

Supporting Information for

Large-scale deployment of seed treatments has driven rapid increase in use of neonicotinoid insecticides and preemptive pest management in U.S. field crops

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Table S1. Neonicotinoid use rates of some common seed-treatment products on four major crops, based on information from pesticide labels.

Crop	Active ingredient	Product (Registrant)	Year registered on crop ^d	Range of rates		
				g/kg seed	mg a.i./seed	g a.i./ha ^e
Maize ^a	Imidacloprid	Gaucho 480 (Gustafson, now Bayer)	2000	-	0.16 – 1.34	11 – 96
		Gaucho 600 (Bayer)	2003	-	0.16 – 1.34	11 – 96
	Clothianidin	Poncho 600 (Bayer)	2003	-	0.25 – 1.25	18 – 90
		NipsItInside (Valent)	2008	-	0.25 – 1.25	18 – 90
		Poncho/VOTiVO (Bayer)	2010	-	0.5	36
	Thiamethoxam	Cruiser 5FS (Syngenta)	2002	-	0.25 – 1.25	18 – 90
Cotton ^a	Imidacloprid	Gaucho 480 (Gustafson, now Bayer)	1994	-	0.375	56
		Gaucho 600 (Bayer)	2003	-	0.375	56
	Clothianidin	Poncho/VOTiVO (Bayer)	2011	-	0.424	63
	Thiamethoxam	Cruiser 5FS (Syngenta)	2002	-	0.3 - 0.375	44 – 56
Soybean ^b	Imidacloprid	Gaucho 480 (Gustafson, now Bayer)	2005	0.63 - 1.25	0.095 – 0.19	40 – 79
		Gaucho 600 (Bayer)	2003	0.63 - 1.25	0.095 – 0.19	40 – 79
	Clothianidin	NipsItInside (Valent)	2009	0.5	0.076	32
		Poncho/VOTiVO (Bayer)	2010	0.86 - 1.3	0.13	55
	Thiamethoxam	Cruiser 5FS (Syngenta)	2004	0.5 - 1	0.076 – 0.15	32 – 63
		CruiserMaxx (Syngenta)	2006	0.5	0.076	32
Wheat ^c	Imidacloprid	Gaucho 480 (Gustafson, now Bayer)	1995	0.05 - 0.94	0.0019 – 0.035	6 – 114
		Gaucho 600 (Bayer)	2003	0.05 - 0.94	0.0019 – 0.035	6 – 114
	Clothianidin	NipsItInside (Valent)	2010	0.098 - 0.7	0.0037 – 0.026	12 – 85
		NipsItSuite (Valent)	2011	0.1 - 0.15	0.0038 – 0.0057	12 – 18
	Thiamethoxam	Cruiser 5FS (Syngenta)	2002	0.29 - 0.52	0.011 – 0.020	36 – 63
		CruiserMaxx Cereals (Syngenta)	2008	0.1 - 0.038	0.0038	12

a. Rates were typically reported on a per seed basis.

b. Rates were typically reported on a seed weight basis; we assumed 661380 seeds/kg to estimate per seed rates

c. Rates were typically reported on a seed weight basis; we assumed 2645520 seeds/kg to estimate per seed rates

d. Based on a search in the Pesticide Product Label System (<http://iaspub.epa.gov/apex/pesticides/f?p=PPLS:1>) by EPA registration number. The year of registration may not be the year the product was commercially available.

e. Assumed the following seeding rates: maize, 71630 seeds/ha; cotton, 148200 seeds/ha; soybean, 419900 seeds/ha; wheat, 3211000 seeds/ha

Table S2. Summary of neonicotinoids and their major agricultural uses in the United States, based on regulatory documents from the U.S. Environmental Protection Agency.

Active ingredient	Year first registered	Information last updated by US-EPA	Registrations (#)		Application methods	Leading agricultural uses	Seed treatment uses
			Standard (section 3)	Special local need			
Acetamiprid ^a	2002	2012	36	14	Spray, seed treatment	Apples, cotton, pears, oranges	Canola, mustard, potato
Clothianidin ^b	2003	2011	29	2	Spray, soil application, trunk injection, seed treatment	Maize	Maize, small grains, canola, cotton, soybeans, many root/tuber vegetables, sorghum, millet, sugar beet, broccoli
Dinotefuran ^c	2004	2011	37	16	Spray, soil application, chemigation	Grapes, cantaloupes, rice, tomatoes, watermelons	n/a
Imidacloprid ^d	1994	2008	397	38	Spray, seed treatment, soil application, trunk injection, chemigation	Maize, potatoes, cotton, lettuce, oranges, pecans, grapes, broccoli, apples, tomatoes, tobacco, soybeans	Maize, canola, cotton, soybeans, small grains, many root/tuber vegetables, sorghum, sugar beets
Thiacloprid ^e	2003 (cancelled 2014)	2012	3	-	Spray	Apples, pears	n/a
Thiamethoxam ^f	1999	2011	55	10	Spray, soil application, seed treatment, chemigation	Soybeans, maize, cotton	Maize, small grains, beans (incl. soybean), canola, cotton, many vegetables, melons, peas, rice, potato, sorghum, sugarbeet, sunflower

a. US-EPA (2014) Acetamiprid Registration Review. Docket EPA-HQ-OPP-2012-0329. Last accessed 10/15/14. Available at:

<http://www.regulations.gov/#!docketDetail;D=EPA-HQ-OPP-2012-0329>

b. US-EPA (2014) Clothianidin Registration Review. Docket EPA-HQ-OPP-2011-0865. Last accessed 10/15/14. Available at:

<http://www.regulations.gov/#!docketDetail;D=EPA-HQ-OPP-2011-0865>

c. US-EPA (2014) Dinotefuran Registration Review. Docket EPA-HQ-OPP-2011-0920. Last accessed 10/15/14. Available at:

<http://www.regulations.gov/#!docketDetail;D=EPA-HQ-OPP-2011-0920>

d. USEPA (2014) Imidacloprid Registration Review. Docket EPA-HQ-OPP-2008-0844. Last accessed 10/15/14. Available at: <http://www.regulations.gov/#!docketDetail;D=EPA-HQ-OPP-2008-0844>

e. US-EPA (2014) Thiacloprid Registration Review. Docket EPA-HQ-OPP-2012-0218. Last accessed 10/15/14. Available at:

<http://www.regulations.gov/#!docketDetail;D=EPA-HQ-OPP-2012-0218>

f. USEPA (2014) Thiamethoxam Registration Review. Docket EPA-HQ-OPP-2011-0581. Last accessed 10/15/14. Available at:

<http://www.regulations.gov/#!docketDetail;D=EPA-HQ-OPP-2011-0581>

Table S3. Estimated neonicotinoids applied (kg active ingredient), and neonicotinoid seed treatments (ST) as a percentage of neonicotinoids applied, for major U.S. field crops from 2000 to 2012. Dashes represent crop-year combinations for which data were unavailable.

Crop	Estimate	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011/ 2012 ^a
Maize	USGS, Neonics. (low) ^b	1	0	68	2	268868	404248	331379	494426	611349	684513	588007	933983
	USGS, Neonics. (high) ^b	1	0	1056	2	353854	452126	353522	543572	661445	694275	594036	947457
	NASS, Non-ST neonics ^c	0	0	0	0	-	0	-	-	-	-	0	-
	ST Neonics. (low) ^d	1	0	68	2	-	404248	-	-	-	-	588007	-
	ST Neonics. (high) ^d	1	0	1056	2	-	452126	-	-	-	-	594036	-
	% ST Neonics. (low – high) ^e	100	-	100	100	-	100	-	-	-	-	100	-
Soy	USGS, Neonics. (low) ^b	0	0	0	0	0	0	73020	83692	184172	300980	593038	535581
	USGS, Neonics. (high) ^b	0	0	0	0	0	0	95358	117693	232589	351661	612878	582474
	NASS, Non-ST neonics ^c	0	0	0	-	0	0	0	-	-	-	-	15120
	ST Neonics. (low) ^d	0	0	0	-	0	0	73020	-	-	-	-	520461
	ST Neonics. (high) ^d	0	0	0	-	0	0	95358	-	-	-	-	567355
	% ST Neonics. (low – high) ^e	-	-	-	-	-	-	100	-	-	-	-	97
Cotton	USGS, Neonics. (low) ^b	13183	16841	25684	31247	103692	110809	161828	127025	97054	81927	127566	276078
	USGS, Neonics. (high) ^b	17086	35352	36962	49244	115260	118578	173075	133039	102554	91629	131778	290941
	NASS, Non-ST neonics ^c	8203	9957	-	29030	-	42301	-	41499	-	-	36287	-
	ST Neonics. (low) ^d	4980	6884	-	2217	-	68508	-	85526	-	-	91279	-
	ST Neonics. (high) ^d	8883	25395	-	20214	-	76277	-	91541	-	-	95491	-
	% ST Neonics. (low – high) ^e	38-52	41-72	-	7-41	-	62-64	-	67-69	-	-	72	-
Wheat	USGS, Neonics. (low) ^b	0	0	0	2	0	2	0	0	0	52216	61462	66717
	USGS, Neonics. (high) ^b	0	0	0	2	0	2	0	0	0	77358	79455	82404
	NASS, Non-ST neonics ^c	0	-	0	-	0	-	0	-	-	0	-	0
	ST Neonics. (low) ^d	0	-	0	-	0	-	0	-	-	52216	-	66717
	ST Neonics. (high) ^d	0	-	0	-	0	-	0	-	-	77358	-	82404
	% ST Neonics. (low – high) ^e	-	-	-	-	-	-	-	-	-	100	-	100

a. For soybeans and wheat, we used NASS data from 2012 and USGS data from 2011 because data for both years were not available in both datasets

- b. Data supplied by Wes Stone, from the Pesticide National Synthesis Project; “low” = EPest-low estimate; “high” = EPest-high estimate (Thelin & Stone 2013)
- c. USDA NASS data (2014b) was adjusted to reflect national totals (see Methods)
- d. Calculated by subtracting non-ST neonicotinoids (NASS) from total neonicotinoids (USGS)
- e. Calculated by dividing ST neonicotinoids by total neonicotinoids

Table S4. Nationwide estimates of insecticides applied (kg active ingredient), and neonicotinoid seed treatments (ST) as a percentage of insecticides applied, for major U.S. field crops from 2000 to 2012. Dashes represent crop-year combinations for which data were unavailable.

Crop	Estimate	2000	2001	2002	2003	2004	2005	2006	2007	2009	2010	2011/ 2012 ^a
Maize	NASS, Non-ST insecticides ^b	4785152	4391551	2743185	3680504	-	2365019	-	-	-	795493	-
	Total insecticides (low) ^c	4785152	4391551	2743253	3680506	-	2769267	-	-	-	1383500	-
	Total insecticides (high) ^c	4785152	4391551	2744240	3680506	-	2817144	-	-	-	1389529	-
	% ST Neonics. (low – high) ^d	0	0	0	0	-	15-16	-	-	-	43	-
Soy	NASS, Non-ST insecticides ^b	141689	154605	503627	-	278315	1218073	1263443	-	-	-	1918316
	Total insecticides (low) ^c	141689	154605	503627	-	278315	1218073	1336463	-	-	-	2438777
	Total insecticides (high) ^c	141689	154605	503627	-	278315	1218073	1358801	-	-	-	2485671
	% ST Neonics. (low – high) ^d	0	0	0	-	0	0	5-7	-	-	-	21-23
Cotton	NASS, Non-ST insecticides ^b	19716776	13170763	-	6183366	-	7466940	-	3832852	-	2740149	-
	Total insecticides (low) ^c	19721756	13177646	-	6185583	-	7535447	-	3918379	-	2831428	-
	Total insecticides (high) ^c	19725658	13196157	-	6203580	-	7543217	-	3924393	-	2835640	-
	% ST Neonics. (low – high) ^d	0	0.1-0.2	-	0.0-0.3	-	0.9-1.0	-	2.2-2.3	-	3.2-3.4	-
Wheat	NASS, Non-ST insecticides ^b	306888	-	402185	-	421385	-	182559	-	395512	-	201050
	Total insecticides (low) ^c	306888	-	402185	-	421385	-	182559	-	447728	-	267767
	Total insecticides (high) ^c	306888	-	402185	-	421385	-	182559	-	472870	-	283454
	% ST Neonics. (low – high) ^d	0	-	0	-	0	-	0	-	12-16	-	25-29

a. For soybeans and wheat, we used NASS data from 2012 and USGS data from 2011 because data for both years were not available in both datasets

b. USDA NASS data⁷ was adjusted to reflect national totals (see Methods). Cotton values are for upland cotton, > 97% of U.S. cotton hectares from 2000 to 2012. Wheat values are for winter, spring, and durum wheat combined.

c. Calculated by adding ST neonicotinoids (Table S3) to Non-ST insecticides for each crop

d. Calculated by dividing ST neonicotinoids (Table S3) by total insecticides for each crop

Table S5. Some insecticidal seed treatments labeled for maize, based on active ingredients other than neonicotinoids. We do not consider products for stored grain control.

Class	Insecticide active ingredient(s)	Product ^a	Year Registered by EPA ^b	Year cancelled ^b	Application method ^b
Organochlorine	Lindane	Isotox Seed Treater (F) ®	1971	2005	Planter-box
		Grain Guard Plus	1992	2005	Planter-box
Organochlorine + Organophosphate	Lindane + Diazinon	Kernel Guard ®	1986	2005	Planter-box
		Agrox Premiere ®	1995	2005	Planter-box
		Germate Plus ®	1987	2004	Planter-box
		Vitavax ®	1987	2004	Planter-box
Organophosphate	Diazinon	Diazinon 50 WP	1983	2005	Planter-box
	Chlorpyrifos	Lorsban ® 30 Flowable	1987	2004	Liquid/slurry treaters
Pyrethroid	Permethrin	Kernel Guard ® Supreme	1998	-	Planter-box
		Pounce ® 25 STD	1998	2010	Commercial seed treaters
	Tefluthrin	Force ® ST/30 CS	1995	-	Commercial seed treaters

a. Major maize seed treatment products were identified based on key references.^{18,57,58,89} One source listed several carbamate insecticides that were little-used as seed treatments,¹⁸ but we could not find trade names for these products or other evidence of their use.

b. Based on a search in the Pesticide Product Label System (<http://iaspub.epa.gov/apex/pesticides/f?p=PPLS:1>) by product name and/or EPA registration number. The year of approval may not be the year the product was commercially available.