

**College of Agriculture and Life Sciences  
Cornell Cooperative Extension**

# In-Depth Look: Managing Diamondback Moth in the Face of Insecticide Resistance

**Brian Nault<sup>1</sup> and Christy Hoepting<sup>2</sup>**

<sup>1</sup>Dept. of Entomology, NYSAES, Geneva, NY

<sup>2</sup>CCE Cornell Vegetable Program

*Empire Producers Expo Cabbage Session: Syracuse, NY - January 17, 2017*



# Diamondback Moth (DBM)

- **Host range and damage**
- **Life history (life cycle and biology)**
- **Management strategies**
- **Results from a 2016 insecticide trial**
- **Guidelines for managing DBM following IRM principles**



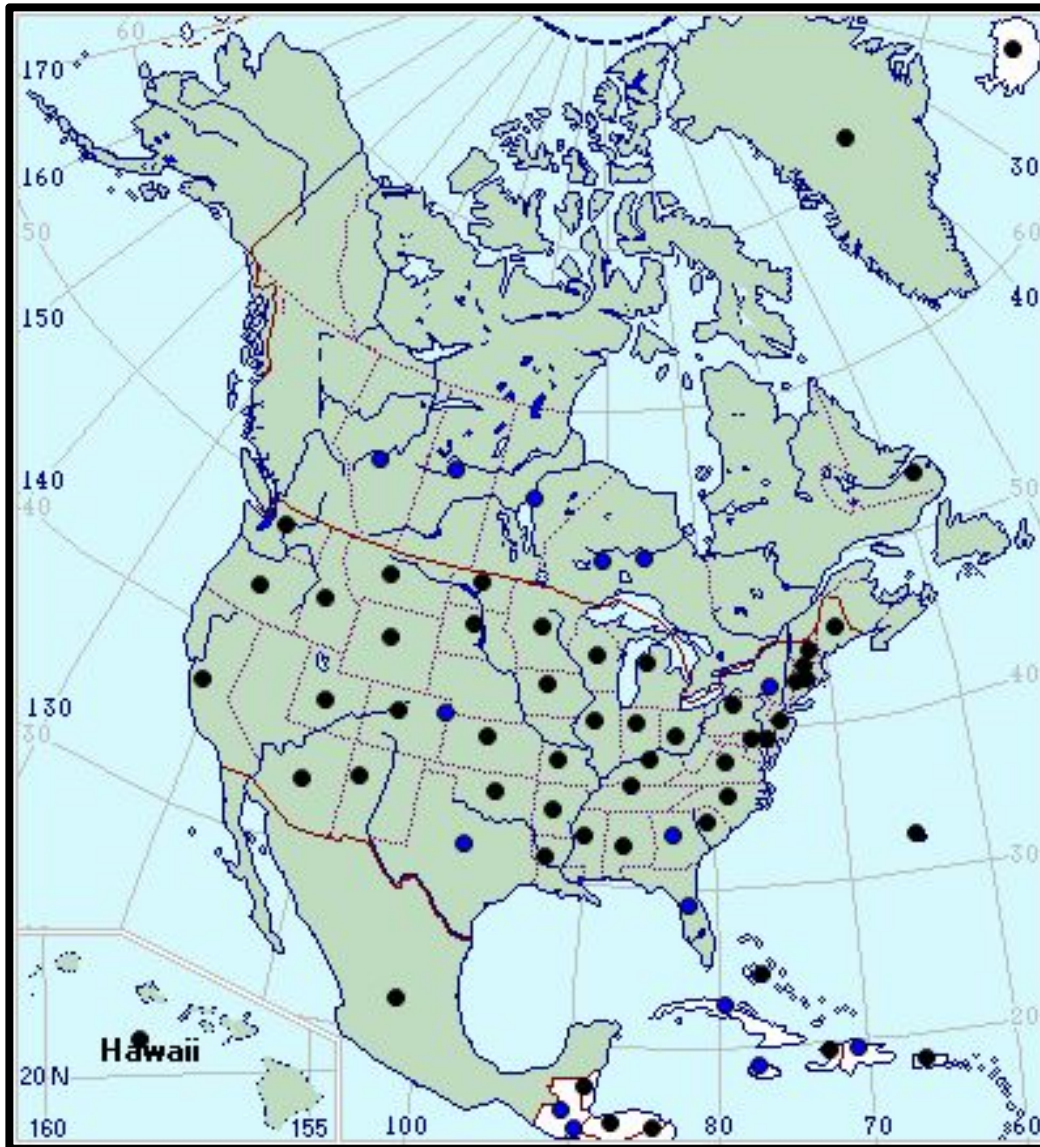
# Diamondback moth (DBM) (*Plutella xylostella*)



- **Estimated cost for managing DBM worldwide is US\$4–5 billion annually, while estimated annual cost in the US is US\$150–200 million**
- **Resistant to 95 insecticide active ingredients in >20 countries (as of 1/16/17)**



# Diamondback moth (DBM) (*Plutella xylostella*)



➤ A global pest that is distributed throughout North America



# Crops Attacked by DBM

- **Broccoli**
- **Brussels sprouts**
- **Cabbage**
- **Canola (rapeseed)**
- **Cauliflower**
- **Chinese cabbage**
- **Collards**
- **Kale**
- **Kohlrabi**



- **Mustard**
- **Radish**
- **Saishin**
- **Turnip**
- **Watercress**



# Diamondback moth damage to cabbage wrapper leaves



Photo: C. Hoepting



# Diamondback moth damage to cabbage head



Photo: C. Hoeping

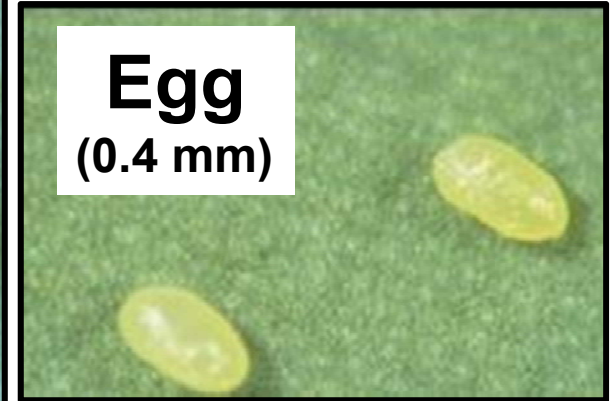


# Life Stages

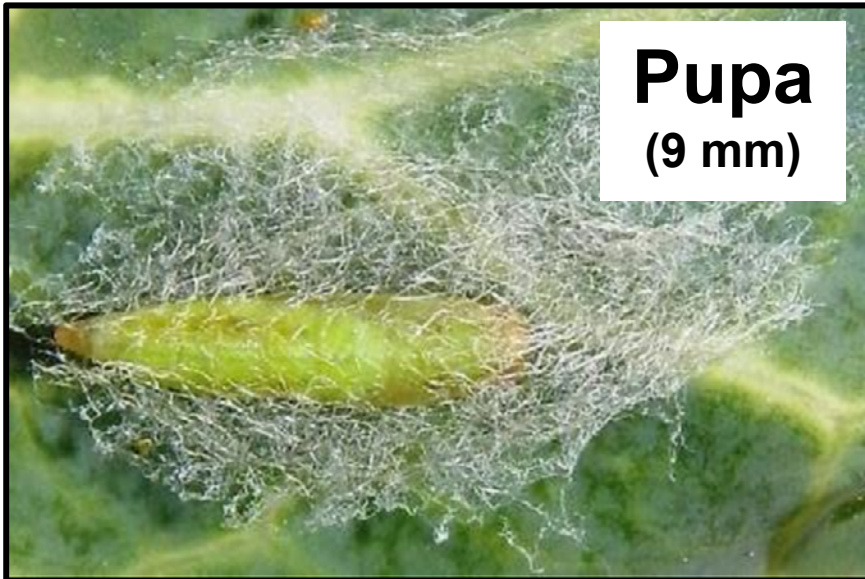
**Adult**  
(6 mm)



**Egg**  
(0.4 mm)



**Pupa**  
(9 mm)



**Larva**  
(2 to 11 mm)

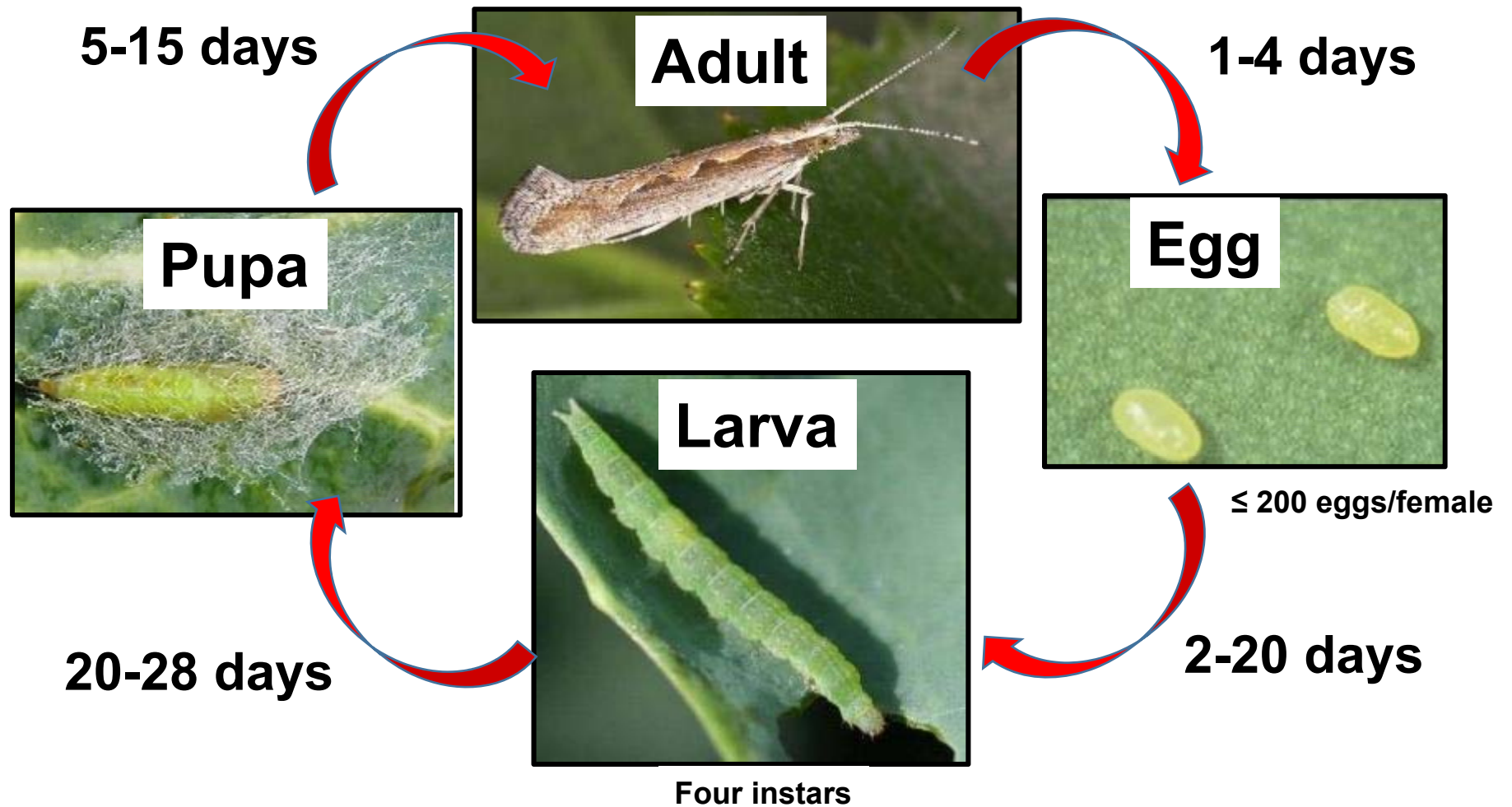






# Life Cycle

One generation = 28 to 67 days



Summarized by Philips et al. 2014



# Number of DBM Generations In New York

Typically 2-3 per year



1-3 generations



1-2 generations

Planting

Cabbage (100-120d)

Planting

Cabbage (60-90d)

Harvest

15-Mar

14-Apr

14-May

13-Jun

13-Jul

12-Aug

11-Sep

11-Oct



# Life History

- **Diamondback moth is not known to overwinter successfully in northern North America; must migrate from the south to the north every year**



- **Diamondback moth reported to migrate from southern US into northern North America**



# Life History

- **Diamondback moth imported into New York on transplants grown in southern US**



- **Survey of cabbage transplants coming into NY from GA and FL (1989- 1992)- 34,013 samples**
- **Company seasonal averages ranged from 1.3 to 12.0 DBM per 100 transplants**
- **DBM were highly resistant to methomyl (Lannate) and permethrin (Ambush)**



# Life History

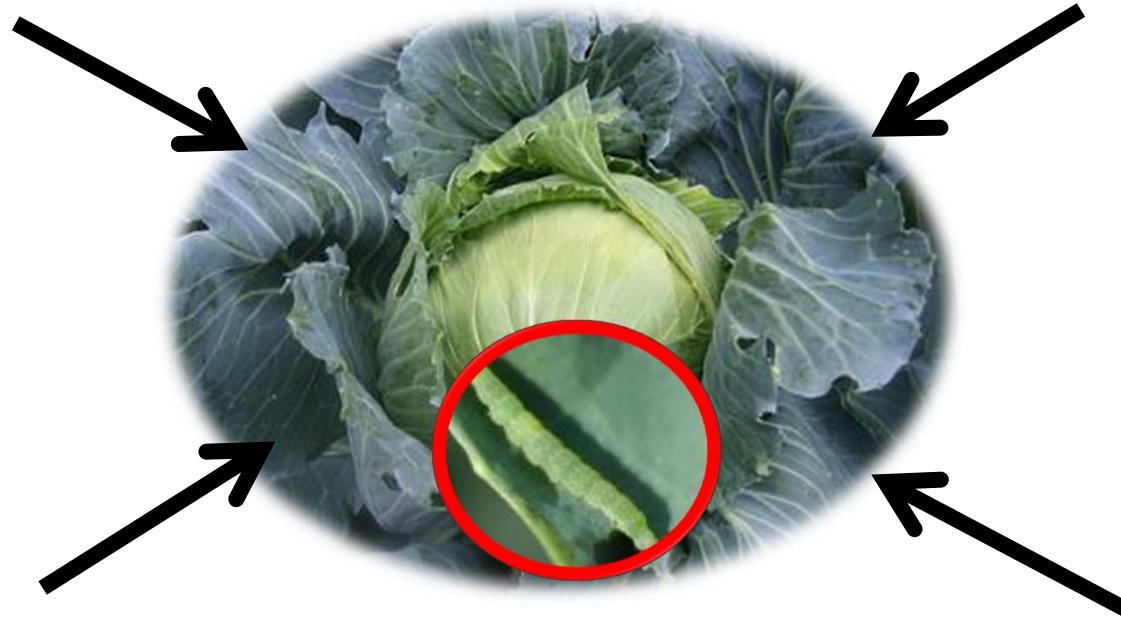
- **Why would Diamondback moths in the southern US be resistant to insecticides?**
  - **DBM has up to 15 generations/year in GA and FL**
  - **Produce a spring crop and a fall crop; collards grown year round; 21,000 acres of cole crops in GA**
  - **Insecticides are the major tool for management**
  - **From a reliable source in Georgia:** “We have had reported problems with every product registered for DBM within the last year (as has Florida). We have also had good control with most every product. [Control generally best with Proclaim, Exirel and the Bts.]”



# DBM Management

**Plant Resistance**

**Chemical Control**



**Cultural Control**

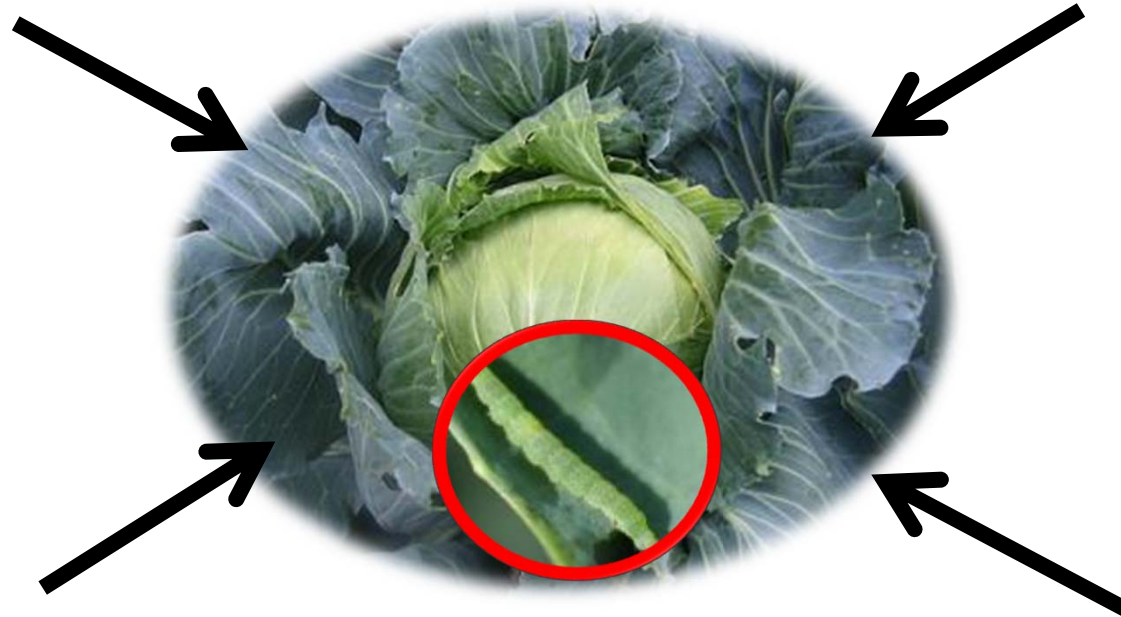
**Biological Control**



# DBM Management

~~Plant Resistance~~

Chemical Control



Cultural Control

Biological Control



# Cultural Control

- **Plant a clean crop** - obtain and transplant DBM-free plants



**Avoid 18 wheels and a truckload of diamondbacks!**





# Cultural Control

- **Intercropping** – not for large commercial plantings; plant non-cole crops adjacent to cole crops

tomato



cabbage





# Cultural Control

- **Trap cropping** – not for large commercial plantings; plant more attractive trap crop adjacent to cash crop

Trap crop:  
collards



Cash crop:  
cabbage



# Biological Control

- **Conserve natural enemies** – minimize use of broad-spectrum insecticides (e.g., pyrethroids, OPs, carbamates); natural enemies can reduce DBM populations by  $>80\%$



parasitic wasp



ground beetle



# Chemical Control

- **Use insecticides** – apply only when necessary and follow IRM principles





# Monitoring and Scouting



- **Pheromone-baited sticky traps** – monitors adult activity



- **Scout field visually**
  - For fields 5-25 acres -sample 10 sites and 4 plants per site per field (40 plants)



# Action Thresholds

Crop Stage	% Cabbage plants infested	
	Kraut	Fresh & Storage
Seedling (cotyledon)	20	20
Early vegetative to cupping	30	30
Early head to harvest	30	15



# Insecticide options for DBM control in New York's cole crops

Group (IRAC group)	Active ingredient	Product
<i>Bacillus thuringiensis</i> (11A)	<i>B.t. var. aizawai</i>	Agree WG; XenTari
	<i>B.t. var. kurstaki</i>	Dipel DF, Biobit HP, others
Carbamates (1A)	methomyl	Lannate LV
Diamides (28)	chlorantraniliprole	Coragen
	cyantraniliprole	Exirel, Verimark
Diamide (28) + Pyrethroid (3A)	chlorantraniliprole + lambda-cyhalothrin	Voliam Xpress/Besiege
GluCl modulators (6)	emamectin benzoate	Proclaim WDG
Oxadiazines (22A)	indoxacarb	Avaunt
Pyrethroids (3A)	lambda-cyhalothrin	Warrior II Zeon Technology
Spinosyns (5)	spinetoram	Radiant SC



# DBM Management

**Plant Resistance**

**Chemical Control**

?



**Cultural Control**

**Biological Control**





# Future DBM Management

- **Genetically modified crops**
  - using the Bt gene to protect vegetable crops (e.g. Bt sweet corn and Bt eggplant in Bangladesh)
- **Sterile insect technique**
  - would require releasing genetically modified DBM (infertile) to mate with wild females, which would eventually reduce population





# Introduction to DBM Problem in western New York in 2016

## Fields disked up due to uncontrollable DBM populations

- Cabbage field where transplants were imported from Georgia
  - Field disked up in early September
- Another field 1/8<sup>th</sup> of a mile away
  - Bare root transplants produced in local seedbed
  - DBM population spiked ~ 5 weeks after planting
  - Field disked up in mid-September
- **Why were DBM populations uncontrollable?**



# Severe DBM Infestation: Worm and frass contaminants





# Grower spray program

## Storage cabbage

Date	Insecticide Trade Name	IRAC Class
July 18-21 (week #1)	Transplanted Lorsban at planting for OM	
Aug-4 (15 DAP)	Sniper	3A
Aug-15 (11 days later)	Lannate SP + Agree WG	1A 11A

Color-coding according to IRAC insecticide mode of action



# Grower spray program

Storage cabbage

Date	Insecticide Trade Name	IRAC Class
Aug-20?	Voilam Xpress + Lannate SP	3A, 28 1A
Aug-25	Proclaim + Swagger	6 3A, 4
<b>DBM population explodes!</b>		

Color-coding according to IRAC insecticide mode of action



# Grower spray program

## Storage cabbage

Date	Insecticide Trade Name	IRAC Class
Aug-29 (4 days later)	<b>Radiant</b>	<b>5</b>
Sep-3 (5 days later)	<b>Avaunt</b> <b>+ Lannate SP</b>	<b>22A</b> <b>1A</b>
Sep-7 (4 days later)	<b>Proclaim</b>	<b>6</b>
Sep-10	<b>Disk up field</b> <b>Set up insecticide trial</b>	





# Insecticide Spray Trial



September 21, 2016





# Insecticide Spray Trial: Treatments

No.	Product and rate per acre	Active ingredient	IRAC group
1.	Untreated		
2.	Lannate SP 1 lb + Agree WG 1 lb*	Methomyl Bt subsp. <i>aizawai</i> (strain GC-91)	1A – carbamate 11A – Bt
3.	Lannate SP 1 lb	methomyl	1A – carbamate
4.	Avaunt 3.5 oz	indoxacarb	22A - oxadiazin
5.	Radiant 10 fl oz	spinetoram	5 - spinosyn
6.	Coragen 7.5 fl oz	Chlorantraniliprole	28 - diamide
7.	Voliam Xpress 9 fl oz	Chlorantraniliprole + lambda cyhalothrin	28 - diamide 3A - pyrethroid
8.	Proclaim 4.8 oz	Emamectin benzoate	6 - avermectin
9.	Warrior II Zeon Technology	Lambda cyhalothrin	3A - pyrethroid

- Used maximum labeled rates for all treatments except \*
- LI700 0.25% v/v included in each treatment

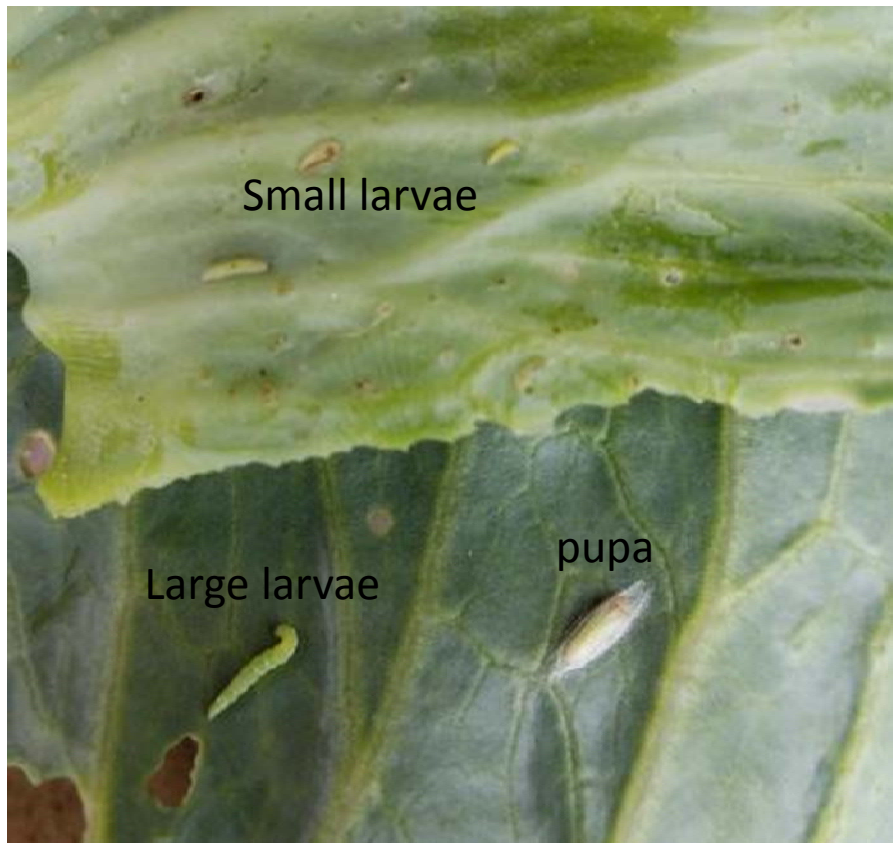


# Insecticide Spray Trial: Procedures

- Small-plot randomized complete block design
  - 4 replications
- Individual plot size: 4 rows of cabbage x 10 ft long
  - Collect data from inside 2 rows only
- 2 sprays (A & B) 1 week apart for each treatment
  - Sep-15, Sep-21
  - Lannate + Agree only got 2<sup>nd</sup> app of Agree
- CO<sub>2</sub> backpack sprayer; 40 gpa; 28 psi
- Evaluations: 1 week after each spray
  - No. DBM of each of 6 plants per treatment
  - **DBM Stages:** small larvae (<0.75 cm), large larvae (>0.75 cm), pupa
  - **Location on plant:** head, wrapper/outer frame leaves



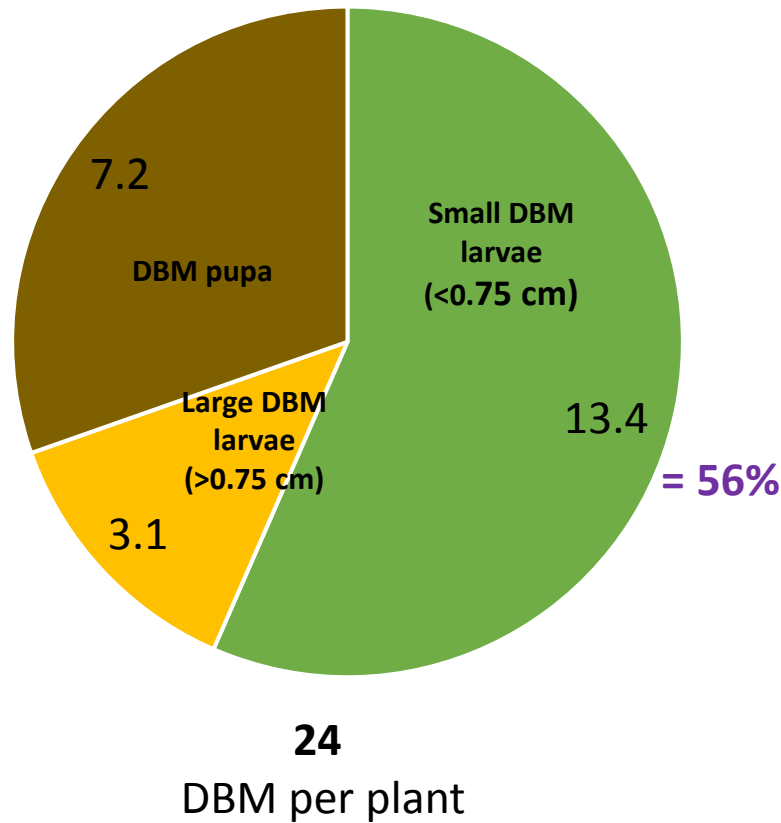
# All Stages of DBM Present



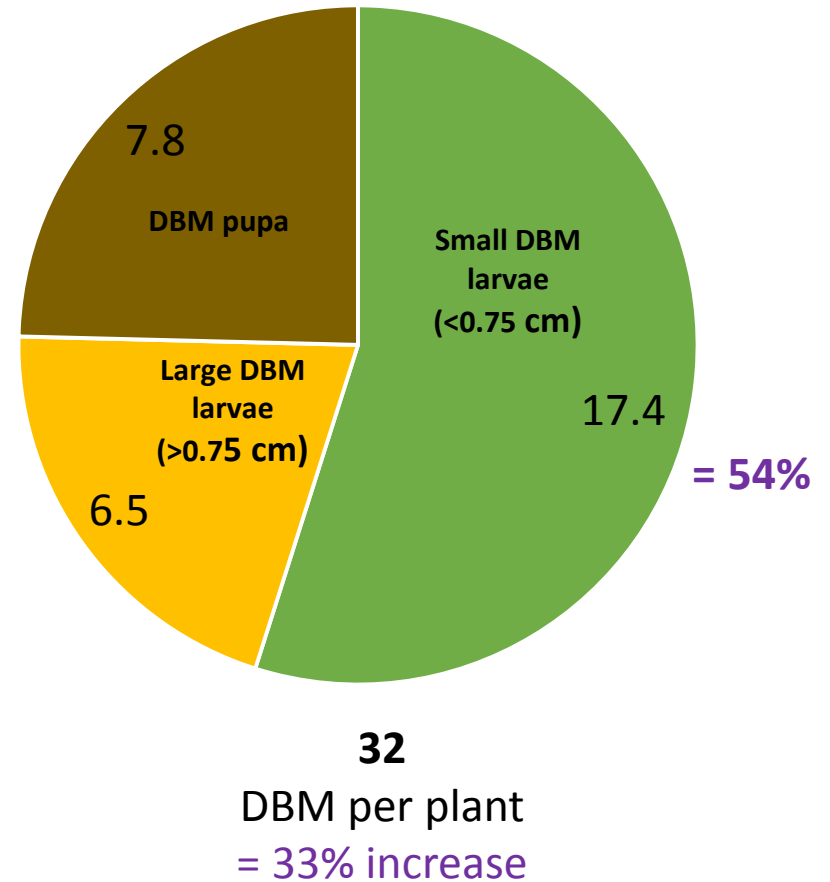


# Relative Distribution of DBM Stages in Whole Plant Untreated

After First Spray (7 DAT A)



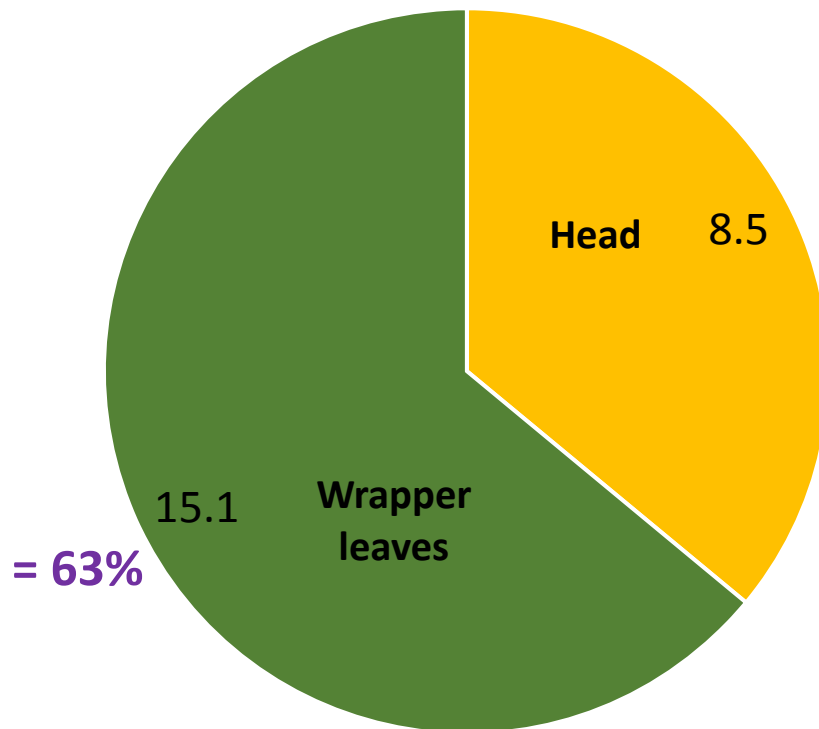
After Second Spray (7-8 DAT B)





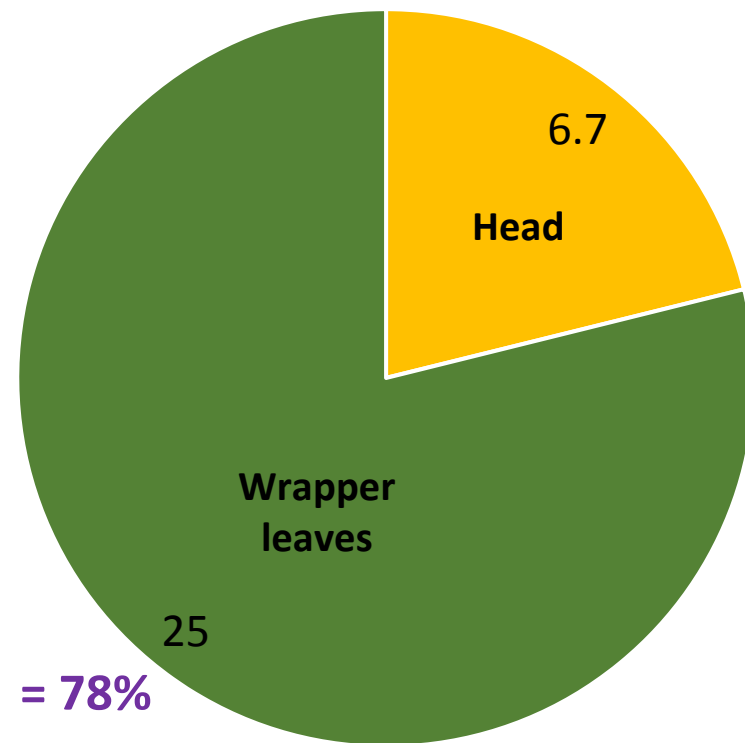
# Relative Location of DBM (larvae + pupa) in Whole Plant Untreated

After First Spray (7 DAT A)



**24**  
DBM per plant

After Second Spray (7-8 DAT B)

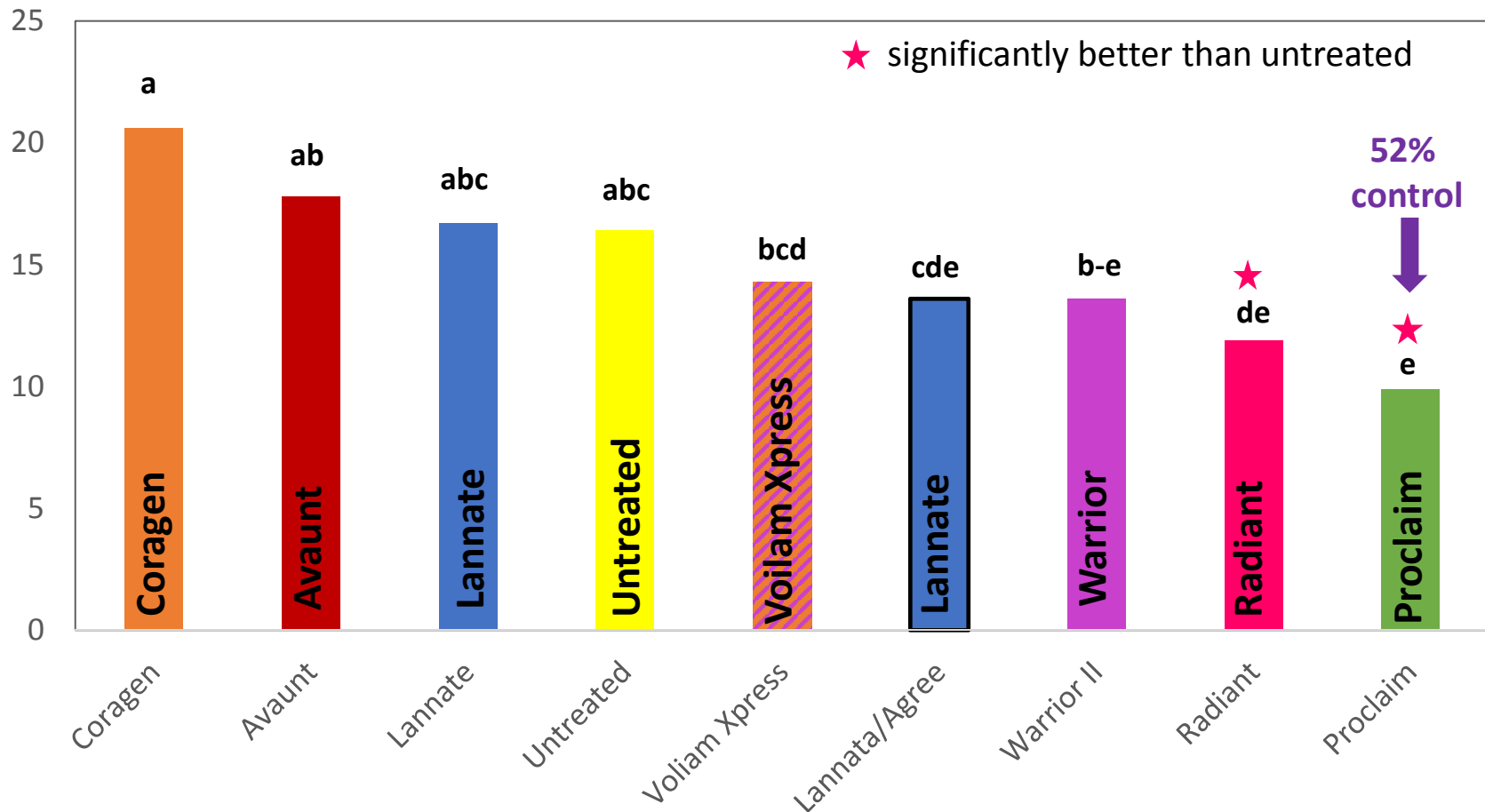


**32**  
DBM per plant  
= 33% increase



# What controlled DBM (all sizes)? After 1<sup>st</sup> Spray

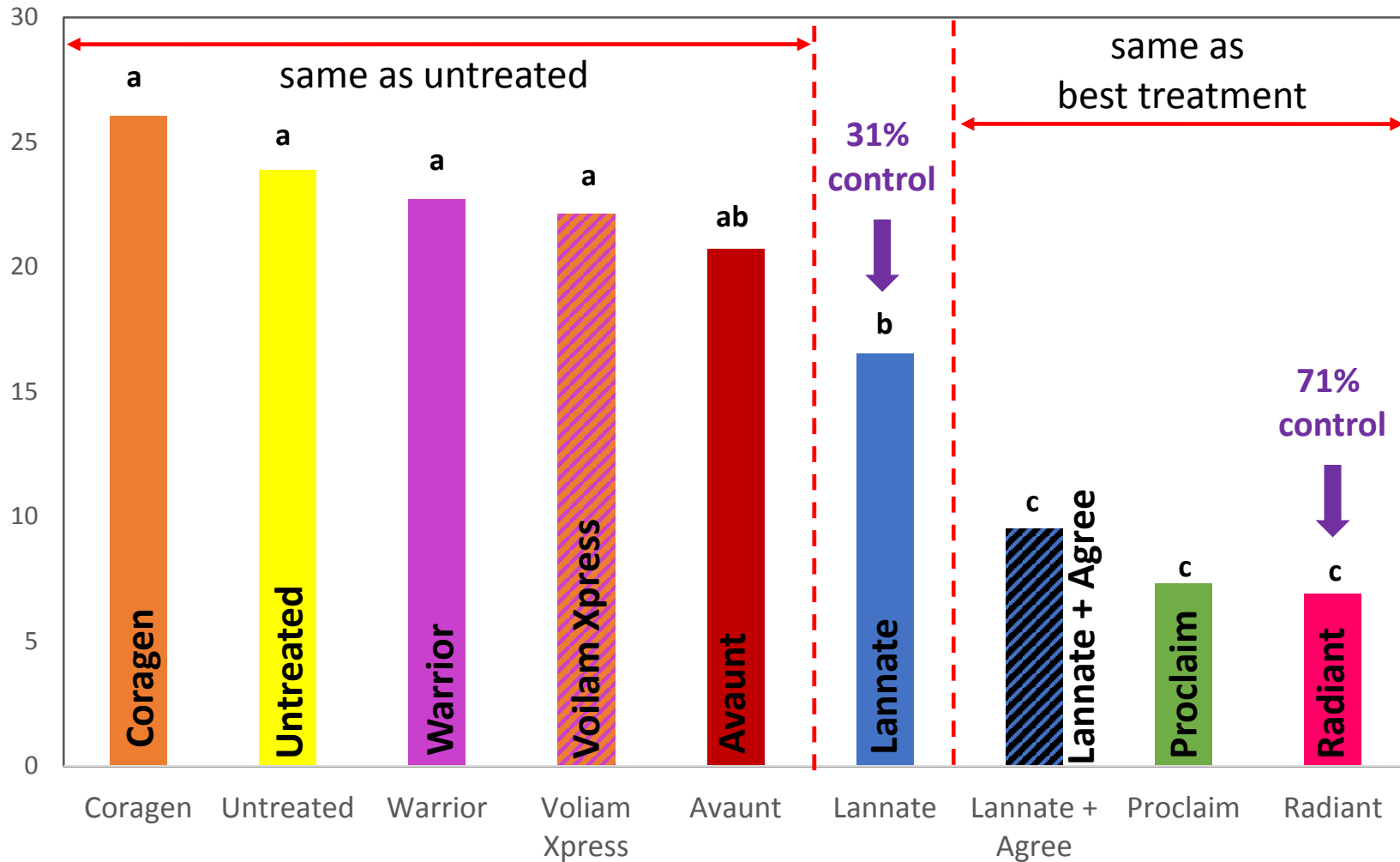
Total Number of DBM Larvae (all sizes) Per Whole Plant (head & leaves): 6 DAT A





# What controlled DBM (all sizes)? After 2<sup>nd</sup> Spray

Total DBM Larvae (all sizes) Per Whole Plant (head + leaves): 7-8 DATB



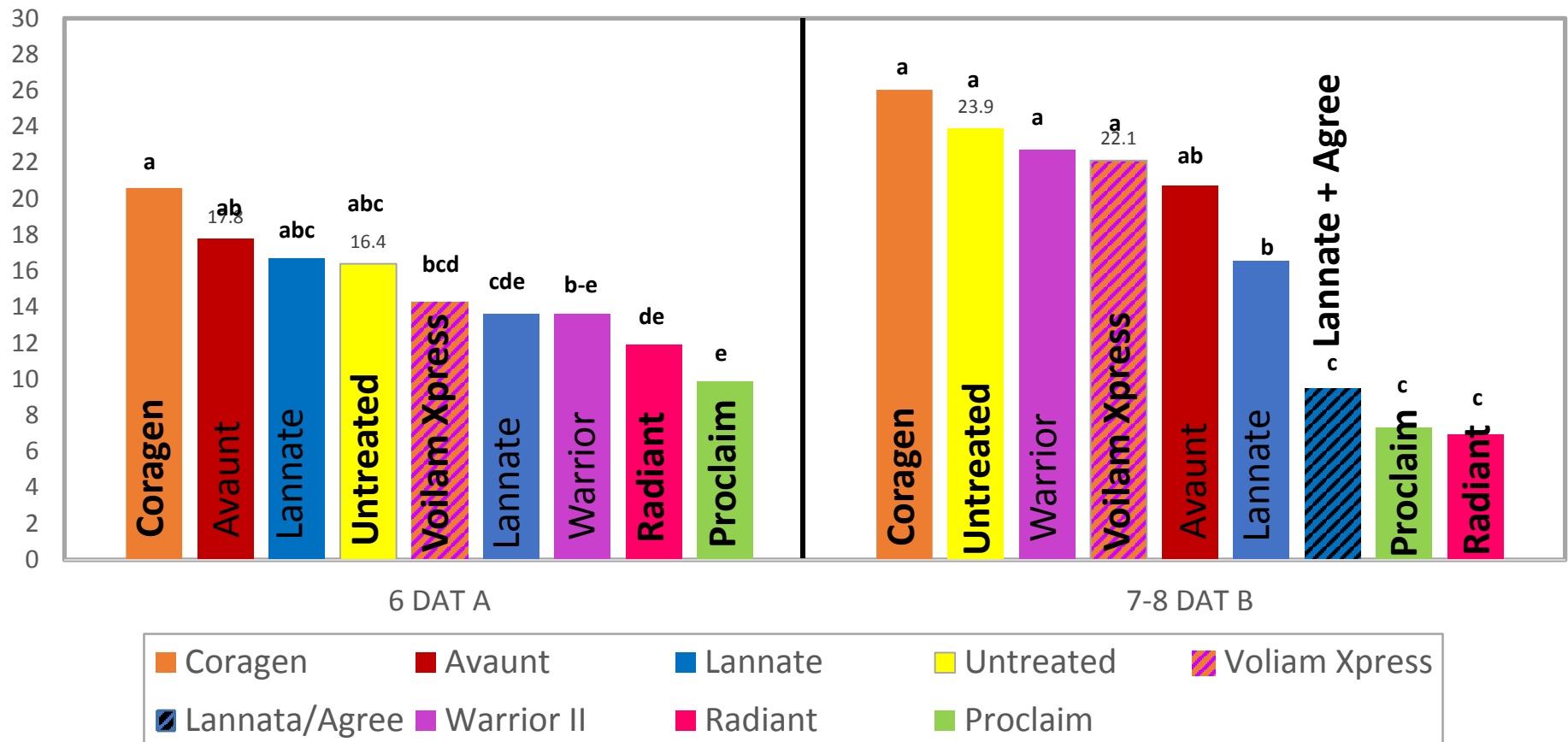


# What controlled DBM (all sizes)?

After 1 spray

After 2 sprays

Total DBM Larvae in Whole Plant (head & leaves)





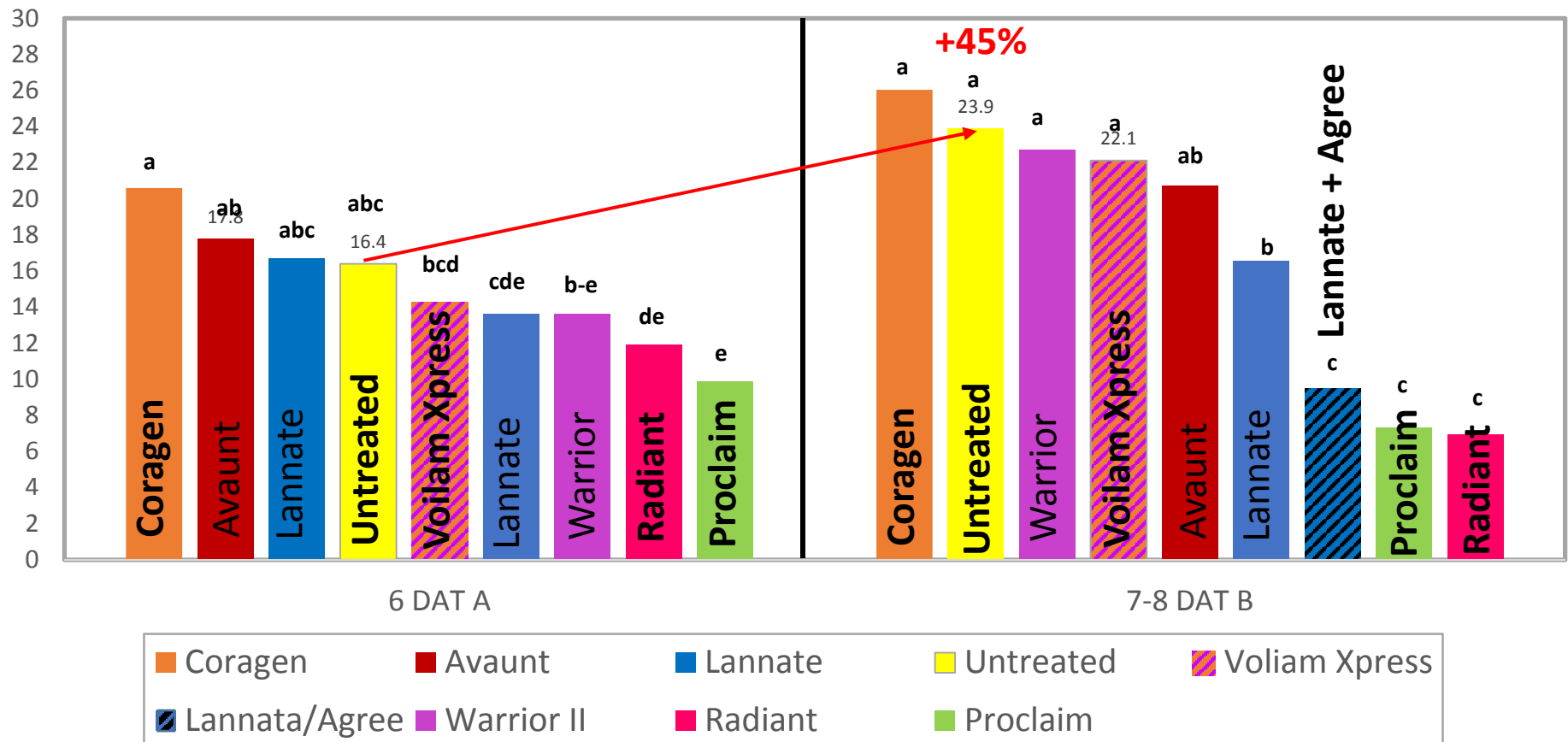


# What controlled DBM (all sizes)?

After 1 spray

After 2 sprays

Total DBM Larvae in Whole Plant (head & leaves)



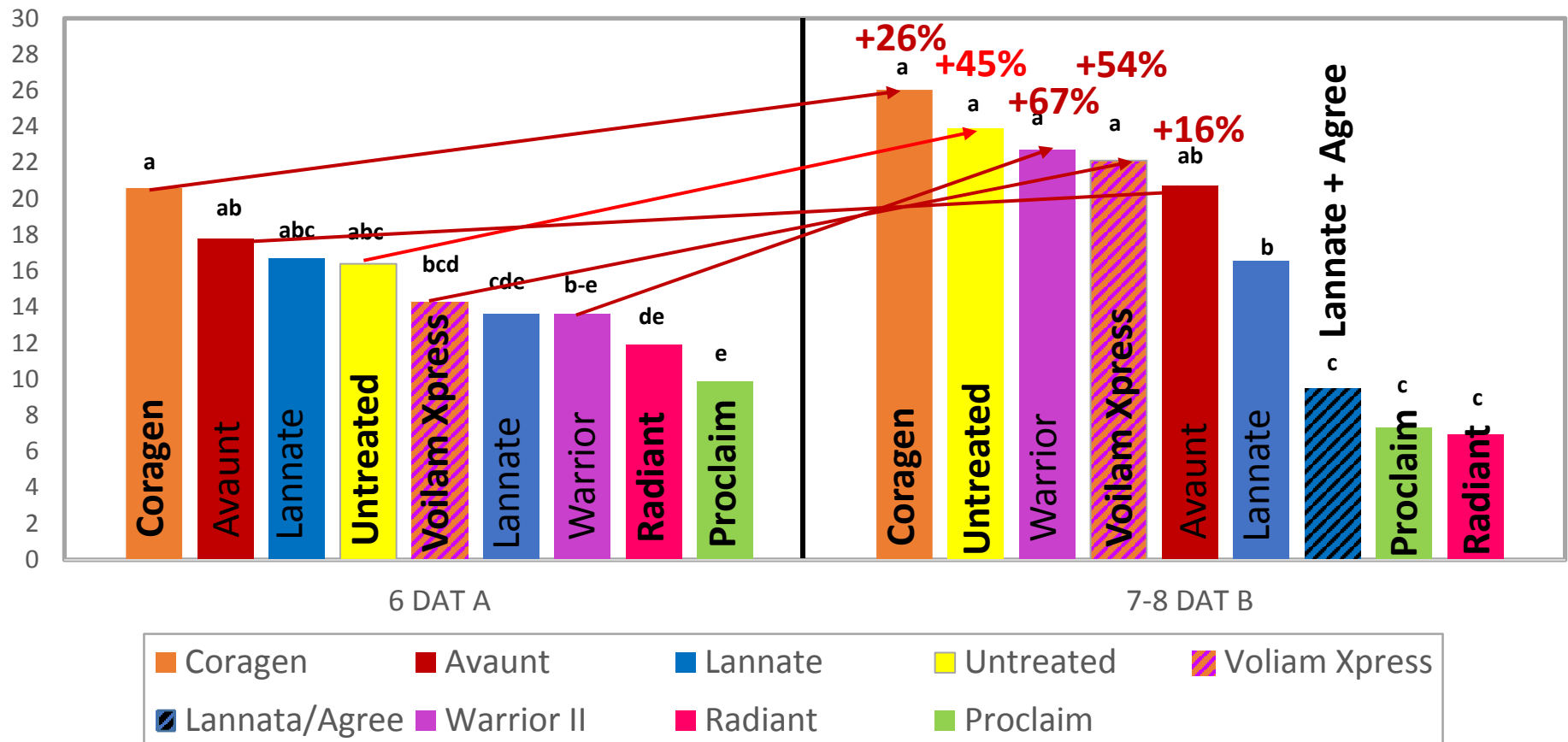


# What controlled DBM (all sizes)?

After 1 spray

After 2 sprays

Total DBM Larvae in Whole Plant (head & leaves)



Purple Numbers: IRAC insecticide classes

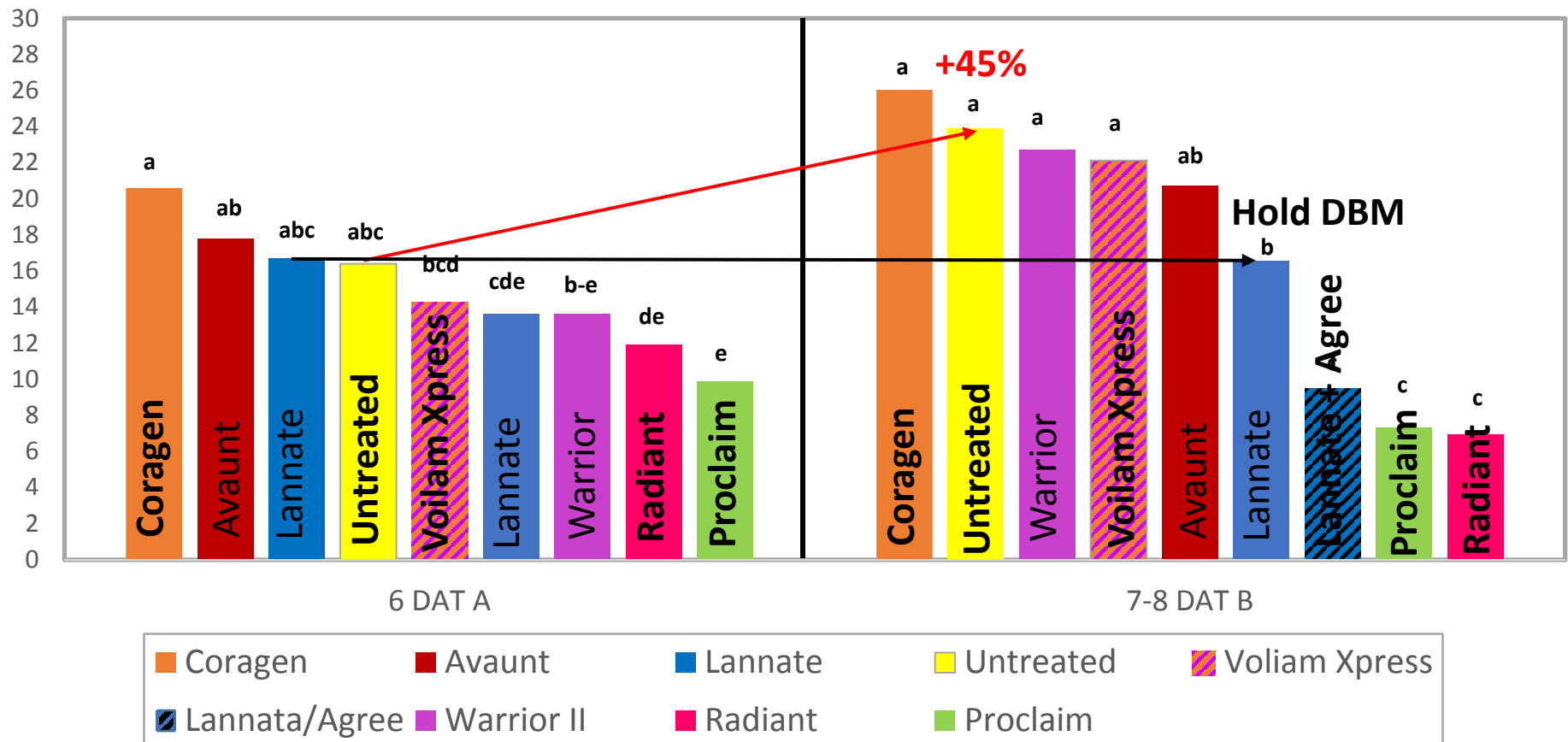


# What controlled DBM (all sizes)?

After 1 spray

After 2 sprays

Total DBM Larvae in Whole Plant (head & leaves)



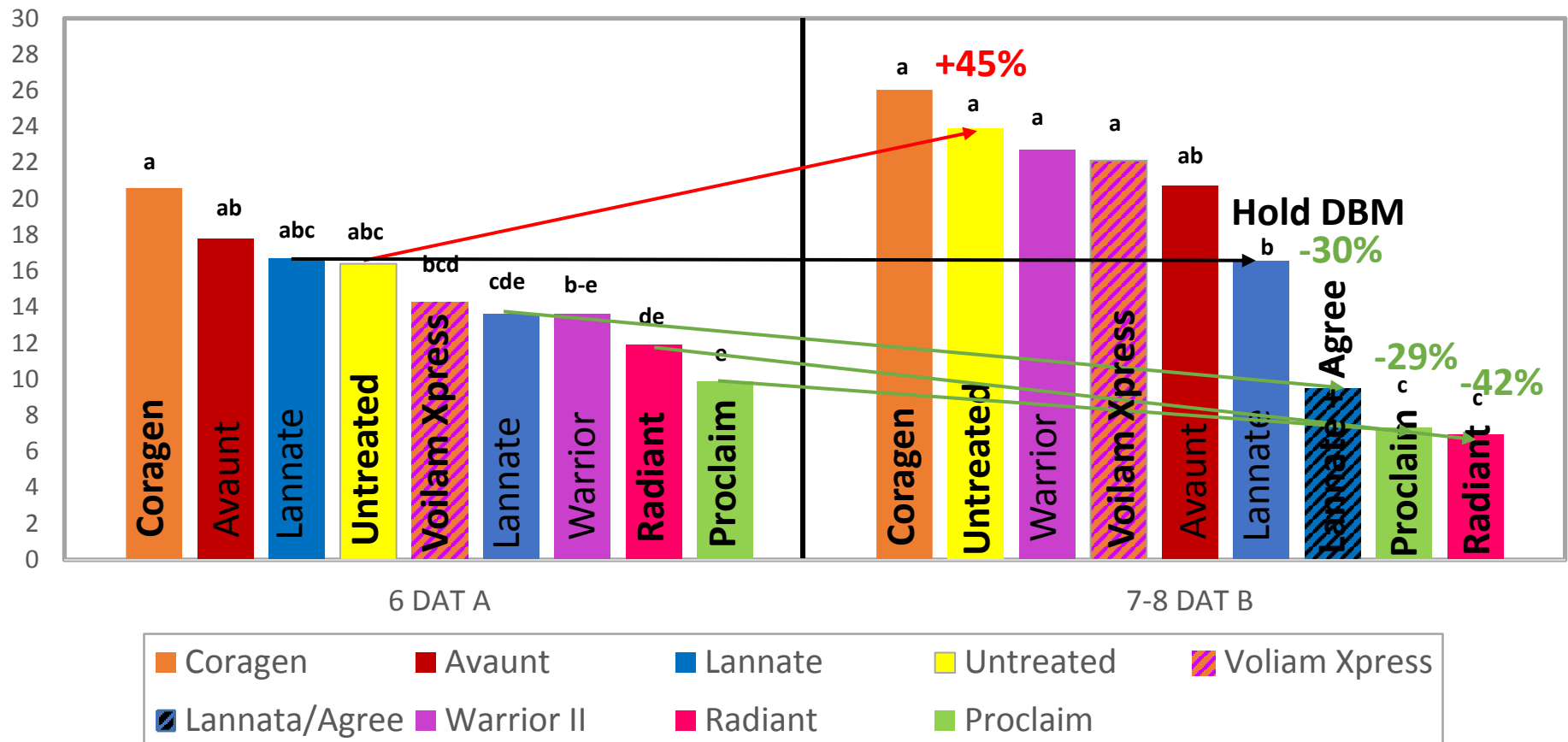


# What controlled DBM (all sizes)?

After 1 spray

After 2 sprays

Total DBM Larvae in Whole Plant (head & leaves)





# Summary

- Evaluated DBM control of large larvae, small larvae, pupa, DBM in the head and in wrapper leaves

## Generally:

- Better control was achieved after 2 sprays compared to after 1 spray (increase control by 10-30%; 2-3 more worms)
- Larvae in the head were better reduced than those in the wrapper leaves, especially after 1 spray
  - Easier target than DBM on undersides of wrapper leaves



# Summary

- **Proclaim** was the only insecticide that consistently provided significant control of DBM
  - After 1 and 2 sprays
  - All stages including pupa
  - In head and wrapper leaves
- **Radiant** also provided significant control of DBM
  - After 1 and 2 sprays
  - Did not prevent progression to pupa
- **Lannate SP + Agree** (2<sup>nd</sup> app only) provided significant control of DBM only after 2 sprays
  - Did not prevent progression to pupa
- **Lannate SP** provided significant control of large larvae (49%) and total larvae (31%) per plant after 2 sprays
  - Held DBM population at same level from 1<sup>st</sup> to 2<sup>nd</sup> spray
  - Mediocre activity (either due to it being a weaker material/overwhelmed by DBM pressure, or early signs of resistance)



# Summary

**Coragen, Voliam Xpress, Warrior and Avaunt FAILED to control DBM**

- DBM populations increased between 1<sup>st</sup> and 2<sup>nd</sup> sprays
- **Coragen** had significantly higher DBM than the untreated
  - 39% higher Total larvae in the wrapper leaves after 1<sup>st</sup> spray
  - 45% higher large larvae per whole plant after 2<sup>nd</sup> spray



# Summary

- These results **strongly suggest** (not proof) that the DBM in this trial were **resistant to active ingredients**:
  - Chlorantraniliprole (= Coragen) – IRAC 28
  - Lambda cyhalothrin (= Warrior) – IRAC 3A
    - (assume all pyrethroids)
  - Indoxacarb (= Avaunt) – IRAC 22A
- Does this explain why the grower lost control of DBM population?





# Grower spray program

## Insecticide Spray Schedule: rate per acre

- Aug-4 (15 DAP):
  - **Sniper (3A)** – **FAILED!**
  - **Agree WG (11A)** - **effective**
- Aug-15 (11 days later)
  - **Lannate SP (1A)** - **mediocre**
  - **Agree WG (11A)** - **effective**
- Aug-20?:
  - **Voliam Xpress (28 + 3A)** – **FAILED!**
  - **Lannate SP (1A)** - **mediocre**
- Aug-25
  - **Proclaim (6)** - **effective**
  - **Swagger (4)** – **FAILED!**

## Note:

- Sniper & Lannate kill beneficial insects
- Make Agree have to work harder

← Weak program!

- **DBM population spikes!**



# Grower spray program

## Insecticide Spray Schedule *cont.*: rate per acre

- Aug-29 (4 days later):
  - **Radiant (5)**
- Sep-3 (5 days later):
  - **Avaunt (22A)**
  - **Lannate SP (1A)**
- Sep-7 (4 days later):
  - **Proclaim (6)**
  - **Lannate SP (1A)**
- Sep-10
  - Decide to disk up field!

-effective

- **FAILED!**

-mediocre

-effective

-mediocre

8 days  
without an  
effective  
spray



# What could have been done differently?

## What made DBM population explosive was a combination of:

- Hot & dry summer causing DBM population to generate quicker
  - Respect resistance management of insecticides
  - Lannate was applied 4-times to same generation
- Broad-spectrum insecticides (Lannate, Sniper, Voliam Xpress, Swagger) wiped out beneficial insects that could have provided some control
  - Reduce use of pyrethroids and carbamates, especially early to let beneficial insects get established
- (Suspected) insecticide resistance to three active ingredients
  - Respect resistance management
  - Be cautious of resistant DBM populations on southern transplants



# IRM Program for DBM in NY

(typical season)

e.g., Cabbage variety – 100-120 days to maturity



**July**                      **August**                      **Sept.**                      **Oct.**

DBM generation times



↑  
Lorsban or  
Coragen at  
transplant

- Rotate classes of chemistry
- Do not use same class more than twice
- Do not apply insecticide more than 2 times



# IRM Program for DBM in NY

(typical season)

e.g., Cabbage variety – 100-120 days to maturity



**July**                      **August**                      **Sept.**                      **Oct.**

	<b>Bt (11A)</b>	<b>Spinosyn (5)</b>	<b>Avermectin (6)</b>
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↑  
Lorsban or  
Coragen at  
transplant

Agree, Xentari or Dipel

Radiant, Entrust

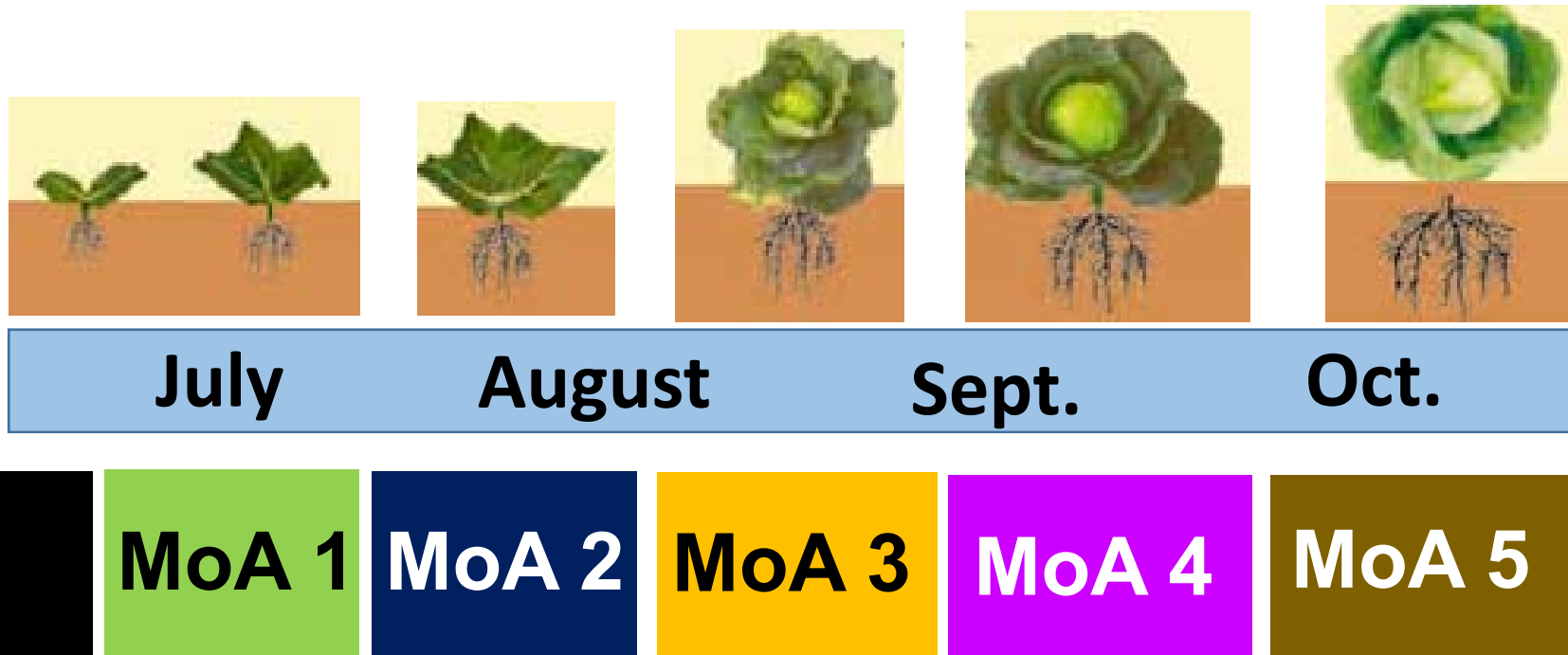
Proclaim WDG



# IRM Program for DBM

(difficult season)

e.g., Cabbage variety – 100-120 days to maturity



↑  
Lorsban or  
Coragen at  
transplant

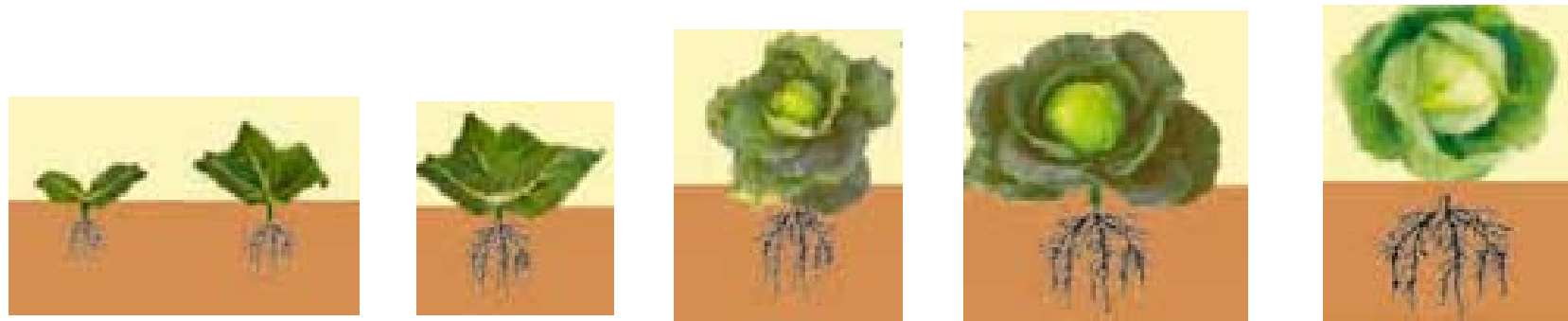
- Rotate classes of chemistry
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# IRM Program for DBM

(difficult season)

e.g., Cabbage variety – 100-120 days to maturity



**July**                      **August**                      **Sept.**                      **Oct.**

	<b>Bt</b> <b>(11A)</b>	<b>Spinosyn</b> <b>(5)</b>	<b>Avermectin</b> <b>(6)</b>	<b>Diamide</b> <b>(28)</b>	<b>Oxadiazine</b> <b>(22A)</b>
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↑  
Lorsban or  
Coragen at  
transplant

Agree, Xentari or Dipel

Radiant, Entrust

Proclaim WDG

Coragen, Exirel

Avaunt



# Questions

