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Longevity of Planting-Time Neonicotinoids in Potato Production Systems of the Pacific Northwest

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Most of the potatoes grown in the Pacific Northwest are treated with a neonicotinoid insecticide at planting, via seed treatment, in-furrow application, or at lay-by. Neonicotinoids have been utilized to control early season insect pests, which includes the Colorado potato beetle, aphids, leafhoppers, and more recently, early infestations of potato psyllid. Most growers and crop advisors have had years of experience using either thiamethoxam (Cruiser Maxx™) as a seed piece treatment, or imidacloprid (Admire™) as an in-furrow treatment for management of these pests and have come to expect eighty or more days of insect control.

During 2016, the early spring weather was conducive for rapid foliar growth. On commercial fields treated with neonicotinoids (at planting), juvenile potato psyllids were observed as early as 60 days after treatment in Burbank, WA, which is much earlier than expected. Presence of nymphs shows that adults colonized the plants, and juveniles developed and were not controlled with the at-plant neonicotinoid. This phenomenon could be due to either excessive leaf tissue (therefore lower concentrations of the insecticide in the overall plant) or these products have limited efficacy on specific pests, such as the potato psyllid.

Previous studies demonstrate that imidacloprid applied as a soil systemic insecticide significantly reduces psyllid feeding presumably as a deterrent and as a result reduced the transmission of zebra chip for 6 weeks after treatment (Butler et al. 2011). This study provides good evidence of the efficacy of this product, but for a shorter window of time than our producers have come to expect with this type of chemistry and use pattern. Huseth et al. (2014) evaluated the longevity of neonicotinoids on potatoes. This study did not test different cultivars, nor did it measure the relationship between canopy size and the amount of neonicotinoid in the plant tissue. This same study showed that the neonicotinoid concentration in the plant varied from one year to the next, indicating that the growing season and the amount of foliage could play a role in the titer of the insecticide. Our experiment aims to address this issue. Huseth et al. (2014) only evaluated the Colorado potato beetle, a pest that is suspected to be easier to control with neonicotinoids than the potato psyllid. Our study focused on the potato psyllid.

The primary objective of this project was to determine how long at plant in-furrow, seed piece, or lay-by treatments with neonicotinoid insecticides protect potato plants from insect pests, specifically potato psyllid. We hypothesized that a potato cultivar with a larger canopy early in the growing season would have a lower concentration of neonicotinoid than a potato cultivar with a smaller canopy. As such, the cultivar with the lower concentration of neonicotinoid would be infested with pest insects earlier than the cultivar with the higher concentration of the neonicotinoid insecticide.

PROCEDURES

Experiments were conducted at the WSU research site in Pasco, WA and maintained mimicking commercial potato production practices in the Columbia Basin. Test plots were arranged in a randomized complete block design with four replications of each treatment. Each experimental plot was four rows wide and twenty-five feet long.

Treatments included neonicotinoids applied in three ways: 1) in-furrow with imidacloprid (Admire Pro 8.7 fl oz/A), 2) seed piece treatment with thiamethoxam (Cruiser Maxx 0.23 fl oz/100 lbs. seed), and 3) a banded lay-by application with thiamethoxam (Platinum 8 fl oz/A). Cruiser Maxx and Platinum contain the same active ingredient, thiamethoxam, and with the rates that were used, were applied in equal amounts of active ingredient per acre. The in-furrow and seed piece treatments were made at planting (April 17, 2017 and April 20, 2018), and the lay-by treatments were made at the six to eight-inch rosette stage (May 22, 2017 and May 21, 2018). The in-furrow and layby treatments were applied with 5 and 10 gallons of water per acre, respectively. All treatments were applied to two different cultivars. One cultivar was an abundant early-season foliage determinant cultivar (Norkotah), and the other of an indeterminant cultivar with typically sparse, early-season foliage (Alturas). Untreated check plots of both cultivars were also planted and evaluated.

Samples of potato foliage were collected seven times during the growing season (43, 49, 56, 70, 84, 98, and 112 days after planting) to evaluate the concentration of the insecticides. Leaf samples consisted of one-gallon bags of foliage collected from at least twenty different plants per plot. The most recent fully developed leaf was collected from each plant. Samples were collected at the same time of day for each sampling period, placed in a container with ice packs, and sent next day shipping to Pacific Agricultural Laboratories (PAL). PAL evaluated the samples for amounts of thiamethoxam, its metabolite clothianidin, and imidacloprid using liquid chromatography mass spectroscopy. At the designated dates as detailed above, we performed destructive plant sampling on three plants in each plot. Destructive whole plant sampling (a wet-weight measurement) provided a relative assessment of the canopy size of the two cultivars at the time of pesticide concentration measurement. The aboveground portion, roots, and tubers were all weighed separately for each three-plant sample.

In addition to evaluating resident insect populations, slip cages with potato psyllids were used to assess the efficacy and residual effects of the insecticides. Each plot was infested with three second instar psyllid nymphs using a slip cage (6 x 9-inch mesh fabric) on a single potato leaf (Figure 1). They were placed on plants on the same seven dates mentioned above. Slip cages remained on the leaves for seven days. Cages were then removed, and mortality of the psyllids was assessed. At the end of the season tubers were dug from a ten-foot section of row from the middle of each plot and yield and quality assessed.

Figure 1. Slip cage utilized to evaluate potato psyllid mortality.

RESULTS AND DISCUSSION

Potato cultivars did not differ in leaf tissue weights early in the season in 2018, but as the season progressed, Norkotah leaf tissue weights were significantly lower than Alturas (Figure 2). This trend was somewhat different than in 2017, where early in the growing season Norkotah leaf tissue weights were higher than Alturas, which was what we expected with the determinant cultivar. The maximum foliar weights for both cultivars differed by season, with both cultivars containing significantly higher maximum foliar weights in 2017 compared to 2018 (Figure 2). During the 2018 growing season, potato growing degree days accumulated more rapidly in May compared to 2017 which may have had an impact on the foliar growth patterns of both cultivars (Figure 3). For most sample dates, insecticide treatment did not influence leaf tissue weights (Tables 1a & 1b). In 2017, during two sample periods (June 12 and 26), plots treated with thiamethoxam as a seed treatment contained lower fresh canopy weights than the untreated check, but as the season progressed, that trend was no longer present (Table 1a). On the July 5, 2018 sample date, plots treated with CruiserMax and Platinum contained lower leaf tissue weights than the untreated check (Table 1b). This data suggests there is likely some inherent cost to the plant from metabolizing the insecticide treatment in terms of reduced tissue weight, but that impact is resolved later in the season and does not appear to diminish yield or quality.

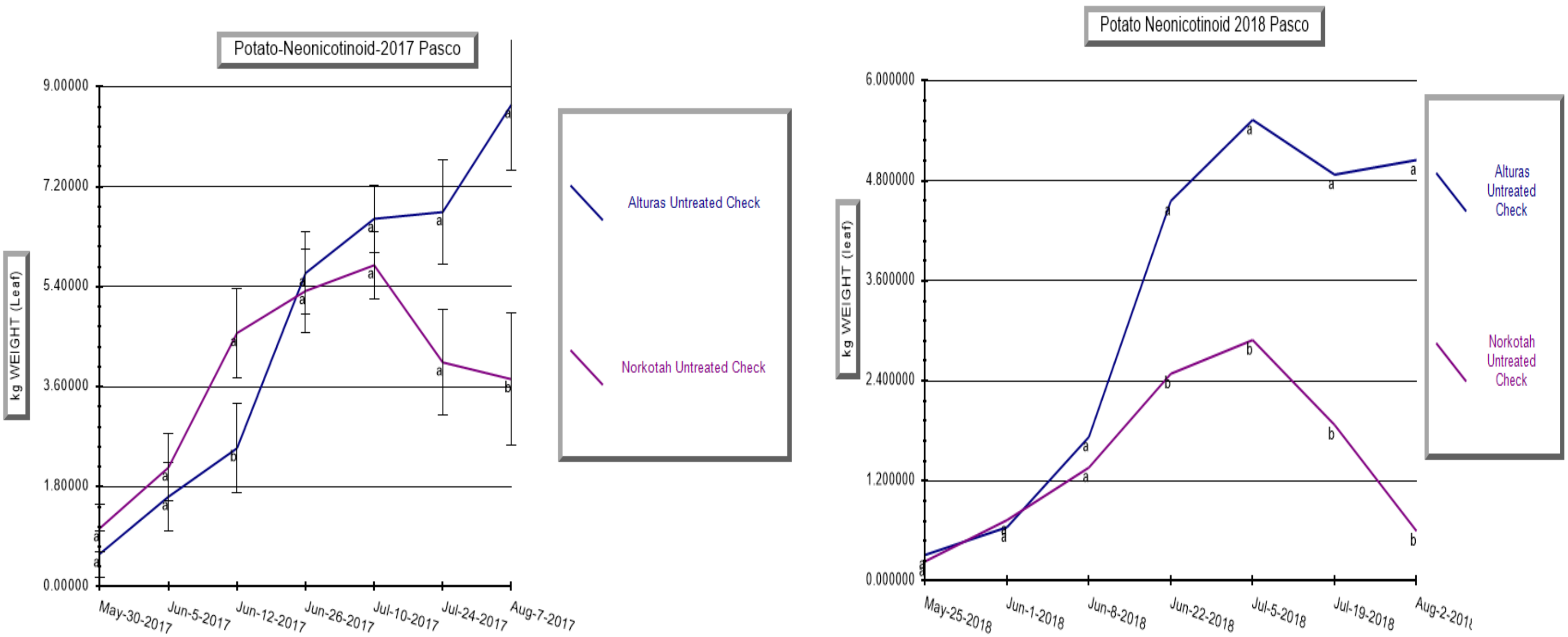

Figure 2. Fresh plant weights for three plants per plot by cultivar during the seven sample periods. Treatments with the same letters are not statistically different from one another (P=0.05 Student-Newman-Keuls test).

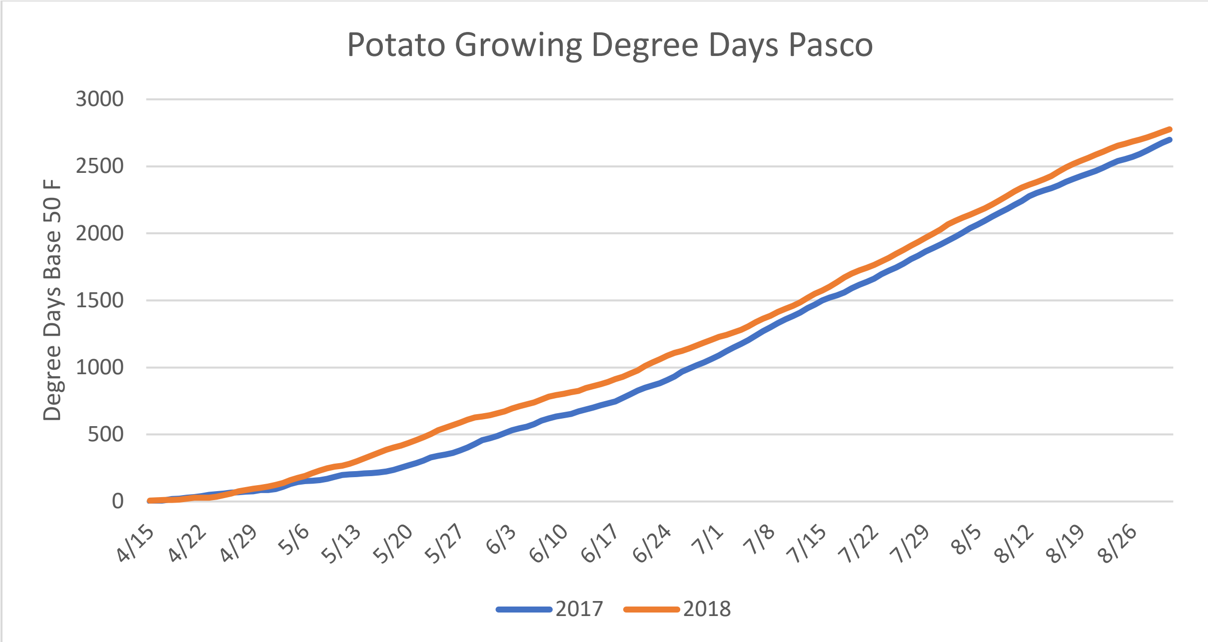

Figure 3. Potato growing degree days (base 50 F) at the WSU AgWeatherNet weather station in Pasco, WA from planting until harvest for 2017 and 2018.

Table 1a. Fresh plant weights for three plants per plot by various factors during the seven sample periods 2017. Treatments with the same letters are not statistically different from one another (P=0.05 Student-Newman-Keuls test).

	Weight in Kg						
Treatment	Date						
	30-May	5-Jun	12-Jun	26-Jun	10-Jul	24-Jul	7-Aug
Alturas	0.680b	1.580b	2.923b	5.087a	6.277a	6.402a	6.811a
Norkotah	0.978a	2.256a	3.733a	4.710a	5.715a	4.583b	3.439b
LSD	0.180	0.373	0.484	1.080	1.277	1.079	1.420-1.893
Untreated Check	0.823a	1.883a	3.530a	5.486a	6.206a	5.666a	5.573a
Admire Pro	0.753a	1.859a	3.405ab	5.030ab	6.446a	5.744a	4.809a
Cruiser Maxx	0.764a	1.782a	2.764b	3.890b	5.187a	5.960a	4.559a
Platinum	0.976a	2.148a	3.614a	5.189ab	6.146a	4.603a	4.664a
LSD	0.254	0.527	0.684	1.080	1.277	1.526	2.134-2.672
Alturas/Untreated Check	0.593b	1.620cd	2.492c	5.647a	6.624a	6.744ab	8.631a
Norkotah/Untreated Check	1.053a	2.145abc	4.567a	5.324a	5.788a	4.587bcd	3.486b
Alturas/Admire Pro	0.640b	1.716bcd	3.330bc	4.955a	6.710a	7.028a	6.562ab
Norkotah/Admire Pro	0.866ab	2.002abc	3.480b	5.104a	6.181a	4.459cd	3.463b
Alturas/Cruiser Maxx	0.658b	1.169d	2.400c	3.998a	5.466a	6.563abc	6.009ab
Norkotah/Cruiser Maxx	0.870ab	2.395ab	3.128bc	3.783a	4.907a	5.356a-d	3.408b
Alturas/Platinum	0.828ab	1.817a-d	3.472b	5.748a	6.309a	5.274a-d	6.292ab
Norkotah/Platinum	1.124a	2.479a	3.756ab	4.631a	5.984a	3.932d	3.400b
LSD	0.360	0.745	0.968	2.161	2.554	2.158	3.266-4.103

Table 1b. Fresh plant weights for three plants per plot by various factors during the seven sample periods 2018. Treatments with the same letters are not statistically different from one another (P=0.05 Student-Newman-Keuls test).

	Weight in Kg						
Treatment	Date						
	25-May	1-Jun	8-Jun	22-Jun	5-Jul	19-Jul	2-Aug
Alturas	0.323a	0.657a	1.680a	4.018a	4.193a	4.930a	5.316a
Norkotah	0.265a	0.602a	1.489a	2.904b	2.781a	1.941b	0.628b
LSD	0.0999	0.1386	0.2455	0.435806-0.503902	0.6532	0.7021	0.301723-0.746946
Untreated Check	0.274a	0.687a	1.544a	3.402a	4.211a	3.373a	2.295a
Admire Pro	0.255a	0.640a	1.690a	3.420a	3.607ab	3.081a	2.408a
Cruiser Maxx	0.293a	0.533a	1.597a	3.659a	2.932b	3.568a	2.512a
Platinum	0.352a	0.658a	1.506a	3.234a	3.199b	3.720a	2.442a
LSD	0.1413	0.1961	0.3472	0.647563-0.683572	0.9238	0.9929	0.706451-0.786746
Alturas (Untreated)	0.312a	0.645a	1.728a	4.559a	5.531a	4.874a	5.050a
Norkotah (Untreated)	0.235a	0.730a	1.360a	2.486a	2.890a	1.872a	0.600a
Alturas (Admire Pro)	0.230a	0.629a	1.791a	3.871a	4.151a	4.464a	5.248a
Norkotah (Admire Pro)	0.280a	0.652a	1.590a	3.010a	3.062a	1.699a	0.646a
Alturas (Cruiser Maxx)	0.278a	0.570a	1.743a	4.155a	3.666a	4.832a	5.368a
Norkotah Cruiser Maxx)	0.308a	0.495a	1.452a	3.209a	2.199a	2.304a	0.713a
Alturas (Platinum)	0.470a	0.786a	1.459a	3.541a	3.425a	5.551a	5.607a
Norkotah (Platinum)	0.235a	0.530a	1.552a	2.948a	2.974a	1.888a	0.558a
LSD	0.1999	0.2773	0.4911	0.821659-1.060458	1.3064	1.4042	0.630936-1.479884

Yields in 2017 did not differ among the Cruiser, Admire Pro, or untreated check treatments (Table 2a). Plots treated with Platinum yielded significantly lower overall in 2017. The overall yield did not differ between cultivars, but grades did, with significantly more oversized Grade 1 tubers, fewer Grade 2, and fewer culls in the Norkotah than Alturas. Despite the differences in plant foliage weights during the growing season, yield and quality were not impacted directly by, or through interaction within any of the main experimental factors.

In 2018, yield and quality were lower for Norkotah than Alturas plots, except with more culls reported in Alturas plots (Table 2b). Norkotah is a determinant, early maturing cultivar, so this result of lower yield and specific gravity was expected. Insecticide treatment did not influence potato yield or quality factors that were evaluated in 2018 (Table 2b). There were not interaction effects of the two main factors evaluated, cultivar and insecticide treatment. When comparing 2017 and 2018, interestingly, Alturas performed better in 2018 than 2017 while the opposite was true for Norkotah. This is probably a result of the growing degree day accumulation patterns that occurred during the two seasons.

Table 2a. Yield and grade data for Norkotah and Alturas, 2017. Treatments with the same letters are not statistically different from one another (P=0.05 Student-Newman-Keuls test). Yield and grade data expressed in kg per plot and ton per acre in total yield.

Treatment	Grade 1		Grade 2							
	4 oz to >	6+ oz	4 oz	4 oz to>	6+ oz	Culls	Marketable Yield(T/A)	Specific Gravity	Solids	Total Yield
Alturas	4.834a	8.223b	2.853a	0.199a	0.420a	1.333a	19.173a	1.06753a	17.980a	32.5a
Norkotah	3.146b	13.803a	1.608b	0.002b	0.016b	0.660b	18.780a	1.06549a	17.549a	31.9a
LSD	0.6324- 0.7721	2.3578	0.3903	0.0696- 0.1485	0.189688- 0.31696	0.569431- 0.59577	3.2464	0.002212	0.4742- 0.4753	5.51
Untreated Check	3.937a	11.688a	2.214a	0.048a	0.091a	0.734a	19.195ab	1.06731a	17.921a	32.6ab
Admire Pro	4.368a	12.538a	2.421a	0.120a	0.208a	1.207a	21.761a	1.06705a	17.881a	36.9a
Cruiser Maxx	4.024a	10.098a	2.311a	0.039a	0.114a	1.014a	18.320ab	1.06536a	17.516a	31.1ab
Platinum	3.394a	9.728a	0.051a	0.051a	0.205a	0.946a	16.630b	1.06633a	17.739a	28.2b
LSD	0.9764- 0.9769	3.3344	0.5519	0.1189- 0.2205	0.493944- 99999.217629	0.752524- 0.89743	4.5911	0.003129	0.6650- 0.6745	7.79
Alturas/Untreated Check	4.885ab	8.723bcd	3.023a	0.118ab	0.365ab	0.843a	19.093a	1.07038a	18.589a	32.4a
Norkotah/Untreated Check	3.142d	14.653a	1.405c	0.009b	0.000b	0.631a	19.298a	1.06425c	17.276c	32.7a
Alturas/Admire Pro	5.863a	9.185bcd	3.033a	0.480a	0.517a	1.717a	22.425a	1.06925ab	18.360a	38.0a
Norkotah/Admire Pro	3.199d	15.890a	1.810c	0.000b	0.037ab	0.792a	21.098a	1.06485bc	17.414b	35.8a
Alturas/Cruiser Maxx	4.710abc	7.668cd	2.683ab	0.154ab	0.437a	1.397a	18.720a	1.06455c	17.336c	31.8a
Norkotah/Cruiser Maxx	3.421cd	12.528ab	1.940bc	0.000b	0.000b	0.694a	17.920a	1.06618ab	17.697a	30.4a
Alturas/Platinum	4.023bcd	7.315d	2.673ab	0.127ab	0.127ab	1.470a	16.455a	1.06595bc	17.662a	27.9a
Norkotah/Platinum	2.843d	12.140abc	1.278c	0.009b	0.009b	0.533a	16.805a	1.06670ab	17.816a	28.5a
LSD	1.2618- 1.6963	4.7155	0.7806	0.4167- 99999.2056	0.512819- 99999.438965	1.210710- 1.232171	6.4928	0.004425	0.9486- 0.9665	11.02

Table 2b. Yield and grade data for Norkotah and Alturas, 2018. Treatments with the same letters are not statistically different from one another (P=0.05 Student-Newman-Keuls test). Yield and grade data expressed in kg per plot and ton per acre in total yield.

Treatment	Grade 1		Grade 2							
	4 oz to >	6+ oz	4 oz	4 oz to>	6+ oz	Culls	Marketable Yield(T/A)	Specific Gravity	Solids	Total Yield
Alturas	5.778a	15.136a	1.803a	0.184a	0.669a	2.489a	23.570a	1.07750 a	20.178 a	39.9a
Norkotah	1.842b	9.511b	1.100b	0.015b	0.147a	0.569b	12.643b	1.07064 b	18.676 b	21.4a
LSD	0.8154	2.3821	0.3614	0.137	0.5163	0.8872	2.4116	0.002766	0.6022	4.08
Untreated Check	3.757a	11.919a	1.358a	0.086a	0.599a	1.576a	17.740a	1.07505 a	19.641 a	30.0a
Admire Pro	3.772a	11.323a	1.550a	0.081a	0.260a	1.384a	16.984a	1.07250 a	19.084 a	28.8a
Cruiser Maxx	3.728a	14.104a	1.401a	0.068a	0.329a	1.804a	19.664a	1.07548 a	19.736 a	33.3a
Platinum	3.984a	11.946a	1.498a	0.164a	0.445a	1.352a	18.038a	1.07325 a	19.246 a	30.6a
LSD	1.1531	3.3688	0.511	0.1937	0.7301	1.2546	3.4106	0.003911	0.8517	5.78
Alturas/Untreated Check	5.636a	15.218a	1.474a	0.148a	0.885a	2.699a	23.360a	1.07880 a	20.463 a	39.6a
Norkotah/Untreated Check	1.878a	8.621a	1.242a	0.025a	0.313a	0.454a	12.120a	1.07130 a	18.820 a	20.5a
Alturas/Admire Pro	5.851a	13.846a	2.109a	0.125a	0.306a	2.211a	22.238a	1.07603 a	19.855 a	37.7a
Norkotah/Admire Pro	1.692a	8.800a	0.990a	0.036a	0.213a	0.556a	11.731a	1.06898 a	18.313 a	19.9a
Alturas/Cruiser Maxx	5.398a	17.497a	1.815a	0.136a	0.658a	2.767a	25.503a	1.07910 a	20.530 a	43.2a
Norkotah/Cruiser Maxx	2.058a	10.711a	0.988a	0.000a	0.000a	0.840a	13.825a	1.07185 a	18.943 a	23.4a
Alturas/Platinum	6.226a	13.982a	1.814a	0.329a	0.828a	2.279a	23.179a	1.07608 a	19.863 a	39.3a
Norkotah/Platinum	1.742a	9.911a	1.182a	0.000a	0.062a	0.425a	12.897a	1.07043 a	18.630 a	21.8a
LSD	1.6309	4.7642	0.7228	0.274	1.0326	1.7743	4.8232	0.005532	1.2045	8.17

In 2017 the neonicotinoid concentration differed between cultivars with the lay-by applications of thiamethoxam and imidacloprid, but not with seed treatment of thiamethoxam, for a majority of the sample periods (Table 3a). The imidacloprid concentration was higher in the Norkotah plots than in Alturas for the second sample period, then lower on the third and fourth sample periods (Table 3a). The observed trend was opposite of what we hypothesized, where the faster growing Norkotah contained higher concentrations of insecticide than the slower growing Alturas early in the growing season. Comparing this data with the plant tissue weights during the same time period, the tissue weights did not differ significantly until June 12 (Figure 1a). Perhaps the plant began to grow rapidly prior to the sample weights being obtained, and therefore, the imidacloprid had systemically moved into the rapidly growing leaf tissue. The same trend is not observed with the other insecticides. All the insecticides evaluated are moderate to highly soluble (340, 610 and 4100 mg/kg for clothianidin, imidacloprid, and thiamethoxam respectively), so if the plant is growing quickly and requiring more water, the neonicotinoid is more likely to be drawn up into the leaf tissue through the xylem. Plants with thiamethoxam applied at lay-by contained significantly higher concentrations of active ingredient in the plant tissue than in the seed treatment plots (Table 3a). The Norkotah plots had a lower concentration of thiamethoxam when applied by seed treatment as compared to the Alturas plots (Table 3a). The treatment of thiamethoxam by lay-by application did not differ by cultivar (Table 3a). Clothianidin is a biologically active (as an insecticide) metabolite of thiamethoxam and was, therefore, analyzed in the tissue tests. Clothianidin followed the same trend of lower concentrations in the faster growing Norkotah cultivar, but results were not statistically significant (Table 3a). The clothianidin concentration did differ in the lay-by application where there was a higher concentration of the compound in the faster growing Norkotah plots, following the same unexpected trend realized on the plots treated with imidacloprid (Table 3a).

In 2018, the concentration of imidacloprid did not differ significantly between the two cultivars, except for one sample date (July 20) where there was no detectible level in the Norkotah plots (Table 3b). The level of imidacloprid was numerically lower for the entire sample season in Norkotah for 2018, whereas it was more variable in 2017. Imidacloprid started at a much higher concentration early in 2018 compared to 2017 but reduced more dramatically (Table 3a and 3b). Leaf tissue weights were much higher in 2017 compared to 2018 and likely explain the initial higher titer level of imidacloprid in 2018 since there was less leaf tissue for the product to be diluted in. This supports the hypothesis that under conditions conducive for more foliar growth that the pesticide concentration would be reduced due to dilution. A similar trend occurs in relation to clothianidin and thiamethoxam, whereby concentrations were higher in 2018 than 2017 (Table 3a & 3b). Concentration of thiamethoxam and clothianidin remained consistently higher over time in 2018 compared to 2017 (Table 3a & 3b). This demonstrates that neonicotinoid concentration can fluctuate significantly from one season to the next and from one cultivar to another and is impacted by plant foliar growth, with larger canopies tending to have reduced pesticide concentrations. In 2018, the level of clothianidin differed by cultivar on June 22 where Alturas plots had higher concentrations than Norkotah (Table 3b). For the other sample periods there was no significant difference in the concentration of clothianidin. The concentration of thiamethoxam was generally higher in plots treated by lay-by application, but not significantly different.

Pesticide titers in leaves varied considerably at the same dose on the same sampling dates. Regularly, individual plants in commercial fields are detected with enormous populations of Colorado potato beetles while adjacent plants contain no beetles. This is likely due to the differences in titer level and could be attributed to pesticide application inaccuracies or simply plants that were inadvertently not treated.

Table 3a. Residue values by treatment, 2017. Values expressed in milligrams of pesticide per kilogram of plant fresh weight. Treatments with the same letters are not statistically different from one another (P=0.05 Student-Newman-Keuls test).

Treatment		5/30/2017	6/5/2017	6/12/2017	6/26/2017	7/10/2017	7/24/2017	8/7/2017
Alturas (Admire Pro)	Imidacloprid (mg/kg)	0.2891a	0.1350a	0.2173a	0.1365a	0.0563a	0.0360a	0.0165a
Norkotah (Admire Pro)	Imidacloprid (mg/kg)	0.2000a	0.3473a	0.0623ab	0.0768ab	0.0615a	0.0368a	0.0215a
Alturas (Platinum)	Clothianidin (mg/kg)	0.0218bc	0.0338b	0.0616b	0.0768a	0.1297a	0.0303a	0.0220a
Norkotah (Platinum)	Clothianidin (mg/kg)	0.0445a	0.0725a	0.1284a	0.1008a	0.0945a	0.0354a	0.0215a
Alturas (Platinum)	Thiamethoxam (mg/kg)	0.1010b	0.1162a	0.1151a	0.1230a	0.1028a	0.0435ab	0.0338a
Norkotah (Platinum)	Thiamethoxam (mg/kg)	0.1352ab	0.0808ab	0.1024a	0.1415a	0.1122a	0.0753a	0.0595a
Alturas (Cruiser Maxx)	Clothianidin (mg/kg)	0.0415ab	0.0470b	0.0366bc	0.0295b	0.0217b	0.0029b	0.0000b
Norkotah (Cruiser Maxx)	Clothianidin (mg/kg)	0.0433a	0.0403b	0.0254c	0.0220b	0.0122bc	0.0033b	0.0025b
Alturas (Cruiser Maxx)	Thiamethoxam (mg/kg)	0.2475a	0.0888a	0.0677b	0.0473b	0.0008b	0.0186bc	0.0064b
Norkotah (Cruiser Maxx)	Thiamethoxam (mg/kg)	0.0847b	0.0479a	0.0270c	0.0299b	0.0000b	0.0074bcd	0.0079b
Alturas (Platinum)	Combined (mg/kg)	0.0338bc	0.1393a	0.1053bc	0.2028a	0.2445a	0.0843a	0.0563a
Norkotah (Platinum)	Combined (mg/kg)	0.0725a	0.0895a	0.0528c	0.2545a	0.2300a	0.1233a	0.0858a
Alturas (Cruiser Maxx)	Combined (mg/kg)	0.0470b	0.1508a	0.1805ab	0.0773a	0.0253a	0.0250a	0.0085a
Norkotah (Cruiser Maxx)	Combined (mg/kg)	0.0403b	0.1590a	0.2395a	0.0528a	0.0123a	0.0215a	0.0130a
LSD Value p=0.05	Imidacloprid	0.02026-0.10503	0.19212	0.15689	0.10177	0.0115	0.00935	0.00862
	Clothianidin	0.02011	0.02178	0.00689-0.03567	0.01615-0.06767	0.01212-0.05476	0.00806-0.02101	0.00912
	Thiamethoxam	0.04651-0.12074	0.0141-0.05486	0.01085-0.04938	0.03986	0.01950-0.06375	0.02404-0.05476	0.01375-0.02641
	Combined	0.07305	0.08269	0.07878	0.12975	0.11418	0.06888	0.03788

Table 3b. Residue values by treatment, 2018. Values expressed in milligrams of pesticide per kilogram of plant fresh weight. Treatments with the same letters are not statistically different from one another (P=0.05 Student-Newman-Keuls test).

Treatment		5/25/2018	6/1/2018	6/8/2018	6/22/2018	7/5/2018	7/20/2018	8/2/2018
Alturas (Admire Pro)	Imidacloprid (mg/kg)	0.5570a	0.2375a	0.0800a	0.0864a	0.0205a	0.0115a	0.0030a
Norkotah (Admire Pro)	Imidacloprid (mg/kg)	0.3139a	0.0763a	0.0319a	0.0628a	0.0070a	0.0000b	0.0000a
Alturas (Platinum)	Clothianidin (mg/kg)	0.2568a	0.1330a	0.1675a	0.0900a	0.0338a	0.0483a	0.0315a
Norkotah (Platinum)	Clothianidin (mg/kg)	0.0850a	0.1468a	0.1425a	0.0610b	0.0218a	0.0263a	0.0298a
Alturas (Platinum)	Thiamethoxam (mg/kg)	0.4020a	0.2250a	0.3395a	0.0723a	0.0365a	0.0208ab	0.0155b
Norkotah (Platinum)	Thiamethoxam (mg/kg)	0.1825a	0.2480a	0.1861a	0.0675a	0.1570a	0.0143bc	0.0438a
Alturas (Cruiser Maxx)	Clothianidin (mg/kg)	0.5125a	0.1175a	0.0865a	0.0809ab	0.0248a	0.0340a	0.0210a
Norkotah (Cruiser Maxx)	Clothianidin (mg/kg)	0.2925a	0.1025a	0.0873a	0.0363c	0.0228a	0.0213a	0.0155a
Alturas (Cruiser Maxx)	Thiamethoxam (mg/kg)	1.4500a	0.4950a	0.1201a	0.0588a	0.0238a	0.0290a	0.0090b
Norkotah (Cruiser Maxx)	Thiamethoxam (mg/kg)	1.0300a	0.1980a	0.0561a	0.0483a	0.0203a	0.0108c	0.0085b
Alturas (Platinum)	Combined (mg/kg)	0.6588a	0.3580a	0.5200a	0.1623a	0.0703a	0.0690a	0.0470a
Norkotah (Platinum)	Combined (mg/kg)	0.2675a	0.3943a	0.3325a	0.1285a	0.1788a	0.0405a	0.0735a
Alturas (Cruiser Maxx)	Combined (mg/kg)	1.9625a	0.6125a	0.2083a	0.1083a	0.0485a	0.0630a	0.0300a
Norkotah (Cruiser Maxx)	Combined (mg/kg)	1.3225a	0.3000a	0.1438a	0.0845a	0.04300a	0.0320a	0.0240a
LSD Value p=0.05	Imidacloprid	0.43263-99999.0882	0.17686	0.04504-99999.01812	0.04157-99999.01426	0.00934	0.00491	0.0031
	Clothianidin	0.12601	0.12208	0.04125	0.02122	0.01543	0.01196	0.01215
	Thiamethoxam	0.2399	0.1907	0.11084-99999.01988	0.02171	0.16611	0.00889	0.01561
	Combined	0.48244	0.38292	0.15522	0.05697	0.22035	0.02015	0.03011

The potato psyllid slip cage assays are difficult to interpret due to the high mortality rates in the untreated check plots during some assay periods. Cages were placed too high in the canopy during one sample period in 2017, likely causing the high mortality in the untreated check plots (June 19th). Psyllids were reared in a laboratory, and then transferred to the field. This did not appear to impact survivorship during the cooler days but appeared to be problematic during warmer weather later in the spring or early summer. The raw percent mortality was subjected to a correction formula to account for mortality not attributed to insecticides. The raw data was subjected to the following formula: Schneider-Orelli Formula (the mortality % in treated plot minus the mortality % in the control plot, all divided by 100 minus the mortality % in the control plot. The result of that equation is then multiplied by 100). For all sample periods in 2017 except the last one, cultivar did not impact psyllid survivorship significantly (Table 4a). In 2017 there was a strong numeric trend for mortality rates being higher in Alturas plots, and if you look at the interaction of the two main factors, Alturas plots treated with either thiamethoxam application (Cruiser Maxx and Platinum) routinely recorded higher mortality rates for psyllids. Insecticide treatment did impact psyllid survivorship, where during all but one sample period in 2017, plots treated with lay-by thiamethoxam (Platinum) had higher psyllid mortality rates than the untreated check plots and more often had numerically higher mortality than the other insecticide treatments (Table 4a).

Alturas plots tended to have higher psyllid mortality rates in slip cages in 2018, similar to what was observed in 2017; in fact, mortality rates were significantly higher on June 8, July 26, and August 9 (Table 4b). This once again is likely due to the different growth patterns of the two cultivars. Norkotah is a determinant cultivar and it is likely, especially toward the end of the sample period, that most of the plants' resources were being directed toward the tubers, resulting in generally reduced insecticide concentration in the leaves and subsequently lower mortality rates to potato psyllids. For efficacy against potato psyllids, based on the slip cages, adequate control was never achieved in Norkotah plots irrespective of insecticide treatment or insecticide titer level. In both seasons, control of potato psyllids in slip cages in Norkotah plots was only above 33% twice, both instances in 2018 with lower canopy weights. In Alturas plots, control was achieved (75% and above) on numerous occasions, but more-so in 2018 than 2017 and in plots treated with Cruiser Maxx or Platinum than with Admire Pro. Insecticide treatment influenced mortality rates in psyllid cages in 2018, but the insecticides did not differ between one another (Table 4b). Mortality rates of psyllids in slip cages in 2018 were greater than in 2017 (Tables 4a & 4b). The lower tissue weights recorded in 2018 apparently caused higher insecticide titer levels which resulted in the increased mortality. This supports the overall hypothesis that under fast growing conditions, potato plant canopies are larger, and the concentration of the pesticide is reduced, leading to lower psyllid mortality compared to seasons where canopy growth is reduced.

Table 4a. Percent mortality of psyllids in slip cages, 2017. Mortality corrected using the Schneider-Orelli Formula. Treatments with the same letters are not statistically different from one another (P=0.05 Student-Newman-Keuls test).

Treatment	Date						
	6-Jun	12-Jun	19-Jun	3-Jul	17-Jul	31-Jul	7-Aug
Alturas	55.92a	43.45a	31.70a	40.60a	26.80a	23.90a	41.83a
Norkotah	33.75a	19.82a	33.30a	24.60a	19.60a	21.90a	15.55b
LSD	24.53	24.23	27.91	30.05	27.46	24.15	24.99
Untreated Check	0.00c	0.00c	0.00b	0.00b	0.00b	0.00b	0.00b
Admire Pro	52.00ab	26.13bc	46.90a	29.0ab	18.40ab	37.50a	45.13a
Cruiser Maxx	45.88b	39.52ab	29.00ab	55.30a	52.50a	10.30ab	18.69ab
Platinum	81.46a	60.88a	54.00a	46.30a	22.00ab	43.80a	50.94a
LSD	34.68	34.26	39.47	42.5	38.84	34.16	35.34
Alturas/Untreated Check	0.00c	0.00c	0.00b	0.00b	0.00b	0.00b	0.00c
Norkotah/Untreated Check	0.00c	0.00c	0.00b	0.00b	0.00b	0.00b	0.00c
Alturas/Admire Pro	62.50ab	27.27bc	43.80ab	25.00ab	8.30ab	25.00ab	71.50a
Norkotah/Admire Pro	41.50bc	25.00bc	50.00ab	33.00ab	28.50ab	50.00a	18.75bc
Alturas/Cruiser Maxx	68.42ab	54.05ab	33.00ab	75.00a	55.00a	20.50ab	33.33abc
Norkotah/Cruiser Maxx	23.35bc	25.00bc	25.00ab	35.50ab	50.00ab	0.00b	4.06c
Alturas/Platinum	92.75a	92.50a	50.00ab	62.50a	44.00ab	50.00a	62.50ab
Norkotah/Platinum	70.17ab	29.27bc	58.00a	30.00ab	0.00b	37.50ab	39.38abc
LSD	49.05	48.46	55.82	60.11	54.92	48.3	49.98

Table 4b. Percent mortality of psyllids in slip cages, 2018. Mortality corrected using the Schneider-Orelli Formula. Treatments with the same letters are not statistically different from one another (P=0.05 Student-Newman-Keuls test).

Treatment	Date						
	1-Jun	8-Jun	15-Jun	29-Jun	12-Jul	26-Jul	9-Aug
Alturas	64.10a	70.80a	18.70a	63.20a	50.00a	45.30a	50.00a
Norkotah	45.30a	13.90b	37.50a	59.40a	32.70a	0.00b	0.00b
LSD	24.42	19.88	24.54	19.76	30.28	20.61	18.27
Untreated Check	0.00b	0.00b	0.00a	0.00b	0.00b	0.00a	0.00b
Admire Pro	68.80a	46.50a	43.70a	87.50a	46.70a	31.30a	34.40a
Cruiser Maxx	78.10a	60.40a	29.10a	81.30a	62.50a	25.00a	31.30a
Platinum	71.90a	62.50a	39.60a	76.50a	56.30a	34.40a	34.40a
LSD	34.53	28.12	34.7	27.95	42.82	29.15	25.84
Alturas/Untreated Check	0.00a	0.00b	0.00a	0.00a	0.00a	0.00a	0.00b
Norkotah/Untreated Check	0.00a	0.00b	0.00a	0.00a	0.00a	0.00a	0.00b
Alturas/Admire Pro	75.00a	87.50a	31.10a	87.50a	62.50a	62.50a	68.80a
Norkotah/Admire Pro	62.50a	5.60b	56.30a	87.50a	31.00a	0.00a	0.00b
Alturas/Cruiser Maxx	93.80a	95.80a	8.30a	100.00a	75.00a	50.00a	62.50a
Norkotah/Cruiser Maxx	62.50a	25.00b	50.00a	62.50a	50.00a	0.00a	0.00b
Alturas/Platinum	87.50a	100.00a	35.40a	65.50a	62.50a	68.80a	68.80a
Norkotah/Platinum	56.30a	25.00b	43.80a	87.50a	50.00a	0.00a	0.00b
LSD	48.83	39.76	49.07	39.53	60.56 a	41.22	36.54

SUMMARY

Cultivars differed in canopy weight early in the growing season as expected in 2017 but did not differ significantly in 2018. We detected a difference in plant foliar weight from season to season which apparently impacted insecticide concentration in the leaves and therefore psyllid control. Tissue weights were lower in 2018, and insecticide concentration was higher resulting in improved psyllid control for longer into the season. Seed treatment with insecticide did reduce canopy weight in one cultivar in 2017 but not in 2018. This reduction in canopy weight did not result in reduced yield or quality.

The slip cages were used in hopes to determine how long the at plant neonicotinoids would be effective at controlling potato psyllids. Since the tissue weights and pesticide concentration varied so much from year to year and one cultivar to another, it is highly unlikely that we could ever make a definitive assessment of days of control. Rather, we can say that under conditions where plant canopy weights are high, psyllid control (in days) is likely to be much shorter than in conditions where plant foliar growth is reduced. For example, in 2017 and 2018, marginal psyllid control was only achieved for Alturas for up to 56 and 70 days after planting respectively for any of the three insecticide treatments. In Norkotah insecticide treated plots, adequate psyllid control was never achieved with any of the three insecticides. In some instances, the layby application of thiamethoxam appeared more effective than the at-plant treatments. This makes sense given the later application of the lay-by treatment and less time for the insecticide to dissipate by various biological break down.

Other data from this study (not shown) suggests that aphid control is realistically achieved with the insecticides evaluated for 75 to 80 days in both cultivars tested. Colorado potato beetle was not evaluated as part of this study, but observations in the experimental area strongly indicate that the at-plant and layby treatments of neonicotinoids are highly effective at controlling the first generation of Colorado potato beetle. A follow-up study focusing on Colorado potato beetle efficacy of these products was conducted in 2019 and will be reported in a subsequent issue of Potato Progress.

This project demonstrates that neonicotinoid concentration in the potato plant, and therefore effectiveness of suppressing pest insects, varies by cultivar and growing season. In rapidly growing cultivars, such as Norkotah, at-plant neonicotinoid treatments may not be effective for psyllid control. For practical purposes, prescriptive prophylactic use of at-plant neonicotinoid insecticides does not make sense for all cultivars and all growing conditions, especially when considering psyllid control. Potatoes grown in areas with low insect pest pressure or that will only be growing for a short period of time may not benefit from an at plant neonicotinoid.

Neonicotinoids are an effective tool for managing early season leafhopper, aphid, and Colorado potato beetle. Therefore, if you are growing potatoes in an area where these pests are common, neonicotinoid insecticides can be a cost-effective insect management strategy. This data however calls into question how effectively systemic insecticides mobilize in different cultivars and different growing seasons. Scouting is still the best method to ensure that potato psyllids and other insect pests do not build up to numbers that cannot be controlled.

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