Environmental fate of neonicotinoids: a potato case study

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Introduction: To date, the in-plant distribution of the in-furrow, systemic neonicotinoid class (IRAC MoA 4A) of insecticides are relatively unknown in potato. Variable insecticide concentration and distribution over time is thought to affect resistance development in numerous insect pests, including key pests of potato (Gould 1984, Isaacs 2002, Daniels et al. 2009). Variable expressions of systemic insecticides in the crop are thought to create sub-lethal refuges promoting the evolution of behavioral and physiological mechanisms of resistance (Hoy et al. 1998). Characterization of insecticide concentrations throughout the growing season in relation to pest density will create a useful baseline estimate of efficacy duration for systemic neonicotinoids within potato foliage. Insecticide expression patterns may better inform timing at which the crop reaches a sub-lethal, chronic dose window. Exposure of tolerant pest populations to sub-lethal insecticide levels will accelerate selection for resistant phenotypes, a process that will have direct implications for neonicotinoid resistance management as well as the longevity of future registrations. Connecting the amount of insecticide delivered into the furrow to the proportion taken up by the plant season-long is a key factor in documenting both in-plant distribution and environmental fate of insecticides. While optimized plant uptake is advantageous for IRM, it will also minimize insecticide loss. Movement of unused compound beyond the root zone is a direct economic loss for the producer and may result in unforeseen environmental consequences.

Emerging concern for groundwater quality has revitalized a discussion about nutrient and pesticide use patterns in potato and their potential impacts on Wisconsin's agro-ecosystem. Positive detections of neonicotinoids by the Wisconsin Department of Agriculture Trade and Consumer Protection (WI-DATCP) in groundwater throughout the state have motivated new research that not only addresses the above ground concentration of neonicotinoids but what possible losses may be occurring below ground (Table 1). Several studies have documented the chemical properties of neonicotinoids and their interaction with biota in the soil, composition of the soil and movement of compound into the water. Few have documented the relative tradeoffs between application method of labeled neonicotinoid rates in potato, in-plant expression of insecticide, and losses into the environment. Our study strives to generate applied solutions which minimize environmental losses of systemic insecticides while providing high doses of insecticide to effectively manage key insect pests of potato.

Table 1. Positive detections of thiamethoxam – WI DATCP

Location	Date(s)	Concentration (ppb)[b]
Private well near Lone Rock	6/23/09 & 6/9/09	0.693-1.26
Private well near Arena	6/23/2008	0.656
Private well near Edgerton	11/2/2009	1.61
Monitoring well Adams County	2008 and 2009[a]	0.82-8.93
Monitoring well Grant County	4/7/2008	1.25
Monitoring well Iowa County 1	2008 and 2009[a]	0.784-2.04
Monitoring well Iowa County 2	2008 and 2009[a]	0.671-2.85
Monitoring well Sauk County	2008 and 2009[a]	1.47-3.66
Monitoring well Waushara County	8/19/08 & 12/1/08	0.638-0.704
Irrigation well Portage County 1	6/10/11 & 8/12/12	0.533-0.58
Irrigation well Portage County 2	7/10/2011	0.148
Irrigation well – Hancock Ag Research Station	7/10/2011	0.59

[a]multiple sampling dates in 2008 and 2009

[b]EPA Enforcement Standard: = 0.012 mg/kg bw/day (120 ppb)
EPA Preventative Action Limit = 24 ppb

Objectives: The objectives of this

project are twofold: 1) quantify in-plant concentration of thiamethoxam in potato between emergence and flowering. Known insecticide expression patterns over time will better inform resistance management strategies for key insect pests of potato under field conditions. 2) Directly compare season long thiamethoxam concentration in water leachate for three systemic and a foliar use patterns in potato. Documentation of temporal insecticide translocation in water will provide an improved understanding of compound stability for several delivery technologies. Results generated will inform a growing body of knowledge about potential negative environmental impacts for certain use patterns on soil, water, and human health

Project History: The research presented on in-plant neonicotinoid expression was conducted in the 2010 and 2011 growing seasons. Forthcoming results will be presented as part of an analysis determining both temporal and spatial (between plant) insecticide concentration variability in potato. Characterization of neonicotinoid leachate from potato was a project component deployed with several systemic use patterns in the 2011 and 2012 growing season.

Approach: Treatment and design as were similar in both objectives one and two. Experiments were conducted at both the Hancock Agricultural Research Station (UW-HARS), Hancock, WI and Coloma Farms Inc., Coloma, WI. The cultivar Russet Burbank was used in each season. All best management practices were conducted at each site (Boerboom et al. 2010).

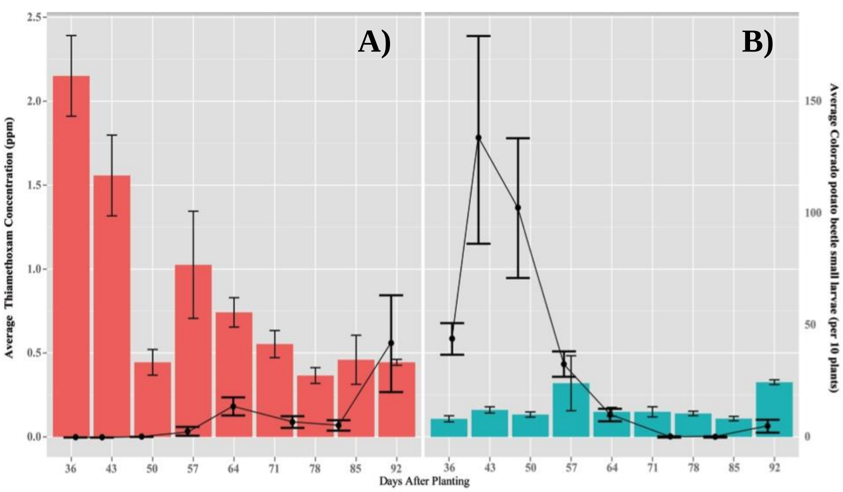

Figure 1. 2011 thiamethoxam concentration in (A) in-furrow and (B) untreated controls over nine consecutive weeks represented as bars and response of Colorado potato beetle adults to treatments (line graphs).

Field experiments: Insecticide treatments of thiamethoxam (Platinum 75SG & Actara 25WG, Syngenta, Greensboro, NC) were selected to represent a common, at-plant potato neonicotinoid and represent the majority of neonicotinoid groundwater detections by WI-DATCP from 2008-2011. Commercially formulated insecticide products at maximum labeled rates for potato in Wisconsin was applied (Boerboom et al. 2010). A randomized complete block design with four treatments (e.g. in-furrow, seed treatment, impregnated polyacrylamide and foliar) and an untreated control was planted. 320 seed piece groups will be planted into open furrows (20 plants per row x 4 rows x 4 repetitions). Each treatment will be flanked by a double guard row of untreated seed pieces on either side of experimental plots. Seed pieces will receive either an at-plant, polyacrylamide or seed treatment application of thiamethoxam (Platinum 75SG 2.67 fl. $^{oz\ ai}/_{a}$). Polyacrylamide horticultural copolymer granules was be impregnated at an application rate of 16 $^{kg}/_{ha}$. Thiamethoxam insecticide solutions (0.834 g/250 ml D.I. water) were mixed with 75 g polyacrylamide then slowly stirred until all liquid is absorbed. Impregnated granules were dried for 24 hours at 20°C. Treated granules were divided into even quantities per row (9.8 g per 20 feet imidacloprid, 9.6 g per 20 feet thiamethoxam) and evenly distributed.

***In-plant chemical quantification*:** At 90% plot emergence, foliage sampling will be collected at each sample plant weekly for nine consecutive weeks. As the canopy develops, terminal leaflet samples will be taken weekly from apical-stem leaves. Leaf samples will be immediately placed upon ice. Using a #4 cork borer leaf core samples will be removed, weighed and frozen. At the conclusion of the study all samples were be removed from the freezer and prepared for assay using a methanol extraction procedure.

Samples were homogenized then centrifuged for one minute. Supernatant will be used for all the following analyses.

In-plant concentration of thiamethoxam was assessed with competitive ELISA (enzyme-linked immunosorbant assay). Neonicotinoid molecules present within the plant tissue will compete with (horseradish peroxidase)-labeled insecticide. Plate wells will have a limited number of antibody binding sites. Samples will be assessed with previously prepared ELISA kits (Beacon Analytical Systems Inc, Portland, ME, thiamethoxam plate, cat # CPP-022) and tests will be conducted according to the manufacturer's instructions. Results will be semi-quantitatively compared using a spectrophotometer (Wallace Victor ^{2} – 1420 Multilabel Counter). Standard curves will be assessed in two ways: 1) spiked technical grade thiamethoxam extractions (Byrne *et al.* 2005) and, 2) all treatments will be directly compared with a dilution series of each active ingredient in water. End-point absorbance of samples will be taken at 450 nm to determine insecticide concentration of each sample with respect to the standard curve. Internal standards provided by the manufacturer will serve as a comparison to both standard curves to determine potential unintended binding of other plant metabolites. Insecticide titers will be assessed with nested ANOVA (R-core).

Lysimeter chemical quantification: Each plot had a zero tension pan-type water collection lysimeter installed directly beneath the potato hill at a depth of 75 cm. Systemic insecticides was be applied at-planting using a hand-held, CO_2 pressurized sprayer as a directed spray to the seed. Lysimeters were be sampled on a bi-monthly frequency. Following collection samples will be maintained at 4-6°C. Water samples will be analyzed every other week for 10 weeks by the WI DATCP-Bureau of Laboratory Services with LCMS. Established standard operating procedures developed by WI DATCP-EQ will used for the analysis of neonicotinoid residues.

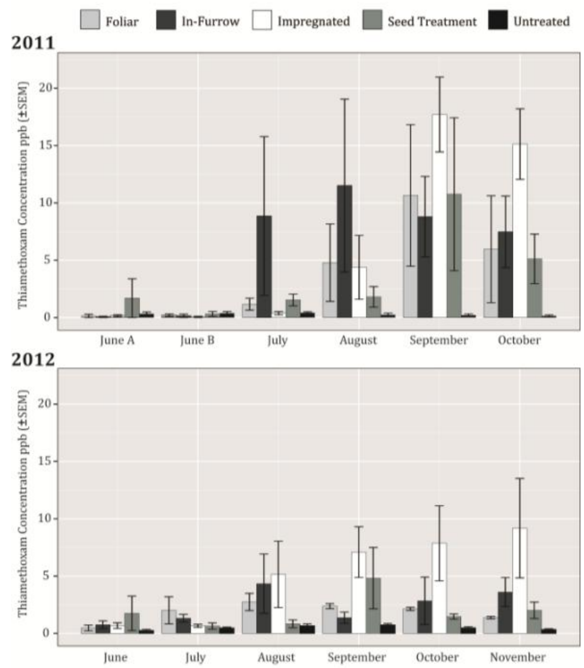

Figure 2. Thiamethoxam concentration in leachate samples over two consecutive growing seasons.

Results: Thiamethoxam concentration in leachate samples indicated a significant effect of delivery method in 2011 (F = 7.451; df = 9,104; p-value = <0.0001) and 2012 (F = 2.599; df = 9,95; p-value = 0.03. The effect of sampling date was also significant but a date by delivery interaction was not. In-plant concentration results will be forthcoming at the 2013 Grower education meeting.

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