

## TABLES AND FIGURES

**Table 1.1:** Results of probit analyses for rynaxypyr using diet incorporation bioassays on *C. rosaceana* neonate larvae from a laboratory as well as field-collected populations

Population	<i>n</i>	Slope (± SE)	$\chi^2$	<i>P</i>	LC <sub>50</sub> (ppm) (95% FL) <sup>1</sup>	LC <sub>90</sub> (ppm) (95% FL) <sup>1</sup>	LCR-LC <sub>50</sub> <sup>2</sup> (95% CL) <sup>4</sup>	LCR-LC <sub>90</sub> <sup>3</sup> (95% CL) <sup>4</sup>
<b>Spring Brood:</b>								
LAB	250	2.61 (0.39)	1.08	0.78	0.33 (0.24-0.77)	1.03 (0.77-1.60)		
PTH	250	3.06 (0.70)	0.18	0.98	0.39 (0.19-0.57)	1.03 (0.71-2.10)	1.18 (0.88-1.59)	1.00 (0.59-1.68)
JAR	250	5.12 (0.99)	0.75	0.86	1.21 (1.01-1.44)	2.16 (1.76-3.19)	3.07 (2.19-4.29)*	2.09 (1.35-3.25)*
JON	250	2.91 (0.37)	4.97	0.17	1.39 (1.02-1.85)	3.83 (2.74-6.58)	4.18 (2.91-5.99)*	3.71 (2.30-5.99)*

*n* = number of larvae assayed.

<sup>1</sup> 95% fiducial limits estimated using POLO (LeOra Software 1987).

<sup>2</sup> LCR-LC<sub>50</sub>, lethal concentration ratio at LC<sub>50</sub> = LC<sub>50</sub> (field population)/LC<sub>50</sub> (LAB population).

<sup>3</sup> LCR-LC<sub>90</sub>, lethal concentration ratio at LC<sub>90</sub> = LC<sub>90</sub> (field population)/LC<sub>90</sub> (LAB population).

<sup>4</sup> 95% confidence limits estimated using lethal concentration ratio significance test (Robertson et al. 2007).

\* LC<sub>50</sub> or LC<sub>90</sub> of field collected population significantly different ( $\alpha = 0.05$ ) from that of the LAB population (Robertson et al. 2007).

**Table 1.2:** Results of probit analyses for rynaxypyr using diet incorporation bioassays on *C. rosaceana* neonate larvae from a laboratory as well as field-collected populations

Population	<i>n</i>	Slope (± SE)	$\chi^2$	<i>P</i>	LC <sub>50</sub> (ppm) (95% FL)	LC <sub>90</sub> (ppm) (95% FL) <sup>1</sup>	LCR-LC <sub>50</sub> <sup>2</sup> (95% CL) <sup>4</sup>	LCR-LC <sub>90</sub> <sup>3</sup> (95% CL) <sup>4</sup>
<b>Spring Brood:</b>								
LAB	180	2.65 (0.57)	0.25	0.99	0.11 (0.07-0.16)	0.35 (0.24-0.69)		
STM	180	2.55 (0.45)	1.34	0.85	0.19 (0.13-0.26)	0.61 (0.42-1.13)	1.70 (1.02-2.79)*	1.76 (0.92-3.38)
KMP	180	1.46 (0.31)	4.68	0.32	0.27 (0.10-0.47)	2.00 (1.05-8.72)	2.40 (1.19-4.64)*	5.79 (2.44-13.77)*
WEB	180	3.84 (0.84)	0.84	0.93	0.57 (0.40-0.75)	1.23 (0.92-2.12)	5.03 (3.11-8.13)*	3.56 (1.97-6.44)*
CLK	180	3.52 (0.92)	1.60	0.81	0.19 (0.12-0.26)	0.44 (0.32-0.91)	1.70 (1.02-2.78)*	1.27 (0.68-2.39)
<b>First Summer Brood:</b>								
LAB	180	2.20 (0.44)	3.44	0.49	0.15 (0.08-0.22)	0.57 (0.33-1.30)		
GRF	180	1.94 (0.47)	0.43	0.98	0.79 (0.43-1.20)	3.60 (2.14-11.97)	5.26 (2.91-9.50)*	6.29 (2.47-16.04)*
ROB	180	2.54 (0.39)	6.76	0.15	0.71 (0.52-0.96)	2.28 (1.58-4.10)	4.76 (2.88-7.87)*	3.98 (2.02-7.84)*

*n* = number of larvae assayed.

<sup>1</sup> 95% fiducial limits estimated using POLO (LeOra Software 1987).

<sup>2</sup> LCR-LC<sub>50</sub>, lethal concentration ratio at LC<sub>50</sub> = LC<sub>50</sub> (field population)/LC<sub>50</sub> (LAB population).

<sup>3</sup> LCR-LC<sub>90</sub>, lethal concentration ratio at LC<sub>90</sub> = LC<sub>90</sub> (field population)/LC<sub>90</sub> (LAB population).

<sup>4</sup> 95% confidence limits estimated using lethal concentration ratio significance test (Robertson et al. 2007).

\* LC<sub>50</sub> or LC<sub>90</sub> of field collected population significantly different ( $\alpha = 0.05$ ) from that of the LAB population (Robertson et al. 2007).

**Table 1.3:** Results of probit analyses for spinetoram using diet incorporation bioassays on *C. rosaceana* neonate larvae from a laboratory as well as field-collected populations

Population	<i>n</i>	Slope (± SE)	$\chi^2$	<i>P</i>	LC <sub>50</sub> (ppm) (95% FL) <sup>1</sup>	LC <sub>90</sub> (ppm) (95% FL) <sup>1</sup>	LCR-LC <sub>50</sub> <sup>2</sup> (95% CL) <sup>4</sup>	LCR-LC <sub>90</sub> <sup>3</sup> (95% CL) <sup>4</sup>
<b>Spring Brood:</b>								
LAB	180	3.82 (0.82)	1.56	0.82	0.09 (0.07-0.12)	0.20 (0.15-0.34)		
STM	180	2.25 (0.55)	2.73	0.60	0.04 (0.02-0.07)	0.16 (0.11-0.37)	0.50 (0.27-0.82)*	0.80 (0.43-1.52)
KMP	180	1.38 (0.19)	15.04	0.01	0.23 (0.11-0.61)	1.92 (0.68-2.50)	2.41 (1.44-4.02)*	9.49 (3.83-23.53)*
WEB	180	1.97 (0.50)	4.40	0.36	0.04 (0.01-0.06)	0.16 (0.12-0.40)	0.40 (0.20-0.71)*	0.78 (0.40-1.53)
CLK	180	3.23 (0.88)	2.86	0.58	0.16 (0.09-0.25)	0.39 (0.28-0.90)	1.70 (1.09-2.64)*	1.95 (1.09-3.49)*
<b>First Summer Brood:</b>								
LAB	180	3.05 (0.64)	1.14	0.89	0.02 (0.01-0.03)	0.05 (0.04-0.10)		
GRF	180	2.97 (0.59)	2.28	0.68	0.06 (0.04-0.09)	0.16 (0.11-0.33)	3.00 (1.86-4.84)*	3.08 (1.66-5.70)*
ROB	180	3.27 (0.39)	0.97	0.91	0.08 (0.06-0.11)	0.20 (0.15-0.37)	4.05 (2.57-6.39)*	3.80 (2.10-6.89)*

*n* = number of larvae assayed.

<sup>1</sup> 95% fiducial limits estimated using POLO (LeOra Software 1987).

<sup>2</sup> LCR-LC<sub>50</sub>, lethal concentration ratio at LC<sub>50</sub> = LC<sub>50</sub> (field population)/LC<sub>50</sub> (LAB population).

<sup>3</sup> LCR-LC<sub>90</sub>, lethal concentration ratio at LC<sub>90</sub> = LC<sub>90</sub> (field population)/LC<sub>90</sub> (LAB population).

<sup>4</sup> 95% confidence limits estimated using lethal concentration ratio significance test (Robertson et al. 2007).

\* LC<sub>50</sub> or LC<sub>90</sub> of field collected population significantly different ( $\alpha = 0.05$ ) from that of the LAB population (Robertson et al. 2007).

**Table 1.4:** Results of probit analyses for spinosad using diet incorporation bioassays on *C. rosaceana* neonate larvae from a laboratory as well as field-collected populations

Population	<i>n</i>	Slope (± SE)	$\chi^2$	<i>P</i>	LC <sub>50</sub> (ppm) (95% FL) <sup>1</sup>	LC <sub>90</sub> (ppm) (95% FL) <sup>1</sup>	LCR-LC <sub>50</sub> <sup>2</sup> (95% CL) <sup>4</sup>	LCR-LC <sub>90</sub> <sup>3</sup> (95% CL) <sup>4</sup>
<b>Spring Brood:</b>								
LAB	180	2.43 (0.33)	13.45	0.01	0.26 (0.16-0.43)	0.87 (0.50-2.63)		
STM	180	1.78 (0.25)	5.59	0.23	0.13 (0.08-0.19)	0.68 (0.41-1.66)	0.50 (0.32-0.78)*	0.78 (0.38-1.60)
KMP	180	1.86 (0.22)	5.90	0.21	0.61 (0.28-1.45)	2.96 (1.28-21.60)	2.36 (1.52-3.66)*	3.41 (1.71-6.83)*
WEB	180	2.09 (0.27)	14.07	0.01	0.25 (0.17-0.36)	1.01 (0.63-2.17)	0.95 (0.62-1.45)	1.16 (0.59-2.28)
<b>First Summer Brood:</b>								
LAB	180	1.78 (0.24)	15.02	0.01	0.16 (0.11-0.24)	0.84 (0.50-1.96)		
GRF	180	3.75 (1.02)	5.08	0.28	0.58 (0.33-0.78)	1.27 (0.93-2.49)	3.61 (2.22-5.89)*	1.52 (1.08-2.77)*
ROB	180	3.46 (0.89)	1.45	0.84	0.49 (0.30-0.66)	1.16 (0.84-2.31)	3.09 (1.91-5.00)*	1.39 (0.70-2.75)

*n* = number of larvae assayed.

<sup>1</sup> 95% fiducial limits estimated using POLO (LeOra Software 1987).

<sup>2</sup> LCR-LC<sub>50</sub>, lethal concentration ratio at LC<sub>50</sub> = LC<sub>50</sub> (field population)/LC<sub>50</sub> (LAB population).

<sup>3</sup> LCR-LC<sub>90</sub>, lethal concentration ratio at LC<sub>90</sub> = LC<sub>90</sub> (field population)/LC<sub>90</sub> (LAB population).

<sup>4</sup> 95% confidence limits estimated using lethal concentration ratio significance test (Robertson et al. 2007).

\* LC<sub>50</sub> or LC<sub>90</sub> of field collected population significantly different ( $\alpha = 0.05$ ) from that of the LAB population (Robertson et al. 2007).

**Table 1.5:** Results of probit analyses for azinphosmethyl using diet incorporation bioassays on *C. rosaceana* neonate larvae from a laboratory as well as field-collected populations

Population	<i>n</i>	Slope (± SE)	$\chi^2$	<i>P</i>	LC <sub>50</sub> (ppm) (95% FL) <sup>1</sup>	LC <sub>90</sub> (ppm) (95% FL) <sup>1</sup>	LCR-LC <sub>50</sub> <sup>2</sup> (95% CL) <sup>4</sup>	LCR-LC <sub>90</sub> <sup>3</sup> (95% CL) <sup>4</sup>
<b>Spring Brood:</b>								
LAB	210	4.25 (0.88)	8.20	0.15	1.33 (1.04-1.66)	2.66 (2.05-4.42)		
KMP	210	2.11 (0.27)	1.17	0.95	9.92 (7.29-13.52)	40.04 (26.99-72.11)	7.46 (5.13-10.58)*	15.04 (8.40-26.94)*
WEB	180	1.52 (0.18)	17.32	0.004	52.69 (33.85-83.81)	368.33 (202.03-963.10)	39.65 (25.88-60.75)*	138.29 (68.54-279.0)*
CLK	210	1.64 (0.19)	10.81	0.06	15.56 (10.52-23.24)	94.32 (56.26-206.07)	11.71 (7.77-17.65)*	35.42 (18.46-67.97)*
<b>First Summer Brood:</b>								
LAB	210	5.10 (1.14)	0.004	1.00	1.96 (1.44-2.43)	3.49 (2.77-5.31)		
GRF	210	2.78 (0.50)	3.02	0.70	50.55 (32.22-72.61)	146.28 (98.60-289.39)	25.83 (17.03-39.19)*	41.91 (24.79-70.86)*
ROB	210	1.48 (0.25)	4.48	0.48	7.56 (3.46-12.79)	55.66 (31.85-138.84)	3.86 (2.12-7.06)*	15.93 (8.08-31.41)*

*n* = number of larvae assayed.

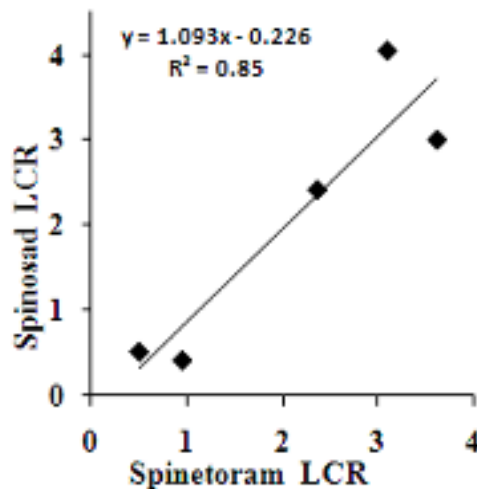
<sup>1</sup> 95% fiducial limits estimated using POLO (LeOra Software 1987).

<sup>2</sup> LCR-LC<sub>50</sub>, lethal concentration ratio at LC<sub>50</sub> = LC<sub>50</sub> (field population)/LC<sub>50</sub> (LAB population).

<sup>3</sup> LCR-LC<sub>90</sub>, lethal concentration ratio at LC<sub>90</sub> = LC<sub>90</sub> (field population)/LC<sub>90</sub> (LAB population).

<sup>4</sup> 95% confidence limits estimated using lethal concentration ratio significance test (Robertson et al. 2007).

\* LC<sub>50</sub> or LC<sub>90</sub> of field collected population significantly different ( $\alpha = 0.05$ ) from that of the LAB population (Robertson et al. 2007).

**Fig. 1.1:** Regression between spinosad and spinetoram lethal concentration ratios at LC<sub>50</sub> in populations of *C. rosaceana* collected from pome fruit orchards in Washington.

**Table 2.1:** The effect of rynaxypyr contaminated diet on *Choristoneura rosaceana* neonate larvae from rynaxypyr selected population (RYN) and unselected susceptible laboratory population (LAB)

Selected Generation	Population	n	Slope ( $\pm$ SE)	$\chi^2$	LC <sub>50</sub> (ppm) (95% FL) <sup>1</sup>	LC <sub>90</sub> (ppm) (95% FL) <sup>1</sup>	LCR-LC <sub>50</sub> <sup>2</sup> (95% CL) <sup>3</sup>
1	RYN	450	1.02 (0.39)	20.74	0.16 (0.07-0.32)	2.94 (1.41-8.37)	2.2 (1.02-4.65)*
	LAB	450	1.08 (0.10)	25.07	0.08 (0.03-0.15)	1.17 (0.56-3.42)	
3	RYN	350	1.72 (0.17)	17.10	0.26 (0.20-0.34)	1.46 (1.00-2.43)	3.1 (2.12-4.43)*
	LAB	350	2.24 (0.28)	6.62	0.08 (0.06-0.11)	0.32 (0.23-0.49)	
5	RYN	210	1.19 (0.17)	10.31	0.77 (0.31-1.48)	9.26 (4.40-33.02)	6.6 (3.27-13.24)*
	LAB	210	1.90 (0.28)	3.01	0.12 (0.08-0.16)	0.55 (0.36-1.09)	
6	RYN	180	1.88 (0.36)	7.71	1.03 (0.50-1.66)	4.93 (2.88-14.19)	6.6 (3.68-11.79)*
	LAB	180	1.59 (0.19)	11.83	0.16 (0.11-0.23)	1.00 (0.59-2.17)	

n = number of larvae assayed.

<sup>1</sup> 95% fiducial limits estimated using POLO (LeOra Software 1987).

<sup>2</sup> LCR-LC<sub>50</sub>, lethal concentration ratio at LC<sub>50</sub> = LC<sub>50</sub> (field population)/LC<sub>50</sub> (LAB population).

<sup>3</sup> 95% confidence limits estimated using lethal concentration ratio significance test (Robertson et al. 2007).

\* Indicates that Lethal Concentration Ratio was significant ( $\alpha = 0.05$ ) (Robertson et al. 2007).

**Table 2.2:** The effect of spinetoram contaminated diet on *Choristoneura rosaceana* neonate larvae from rynaxypyr selected population (RYN) and unselected susceptible laboratory population (LAB)

Selected Generation	Population	n	Slope ( $\pm$ SE)	$\chi^2$	LC <sub>50</sub> (ppm) (95% FL) <sup>1</sup>	LC <sub>90</sub> (ppm) (95% FL) <sup>1</sup>	LCR-LC <sub>50</sub> <sup>2</sup> (95% CL) <sup>3</sup>
1	SPIN	450	2.56 (0.37)	4.18	0.10 (0.07-0.12)	0.31 (0.23-0.48)	1.26 (0.86-1.85)
	LAB	450	4.00 (0.90)	3.62	0.08 (0.06-0.10)	0.16 (0.13-0.26)	
2	SPIN	350	2.53 (0.33)	3.96	0.12 (0.09-0.15)	0.39 (0.29-0.59)	2.3 (1.59-3.26)*
	LAB	350	1.75 (0.16)	7.61	0.05 (0.02-0.19)	0.29 (0.12-2.10)	
4	SPIN	350	3.63 (0.58)	2.98	0.17 (0.14-0.20)	0.38 (0.30-0.56)	3.5 (2.37-5.09)*
	LAB	350	2.72 (0.55)	6.22	0.05 (0.02-0.07)	0.14 (0.10-0.39)	
6	SPIN	210	3.01 (0.48)	2.52	0.22 (0.17-0.29)	0.59 (0.43-1.02)	3.64 (2.42-5.46)*
	LAB	210	1.97 (0.24)	7.59	0.06 (0.04-0.11)	0.27 (0.15-0.87)	

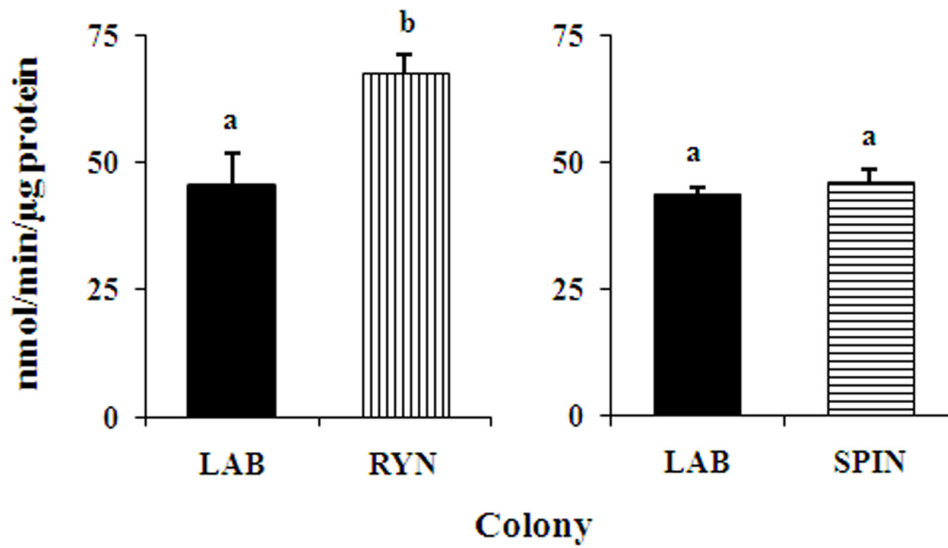
n = number of larvae assayed.

<sup>1</sup> 95% fiducial limits estimated using POLO (LeOra Software 1987).

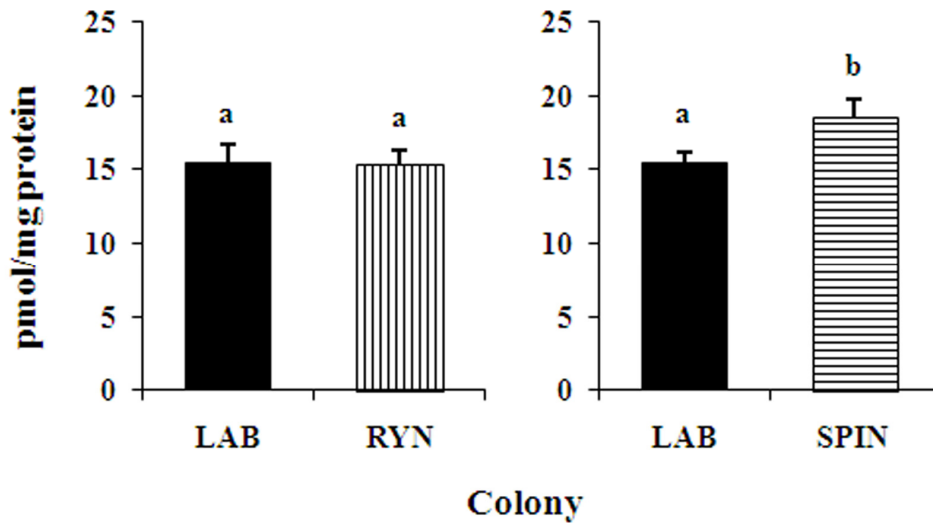
<sup>2</sup> LCR-LC<sub>50</sub>, lethal concentration ratio at LC<sub>50</sub> = LC<sub>50</sub> (field population)/LC<sub>50</sub> (LAB population).

<sup>3</sup> 95% confidence limits estimated using lethal concentration ratio significance test (Robertson et al. 2007).

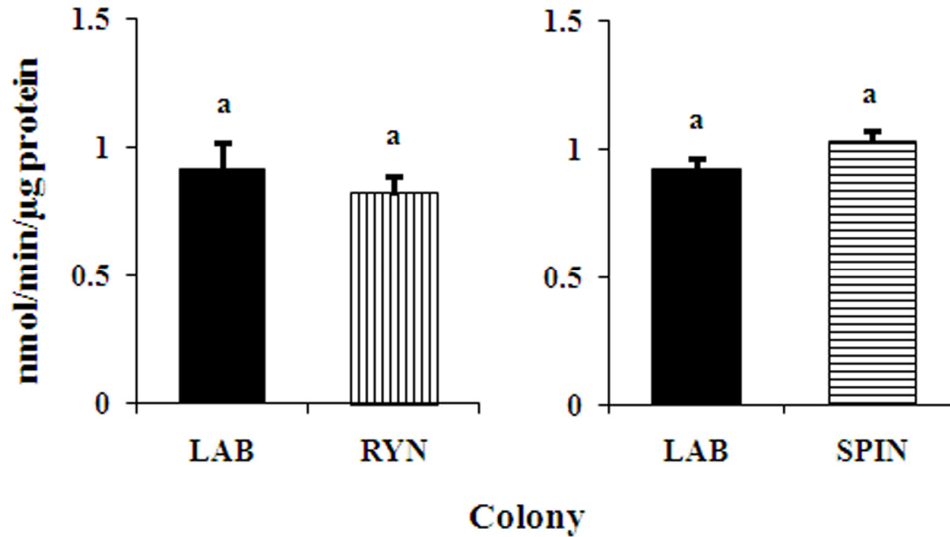
\* Indicates that Lethal Concentration Ratio was significant ( $\alpha = 0.05$ ) (Robertson et al. 2007).



**Fig. 3.1:** Activity of esterases (Mean + SEM) in rynaxypyr-selected (RYN) and spinetoram-selected (SPIN) colonies after nine generations of selection for resistance in laboratory, and the unselected laboratory (LAB) colony of *C. rosaceana*. Graph bars containing similar letters on the top are not significantly different ( $\alpha = 0.05$ , *t*-test).



**Fig. 3.2:** Level of oxidases (pmol equivalent cytochrome-P450 U) (Mean + SEM) in rynaxypyr-selected (RYN) and spinetoram-selected (SPIN) colonies after nine generations of selection for resistance in laboratory, and the unselected laboratory (LAB) colony of *C. rosaceana*. Graph bars containing similar letters on the top are not significantly different ( $\alpha = 0.05$ , *t*-test).



**Fig. 3.3:** Activity of glutathione-*S*-transferases (Mean + SEM) in rynaxypyr-selected (RYN) and spinetoram-selected (SPIN) colonies after nine generations of selection for resistance in laboratory, and the unselected laboratory (LAB) colony of *C. rosaceana*. Graph bars containing similar letters on the top are not significantly different ( $\alpha = 0.05$ , *t*-test).

**Table 3.1:** Toxicity of rynaxypyr to *C. rosaceana* neonate larvae from a colony (RYN) subjected to selection for resistance to rynaxypyr for 12 generations and the unselected laboratory (LAB) colony after synergism.

Colony	Compound	N	Slope ( $\pm$ SE)	LC <sub>50</sub> (ppm) (95% FL) <sup>1</sup>	SR <sup>2</sup> (95% CL) <sup>3</sup>
LAB	Rynaxypyr	180	1.51 (0.18)	0.12 (0.08-0.18)	
	Rynaxypyr + DEF	180	1.59 (0.20)	0.09 (0.06-0.12)	1.44 (0.86-2.39)
	Rynaxypyr + DEM	180	1.44 (0.18)	0.13 (0.09-0.19)	0.95 (0.56-1.61)
	Rynaxypyr + PBO	180	1.71 (0.26)	0.13 (0.08-0.20)	0.94 (0.54-1.64)
RYN	Rynaxypyr	180	2.60 (0.24)	1.05 (0.31-1.91)	
	Rynaxypyr + DEF	180	1.65 (0.25)	0.41 (0.26-0.62)	2.54 (1.41-4.6)*
	Rynaxypyr + DEM	180	1.63 (0.29)	1.08 (0.51-1.90)	0.97 (0.53-1.78)
	Rynaxypyr + PBO	180	1.63 (0.25)	0.99 (0.41-2.02)	1.07 (0.59-1.92)

n = number of larvae assayed.

<sup>1</sup> 95% fiducial limits estimated using POLO (LeOra Software 1987).

<sup>2</sup> SR, synergistic ratio = LC<sub>50</sub> (without synergist)/LC<sub>50</sub> (with synergist).

<sup>3</sup> 95% confidence limits estimated using lethal concentration ratio significance test (Robertson et al. 2007).

\* Indicates that synergistic ration was significant ( $\alpha = 0.05$ ) (Robertson et al. 2007).



**Table 3.2:** Toxicity of spinetoram to *C. rosaceana* neonate larvae from a colony (SPIN) subjected to selection for resistance to spinetoram for 12 generations and the unselected laboratory (LAB) colony after synergism.

Colony	Compound	<i>n</i>	Slope ( $\pm$ SE)	LC <sub>50</sub> (ppm) (95% FL) <sup>1</sup>	SR <sup>2</sup> (95% CL) <sup>3</sup>
LAB	Spinetoram	300	1.86 (0.18)	0.06 (0.03-0.14)	
	Spinetoram + DEF	300	2.56 (0.44)	0.07 (0.05-0.09)	0.95 (0.65-1.40)
	Spinetoram + DEM	300	2.11 (0.29)	0.06 (0.04-0.08)	1.11 (0.75-1.64)
	Spinetoram + PBO	300	1.71 (0.16)	0.04 (0.02-0.06)	1.83 (1.26-2.64)*
SPIN	Spinetoram	300	2.71 (0.34)	0.34 (0.27-0.42)	
	Spinetoram + DEF	300	2.58 (0.32)	0.33 (0.26-0.41)	1.05 (0.76-1.44)
	Spinetoram + DEM	300	1.99 (0.19)	0.21 (0.12-0.38)	1.66 (0.68-2.31)
	Spinetoram + PBO	300	1.76 (0.27)	0.10 (0.04-0.16)	3.58 (2.28-5.61)*

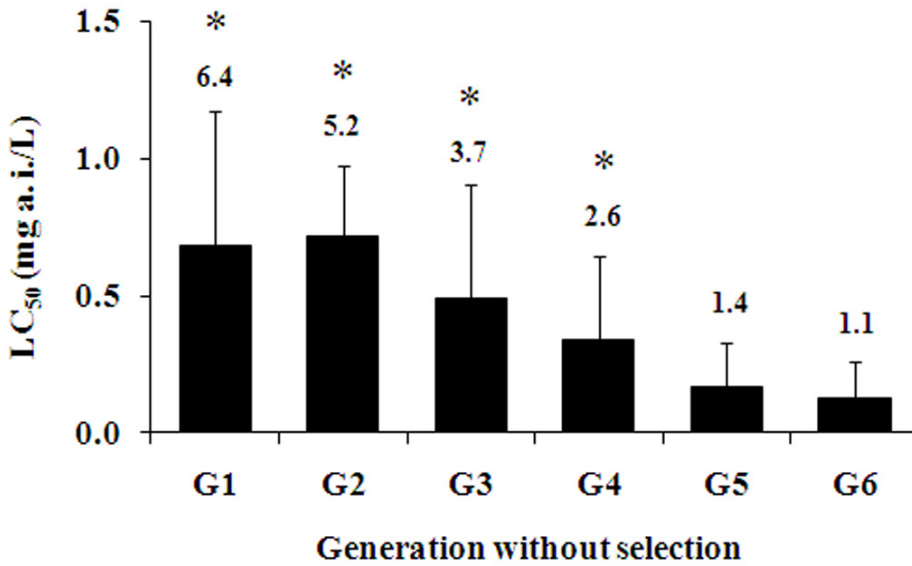
*n* = number of larvae assayed.

<sup>1</sup> 95% fiducial limits estimated using POLO (LeOra Software 1987).

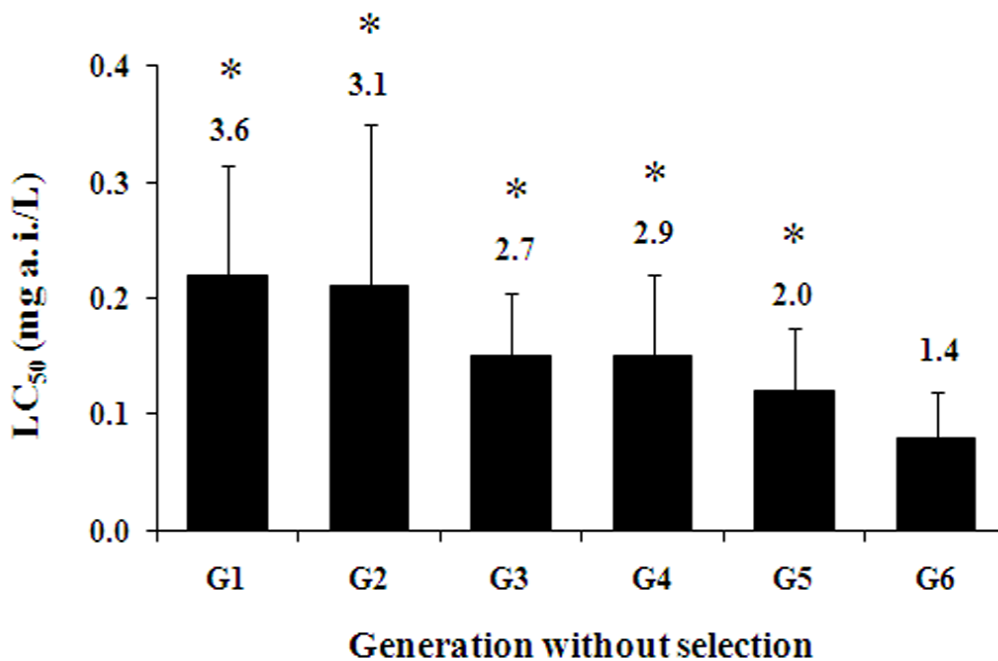
<sup>2</sup> SR, synergistic ratio = LC<sub>50</sub> (without synergist)/LC<sub>50</sub> (with synergist).

<sup>3</sup> 95% confidence limits estimated using lethal concentration ratio significance test (Robertson et al. 2007).

\* Indicates that synergistic ration was significant ( $\alpha = 0.05$ ) (Robertson et al. 2007)



**Fig. 3.4:** Toxicity of rynaxypyr (LC<sub>50</sub> + 95% CL) to *C. rosaceana* neonate larvae from rynaxypyr-selected colony when reared in the absence of selection pressure (RYN-Rev). Numbers on top of the graph bars represent resistance ratios (RR); and \*Indicates that the RR is significant ( $\alpha = 0.05$ ).



**Fig. 3.5:** Toxicity of spinetoram (LC<sub>50</sub> + 95% CL) to *C. rosaceana* neonate larvae from spinetoram-selected colony when reared in the absence of selection pressure (SPIN-Rev). Numbers on top of the graph bars represent resistance ratios (RR); and \*Indicates that the RR is significant ( $\alpha = 0.05$ ).