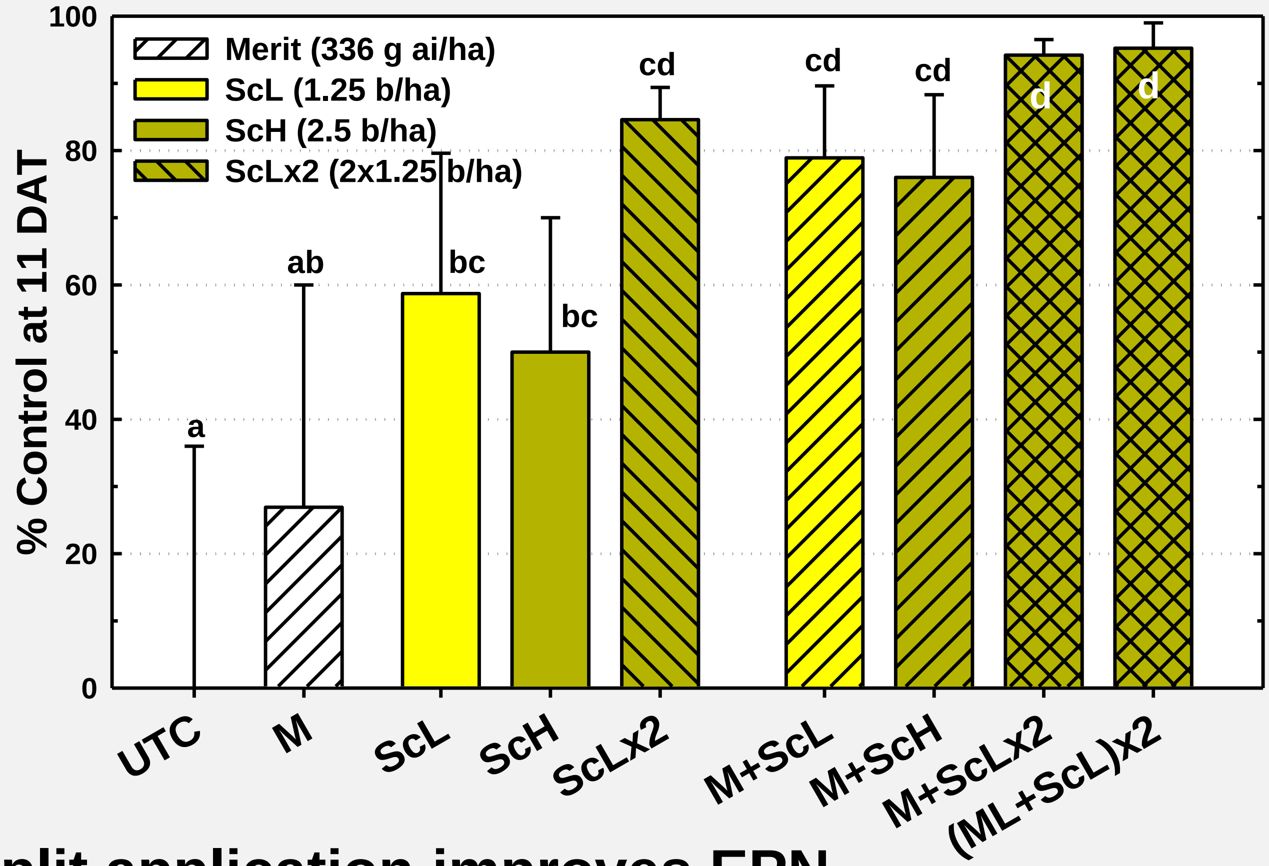
- ***Sc* most consistent suppression**



McGraw et al. (2010)

EPN + Merit - Field 2014

Merit: 0.3 lb ai/ac; EPN: 0.5 or 1.0 b IJs/ac



- Split application improves EPN
- Additive Merit-EPN interaction
- Merit + split *Sc* → excellent control
- Merit simultaneously controls white grubs

EPN vs. ABW

- ***Steinernema carpocapsae*** **or** ***Heterorhabditis bacteriophora*****.**
- **Apply when larvae start to appear in soil.**
- **If soil dry and/or hot, ~0.1" irrigation before application.**
- **~0.25" post-treatment irrigation.**
- **Keep soil moderately moist at least 1 wk.**
- **Split application tend to improve efficacy.**
- **No effect of resistance.**

Chromobacterium subtsugae

- GRANDEVO® CG ! - 30% ai
- ***C. subtsugae*** **strain PRAA4-1 and spent fermentation media**
- 2-4 lbs/ac f. surface feeders
- 10-20 lbs/ac f. white grubs
- OMRI approved
- **Activity vs. white grubs (varies with species), chinch bugs, billbugs, sod webworms.**

Burkholderia spp.

- VENERATE® XC ! – 94.46% ai
- ***Burkholderia* spp. strain A396 cells and spent fermentation media**
- For fruit and vegetables
- Turfgrass not on label yet
- OMRI approved
- **Activity vs. caterpillars and billbugs**

Azadirachtin

- Molt-x® – 3.0% ai
- ***Azadirachtin*, botanical extract from neem tree**
- 8-10 (max. 22.5) fl oz/ac
- OMRI approved
- **Activity vs. numerous insects incl. weevils**

Field Efficacy vs. ABW Adults

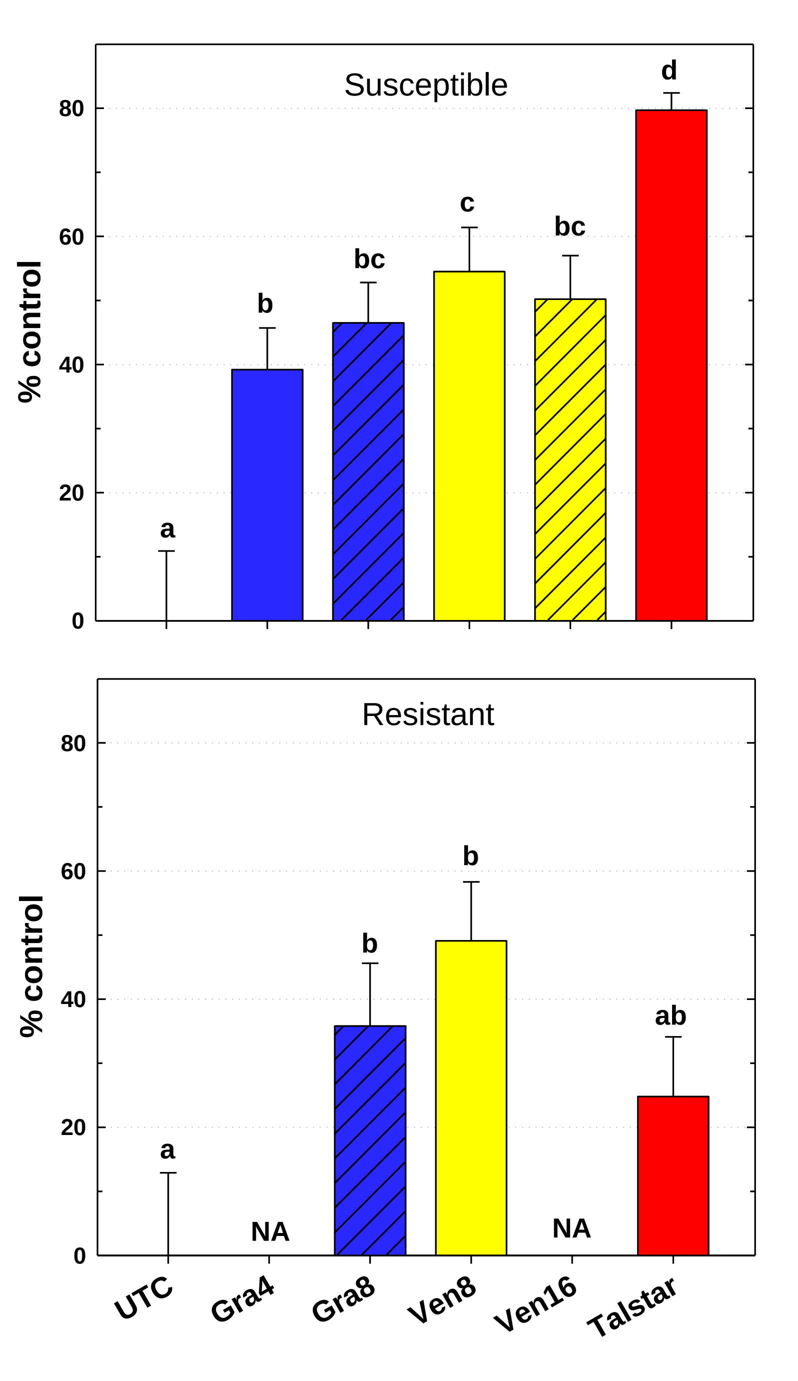
susceptible (2x)
resistant (60x)

Grandevo

2x 4-8 lbs/ac

Venerate

2x 8-16 pt/ac



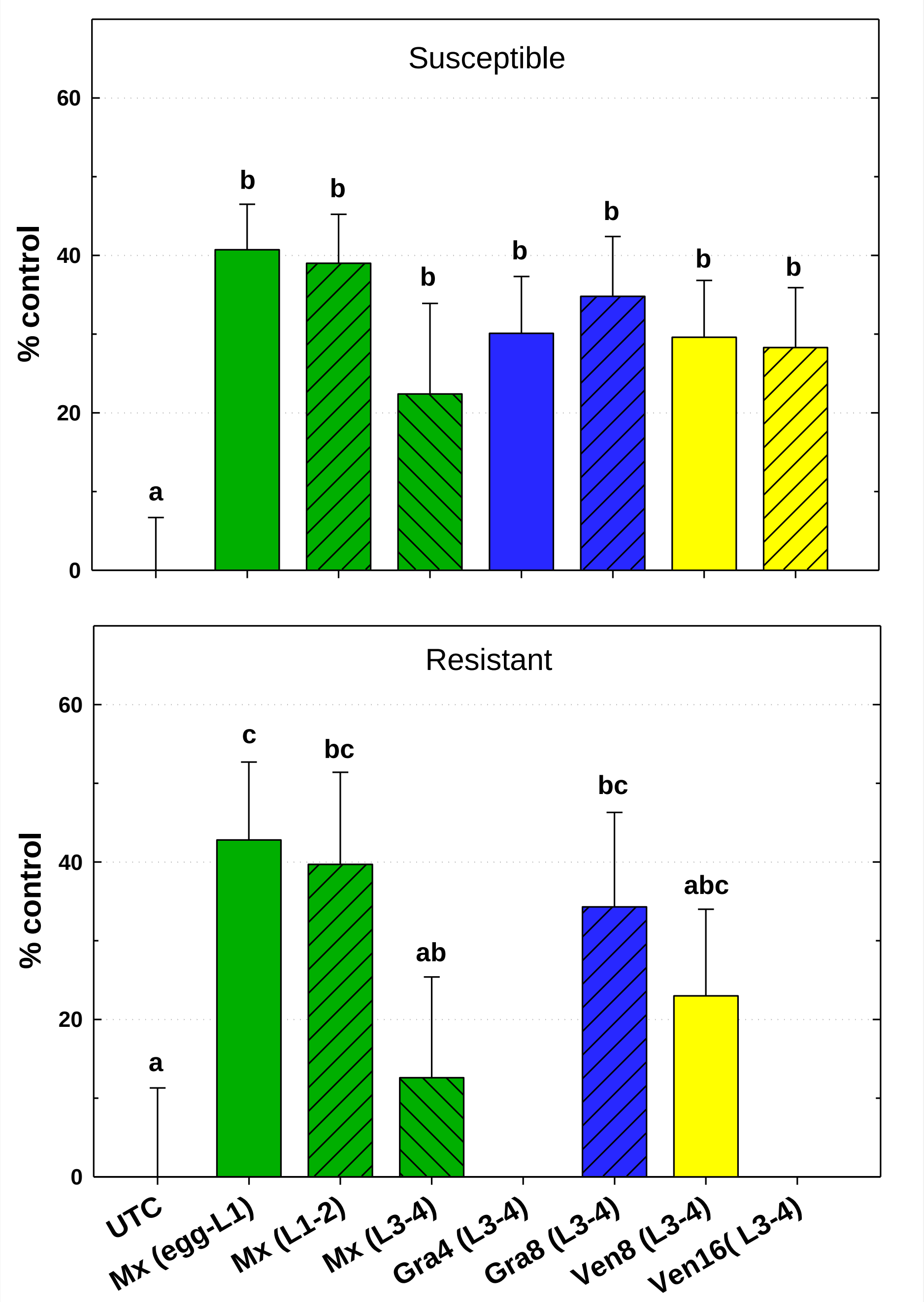
Field Efficacy vs. ABW Larvae

susceptible (2x)
resistant (60x)

Grandevo
2x 4-8 lbs/ac

Venerate
2x 8-16 pt/ac

Molt-X
2x 1.4 pt/ac



Civitas Turf Defense

a.i. Mineral oil (88.8%)

- Primarily fungicide, also insects on label
- Insects rec. 8.5 - 17 fl.oz. in 1.5 gal/1,000 ft^2
- Greenhouse: best if soil saturated, 2-4 gal/1000 ft^2 spray volume, 0.05-0.1” post-spray irrigation.
- Field results highly variable: 13-55% control. Probably best if 17 floz at peak adults or 2x 8.5 floz ~7 days apart around peak adults.
- Not affected by resistance

Entomopathogenic Fungi

- facultative lethal parasites of insects
- *Beauveria* & *Metarhizium* species
- host range +/- broad; many different strains


before spore germination after

***Metarhizium* sp. (white grub)**

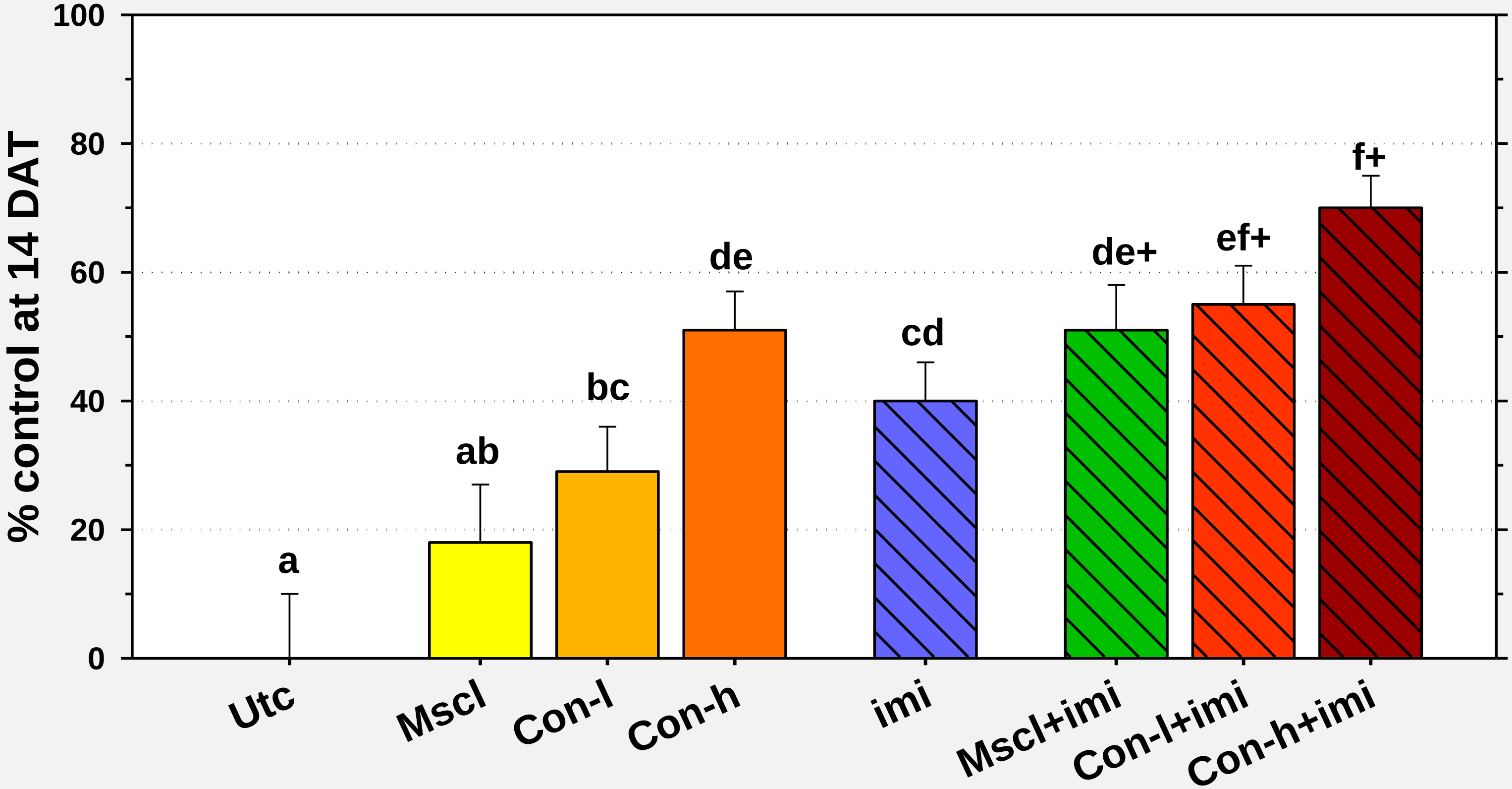
***Beauveria* sp. (chinch bug)**

F52 conidia-based liquid formulation

- Met 52 EC
- 11% a.i, 89% petroleum distillates
- ~5.5×10^{9} CFU g^{-1}
- Rec. field rates: 6.4-9.6 kg ha^{-1}
- Field rates: 9.6-19.2 kg ha^{-1}
  → ~$5\text{-}10\times10^{13}$ CFU ha^{-1}

Spring 2019 - field test

Mscl (50 kg/ha), imi (336 g ai/ha), Con-l/Con-h (9.6/19.2 kg/ha)



- **Microsclerotia: ineffective**
- **Imidacloprid: low efficacy**
- **Conidia: low efficacy**
- **Microsclerotia & Conidia + imi: additive mortality**

REMEMBER

- **Intensive insecticide use is very likely to lead to ABW resistance.**
- **Getting on the pesticide treadmill with ABW is a 1-way road that over time gets ever uglier and harder to leave.**
- **The sooner you leave the better !**
- **Best not to get there in the first place !**

Outlook: Turning ABW into an ally

- In mixed bentgrass-Poa annua fairways
- Monthly applications of low rate paclobutrazol (6-12 fl oz/acre) combined with ABW larvicides only when needed (threshold) dramatically reduce *Poa annua* with limited and short time negative effects on turf quality.

→ Ongoing research: at what Poa levels can ABW alone suppress Poa?

ABW+Paclo vs Poa - % Poa reduction in 1 year

Paclobutrazol (fl oz/A)	ABW Preventive	ABW Threshold	No ABWcides
0	---	**28** (20-37)	**44** (32-56)
4	**47** (33-61)	**70** (57-83)	**70** (56-79)
6	**55** (46-63)	**82** (72-92)	**82** (77-87)
12	**88** (84-93)	**78** (68-87)	**88** (87-90)

- High rate of Paclo most effective
- ½ rate Paclo with Threshold or No-Insecticides similar
- 1/3 rate Paclo w/ Threshold or No-Insecticides quite effective

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My Rutgers Entomology Webpage:

http://entomology.rutgers.edu/personnel/albrecht-koppenhofer/

→ Extension presentations

→ Extension publications

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