Seed treatment effects on neonicotinoid concentration in irrigation run-off from lettuce fields

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March 19, 2021

The objective of this project was to evaluate neonicotinoid and azoxystrobin concentration in irrigation run-off in lettuce that had been either seed treated or received a drenched pesticide application in the seed line during planting.

Procedures:

Field trials were conducted at the USDA-ARS Spence Rd. research farm in Salinas CA in the fall of 2019 and 2020. Soil from the experimental sites was sampled from the 0 to 30 cm depth prior to planting to determine the background level of neonicotinoid pesticides. Romaine lettuce (*cv.* True heart) was planted in two rows spaced 12 inches apart on 40-inch, wide beds on September 11, 2019 and September 22, 2020. In row spacing of seeds was 2 and 2.25 inches (156,973 and 139,393 seeds per acre) for the 2019 and 2020 field trials, respectively. Plots measuring 285 ft × 13.33 ft (4 beds) were assigned the treatments listed below following a randomized complete block design, replicated 4 times:

1. Untreated control.
2. Imidacloprid seed treatment.
3. Clothianidin seed treatment.
4. Azoxystrobin seed treatment + imidacloprid drenched at planting.

The application rate of imidacloprid of the seed treatment (treatment 2) was 2.43 and 2.15 fl oz/acre of product (Admire Pro) for 2019 and 2020, respectively. These rates were equivalent to 34.7 and 39.1 g of active ingredient per acre (ai/acre) for the 2019 and 2020 trials, respectively. The seed drenching treatment of imidacloprid was (treatment 3) 10.25 fl oz/acre of product (Admire Pro) for both years and was equivalent to 165.5 g of active ingredient per acre (g of ai/acre). The field application rate of the clothianidin (Nipsit) seed treatment was 5.24 and 4.12 oz of product/acre for 2019 and 2020, respectively. This was equivalent to 71.5 and 55.8 g of active ingredient per acre for 2019 and 2020 trials, respectively. The seed treatment with azoxystrobin equated to 0.00186 and 0.0012 fl oz of product/acre for 2019 and 2020, respectively, which was equivalent to 5.48 and 3.56 mg ai/acre.

The field was irrigated with overhead sprinklers within 2 to 6 days after planting. Impact sprinklers (Rainbird 20JH, 7/64 inch nozzles) on 18-inch high risers were spaced 30 ft apart along each lateral line. The sprinkler lateral lines were spaced 8 beds apart so that each plot was adjacent to one sprinkler line. A flowmeter (Seametric AG2000), installed on the main line was used to monitor the applied water volume for each irrigation. Irrigation dates and volumes applied are shown in Tables 1 and 2 for the 2019 and 2020 trials. The bed tops and furrows were cultivated by tractor between the 4th and 5th irrigation events, which is a standard practice to eliminated emerging weeds.

Runoff volumes were monitored during six irrigation events per trial using flumes installed at the lower end of the untreated control plots. The three furrows between the four beds of plots were connected together about 15 ft from the end of the field into a single furrow that channeled the runoff water through the flume. Similarly the three furrows between the four beds of the other plots were connected together into a single furrow about 15 ft from the end of the field to facilitate sampling of the runoff. The runoff area of each plot equaled 0.055 acres. The height of the water in the flumes in the control plots was monitored with a float mechanism placed in a stilling well connected to the flume and recorded by a datalogger (CR1000, Campbell

Sci. Logan Utah) at 5-minute intervals. A calibration equation was used to transform the height measurements into flow rate in units of gallons per minute.

Runoff water was sampled at 5-minute intervals from the lower end of all plots using automated peristaltic pumps (RF-100, Greylor Co., Cape Coral, FL. USA) throughout the irrigation events. The pump in each replication was activated by a datalogger when the flow rate was greater than 0.25 gal/minute (gpm). The volume of runoff sampled at each interval was proportional to the measured flow rate through the flume and varied from about 125 ml at 1.5 gpm to 810 ml at 10 gpm. Runoff was collected through a stainless-steel tube suspended above the furrow and drawn through a silicone tubing into a 12 L stainless-steel container. Composite samples of runoff from each container were transferred into amber-glass bottles and placed in coolers with ice to maintain the samples at 4 °C. Samples from plots of the same treatment were composited together in 2019 due to limited resources for pesticide analysis. Samples from each plot were analyzed separately for the 2020 trial. Samples were packed with ice and shipped overnight to the USGS laboratory in Sacramento CA where they were analyzed for the concentration of constituent pesticides.

Each sample pump was cleaned prior to the irrigation events by drawing methanol followed by deionized (DI) water through the stainless-steel tube and silicone tubing. The stainless-steel containers were also cleaned by rinsing with methanol followed by DI water. Blanks samples were collected from predetermined plots by drawing deionized water through the pumping system into an amber bottle.

Mass of pesticide loss from each plot was estimated by multiplying the concentration of pesticide by the runoff volume. Cumulative loss of pesticide was estimated by summing the mass of pesticide lost for each irrigation event. Statistical analysis of concentration and mass of pesticide lost in runoff was performed for the 2020 trial using the general linear means procedures in SAS 9.4. Protected LSD means separation tests were performed to identify treatment differences at the $p = 0.05$ confidence level. Student t-tests were conducted to determine if the drenched and seed treated treatments with imidacloprid were statistically different at the $p < 0.05$ confidence level.

Results

Applied water totaled 12.3 and 10.8 inches for the six runoff events in the 2019 and 2020 trials, respectively (Tables 2 and 3). Runoff volumes expressed as a percentage of applied irrigation water were similar between the two trials, averaging 10.9 and 9.3 % of the applied water for the 2019 and 2020 trials, respectively (Tables 3 and 4). Runoff volumes varied among replication areas within the field either due to differences in soil properties or preexisting differences in moisture content of the soil. In 2019 the plot with the highest volume of runoff was more than twice the volume in the plot with the least runoff. In 2020, the plot with the highest volume of runoff was 4 times greater than the runoff volume in the plot with the least runoff.

The concentration of pesticides measured in the runoff for the 2019 and 2020 trials are summarized in Tables 5 and 6. Because samples were composited at each runoff date in 2019 the variation in concentration among the 4 replicated plots could not be assessed. However, the composite values of the runoff samples indicated that over the six irrigation events that Clothianidin seed treatment had the highest concentration of clothianidin and that the Imidacloprid seed treatment had about one third the concentration of imidacloprid compared to the Imidacloprid drenched treatment (Table 5). The cumulative mass of pesticide loss during the 6 irrigation events ranged from 1.3 to 13.3 mg/acre for clothianidin and 2.9 to 19.5 mg/acre for imidacloprid in 2019.

The pesticide concentrations in runoff collected for the treatments in the 2020 trial followed a pattern similar to the results of the 2019 trial. The concentration and mass of clothianidin in the runoff was greatest in the Clothianidin seed treatment and runoff from the drenched imidacloprid treatment had a statistically significantly greater concentration and mass of imidacloprid compared to the other treatments (Table 6). A student-t test ($p = 0.05$) indicated that the average concentration and mass of imidacloprid in the runoff for the drenched treatment was significantly greater than the average concentration of the imidacloprid seed treatment. Cumulative loss of imidacloprid during the six irrigation events averaged five times greater for the drenched treatment compared to the seed treatment although the differences were not significant (Table 7). The cumulative losses of azoxystrobin, clothianidin, and imidacloprid were greatest during the first four irrigation events (Figures 1 -3). After the cultivation of the field, losses of these pesticides in the runoff diminished during the last two irrigation events.

Table 1. Applied irrigation water volumes for the 2019 field trial.

Irrigation Date	**Applied Water**
	inches
9/13/2019	0.9
9/14/2019	1.1
9/16/2019	1.3
9/18/2019	1.9
9/20/2019	1.6
9/24/2019	2.0
9/27/2019	2.2
10/2/2019	0.3
10/4/2019	0.2
10/11/2019	1.0
10/15/2019	2.6
10/18/2019	2.0
Total	17.1

Table 2. Applied irrigation water volumes for the 2020 field trial.

Irrigation Date	**Applied Water**
	inches
9/28/2020	2.8
9/29/2020	2.2
9/30/2020	1.5
10/2/2020	1.6
10/6/2020	1.6
10/16/2020	0.7
10/20/2020	2.9
10/21/2020	1.0
Total	14.3

Table 3. Applied water and runoff volumes for the untreated control treatment for six irrigation events from the 2019 field trial.

		Runoff Volume						
Date	Applied Water	rep A	rep B	rep C	rep D	AVG	STD	% of applied water
	-------------------------------	inches	---------------------------------------					
9/18/2019	1.9	0.00	0.00	0.19	0.12	0.08	0.09	4
9/20/2019	1.6	0.23	0.01	0.26	0.24	0.18	0.12	11
9/24/2019	2.0	0.20	0.10	0.31	0.20	0.20	0.09	10
9/27/2019	2.2	0.27	0.75	0.23	0.18	0.36	0.26	16
10/15/2019	2.6	0.02	0.01	0.45	0.25	0.18	0.21	7
10/18/2019	2.0	0.17	0.23	0.67	0.28	0.34	0.22	17
Total	12.3	0.89	1.09	2.10	1.27	1.34		10.9

Table 4. Applied water and runoff volumes for the untreated control treatment for six irrigation events from the 2020 field trial.

		Runoff Volume						
Date	Applied Water	rep A	rep B	rep C	rep D	AVG	STD	% of applied water
	-------------------------------	inches	---------------------------------------					
9/29/2020	2.2	0.04	0.23	0.11	0.04	0.11	0.09	5
9/30/2020	1.5	0.06	0.38	0.20	0.05	0.17	0.15	12
10/2/2020	1.6	0.11	0.39	0.21	0.09	0.20	0.14	12
10/6/2020	1.6	0.16	0.53	0.23	0.14	0.27	0.18	16
10/20/2020	2.9	0.10	0.17	0.06	0.04	0.09	0.06	3
10/21/2020	1.0	0.12	0.31	0.14	0.10	0.17	0.10	17
Total	10.8	0.58	2.01	0.96	0.46	1.00		9.3

Table 5. Pesticide concentration and estimated mass in runoff of treatments in 2019 trial.

Treatment	date	Concentration in runoff			Mass lost in runoff		
		Azoxystrobin	Clothianidin	Imidacloprid	Azoxystrobin	Clothianidin	Imidacloprid
		------------ ng/L -------------			------------ mg/acre -------------		
Control	9/18/2019	57.0	18.5	23.8	0.45	0.15	0.19
Imidacloprid seed	9/18/2019	3.2	7.7	64.4	0.03	0.06	0.51
Chlothianidin seed	9/18/2019	4.0	302.4	24.7	0.03	2.40	0.20
Imidacloprid drench	9/18/2019	3.1	4.5	175.3	0.02	0.04	1.39
Control	9/20/2019	3.6	7.2	11.5	0.07	0.13	0.22
Imidacloprid seed	9/20/2019	4.1	5.3	39.5	0.08	0.10	0.74
Chlothianidin seed	9/20/2019	3.9	116.0	15.3	0.07	2.17	0.29
Imidacloprid drench	9/20/2019	3.9	5.2	236.5	0.07	0.10	4.43
Control	9/24/2019		7.9	11.7		0.16	0.24
Imidacloprid seed	9/24/2019		5.3	42.2		0.11	0.88
Chlothianidin seed	9/24/2019		27.8	12.8		0.58	0.27
Imidacloprid drench	9/24/2019		4.2	82.3		0.09	1.71
Control	9/27/2019		8.1	12.1		0.30	0.44
Imidacloprid seed	9/27/2019		7.2	35.9		0.26	1.32
Chlothianidin seed	9/27/2019		59.8	13.2		2.20	0.48
Imidacloprid drench	9/27/2019		6.3	68.5		0.23	2.51
Control	10/15/2019		15.4	24.8		0.29	0.46
Imidacloprid seed	10/15/2019		15.0	64.9		0.28	1.21
Chlothianidin seed	10/15/2019		97.7	23.7		1.82	0.44
Imidacloprid drench	10/15/2019		13.6	114.3		0.25	2.13
Control	10/18/2019		18.2	32.8		0.63	1.13
Imidacloprid seed	10/18/2019		19.8	77.0		0.68	2.66
Chlothianidin seed	10/18/2019		120.2	39.1		4.15	1.35
Imidacloprid drench	10/18/2019		17.6	210.3		0.61	7.27
Control	Average	30.3	12.6	19.4	0.26	0.28	0.45
Imidacloprid seed	Average	3.7	10.0	54.0	0.05	0.25	1.22
Chlothianidin seed	Average	4.0	120.6	21.5	0.05	2.22	0.50
Imidacloprid drench	Average	3.5	8.6	147.9	0.05	0.22	3.24
Control	standard dev.	37.7	5.4	9.0	0.3	0.2	0.4
Imidacloprid seed	standard dev.	0.7	6.0	16.9	0.0	0.2	0.8
Chlothianidin seed	standard dev.	0.1	95.8	10.1	0.0	1.2	0.4
Imidacloprid drench	standard dev.	0.6	5.6	69.6	0.0	0.2	2.2
Control	Cumulative				0.52	1.66	2.69
Imidacloprid seed	Cumulative				0.10	1.50	7.32
Chlothianidin seed	Cumulative				0.10	13.33	3.03
Imidacloprid drench	Cumulative				0.10	1.31	19.45

Table 6. Average concentration and mass of clothianidin and imidacloprid in runoff from the 2020 field trial.

		Average Concentration in Runoff				Average Mass of Pesticide Lost in Runoff			
		Clothianidin		Imidacloprid		Clothianidin		Imidacloprid	
Treatments	N	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev
		---------------- ng/L ---------------				---------------- mg/acre -----------------			
Control	24	19	9	13	8	0.32	0.25	0.19	0.16
Imidacloprid seed	24	18	9	58	63	0.35	0.35	0.95	1.21
Clothianidin seed	24	220	180	10	5	3.43	3.66	0.16	0.14
Imidacloprid drench	24	20	11	574	1142	0.35	0.39	5.14	6.75
$LSD_{0.05}$		51		308		1.06		1.85	

Table 7. Cumulative mass of clothianidin and imidacloprid in runoff from the 2020 field trial.

		Azoxystrobin		Clothianidin		Imidacloprid	
Treatment	n	Average	Std.Dev.	Average	Std.Dev.	Average	Std.Dev.
			---------------------- mg/acre ------------------------				
Control	4	0.5	0.01	1.9	1.4	1.1	0.8
Imidacloprid seed	4	0.3	0.02	2.1	1.8	5.7	4.6
Clothianidin seed	4	0.2	0.02	20.6	8.8	1.0	0.8
Imidacloprid drench	4	1.20	0.20	2.1	2.1	30.9	35.1
$LSD_{0.05}$		0.7		7.1		NS	

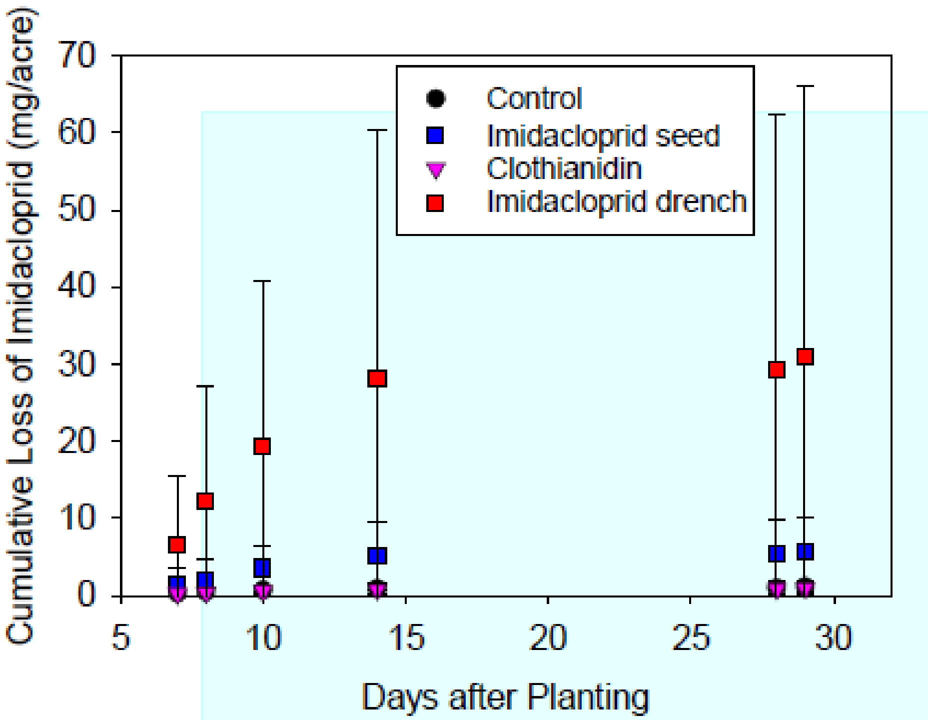

Figure 1. Cumulative loss of imidacloprid in runoff from the 2020 field trial.

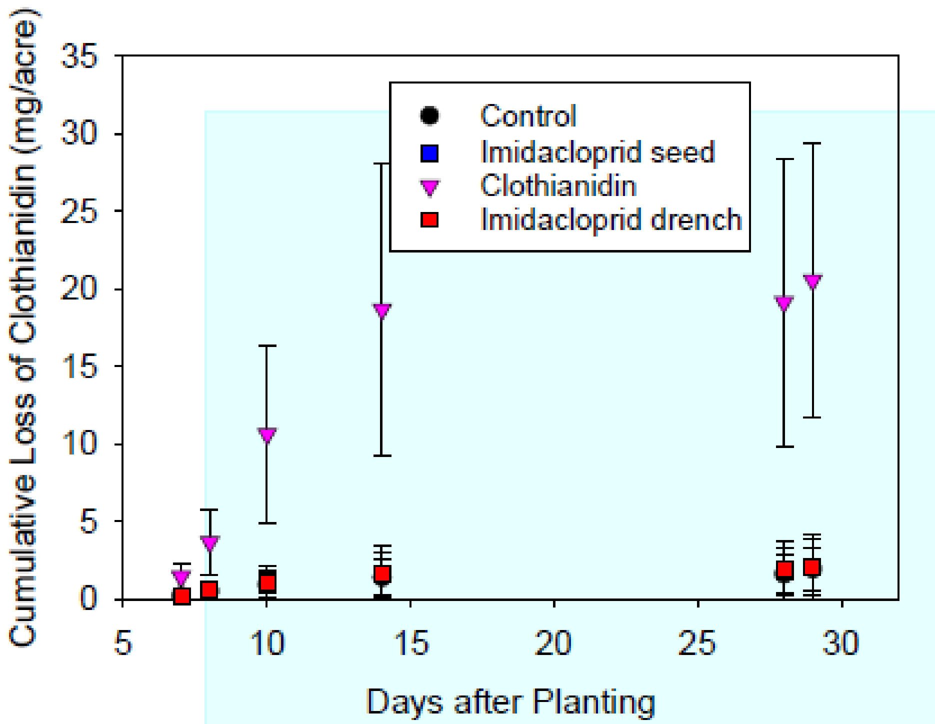

Figure 2. Cumulative loss of clothianidin in runoff from the 2020 field trial.

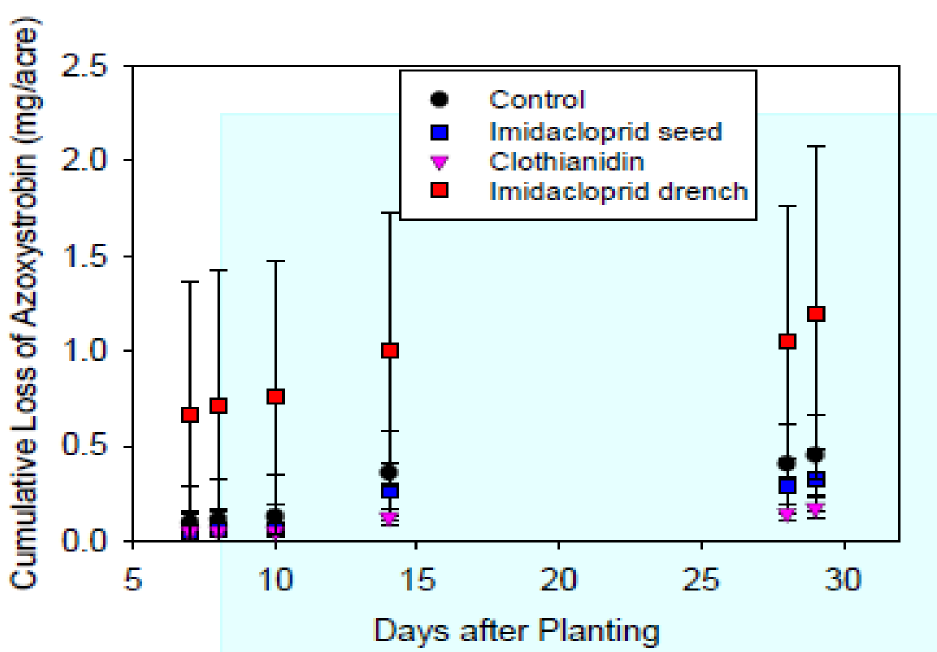

Figure 3. Cumulative loss of azoxystrobin in runoff from the 2020 field trial. Only lettuce seed planted in the imidacloprid drench treatment was treated with azoxystrobin.

Figure 4. Equipment for sampling and monitoring irrigation runoff volume in the 2020 field trial.