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OFFICE OF CHEMICAL SAFETY
AND POLLUTION PREVENTION

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MEMORANDUM

SUBJECT: Benefits and Impacts of Potential Mitigation for Neonicotinoid Seed Treatments on Small Grains, Vegetables, and Sugarbeet Crops

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SUMMARY

The Environmental Protection Agency (EPA) is evaluating whether risk mitigation measures are needed to address risk concerns to avian and mammalian species associated with the use of three nitroguanidine neonicotinoid insecticide seed treatments: clothianidin, imidacloprid, and thiamethoxam. The highest risks are associated with small seeds including small grains, sugar beet, and some vegetables. These small seeds can be consumed by small animals whose low body mass increases the potential for adverse effects of exposure to the neonicotinoid seed treatment.

Neonicotinoids are unique because there are few insecticidal seed treatments and they have both contact and systemic activity. Thus, these neonicotinoids control both soil pests and above ground insects that attack early stages of the crop during emergence. In canola, acetamiprid seed treatments could replace neonicotinoid seed treatments for control of the primary pest, flea beetles. Growers do not have alternative seed treatments in lieu of neonicotinoids for below ground pest control in sugar beets. In small grains, growers may use chlorpyrifos seed treatments to control a subset of soil borne insects controlled by neonicotinoids. In some vegetable crops, cyromazine and chlorpyrifos offer alternatives for below ground maggot and beetle control. Neither chlorpyrifos nor cyromazine provide the above ground systemic protection of neonicotinoids. Therefore, in the absence of neonicotinoid seed treatments, growers would likely make at-plant and/or early-season foliar applications of organophosphates, pyrethroids, or neonicotinoids. There would be an increase in cost, not simply monetarily, but also in labor and managerial effort, and could compromise pest control.

The Agency is considering a requirement that small seeds be pelleted, making them larger and harder for small animals to consume, which may reduce risks. The capacity to pellet seeds varies across crops. Sugar beet seeds and some vegetable crops are currently pelleted but small grains are not pelleted. It may not be possible to pellet the seeds of many crops and doing so may be cost-prohibitive on low value crops. Requiring an increase in the size of pelleted seeds could have large impacts because the process may affect germination, stand establishment, and growers may have to change planting equipment.

BACKGROUND

FIFRA Section 3(g) mandates that EPA periodically review the registrations of all pesticides to ensure that they do not pose unreasonable adverse effects to human health and the environment. This periodic review is necessary considering scientific advancements, changes in policy, and changes in use patterns that may alter the conditions underpinning previous registration decisions. In determining whether effects are unreasonable, FIFRA requires that the Agency consider the risks and benefits of any use of the pesticide.

As part of the ecological risk assessments, EPA evaluated the risks to mammals and birds from potential consumption of seeds treated with neonicotinoids. Seeds treated with clothianidin, thiamethoxam, and imidacloprid pose potential risks (EPA 2017a, b, c); dinotefuran is not currently registered for seed treatments. Overall risk conclusions consider multiple factors that contribute to exposure. Two major considerations are seed size, which influences which species are likely to consume the seed, and the percent of the diet, or quantity of seed consumed, needed to reach the level of concern. Smaller seeds generally present greater risks than larger seed because they are more likely to be consumed by small species and these smaller animals, because of their size and the low body mass, would have to consume a relatively small quantity of seeds to reach the level of concern. A possible strategy to reduce exposure is to pellet seeds, making them larger and less likely to be consumed by small birds and mammals.

This memorandum discusses the benefits of neonicotinoid seed treatments in the production of small grains, sugar beet, and certain small-seed vegetable crops. Benefits are described relative to other methods of pest control. This memorandum also discusses the implications of pelleting seeds to a larger size to discourage consumption by small birds and mammals.

METHODOLOGY

The unit of analysis for this assessment is an acre of a crop planted with neonicotinoid-treated seed. The benefits of neonicotinoid use are assessed in comparison to the available pest control options in terms of increased pest control costs per acre or, if appropriate, losses in yield or quality of product. In this sense, pest control costs are interpreted broadly. In addition to monetary costs, there may be less quantifiable advantages of one control method over another such as convenience of use or increased management flexibility.

BEAD examined average seed size and narrowed the scope of the assessment to small grain, vegetable, and sugar beet crops. Sites of concern were further narrowed to crops that are direct seeded because crops that are grown from transplants present less opportunity for exposure; seedlings are grown in greenhouses or other protected areas.

For remaining sites for which neonicotinoid seed treatments are available, BEAD identified the primary pests targeted by the neonicotinoids. Using the target pest list, BEAD identified possible alternative chemicals and methods of control. The memorandum then considers the advantages or disadvantages of neonicotinoid seed treatments in comparison to other options qualitatively. Information for these purposes came from public comments received following publication of risk assessments, stakeholder outreach conducted by USDA, and publicly available extension information as well as market research data, collected through annual surveys of growers conducted by a leading private research firm. Quantitative data are not available for all sites, but BEAD extrapolates findings from other, related sites.

BEAD also collected information on pelleting practices and the feasibility of changing those practices to increase seed sizes to reduce the potential that they would be consumed by small birds and mammals. BEAD summarized and evaluated the information, based on professional judgement, provided by USDA as well as publicly available sources for this analysis.

The memorandum is outlined as follows: identification of the crops of concern, discussion of crop production and estimates of neonicotinoid seed treatment usage for each crop, target pests, and possible alternatives, which may involve a different application method. Lastly, there is a discussion of the possibility of pelleting various seed types.

SCOPE OF ASSESSMENT

This memorandum presents information on seed treatment uses of the three nitroguanidine (i.e., imidacloprid, thiamethoxam, and clothianidin) neonicotinoids in small seed vegetables, sugar beet, and small grain production. Criteria for crop selection and discussion include: small seed size, neonicotinoid seed treatment use, and direct seeded crop production (i.e., not transplanted). Seed size by weight in milligrams per seed of a broad range of crops is presented in Figure 1.

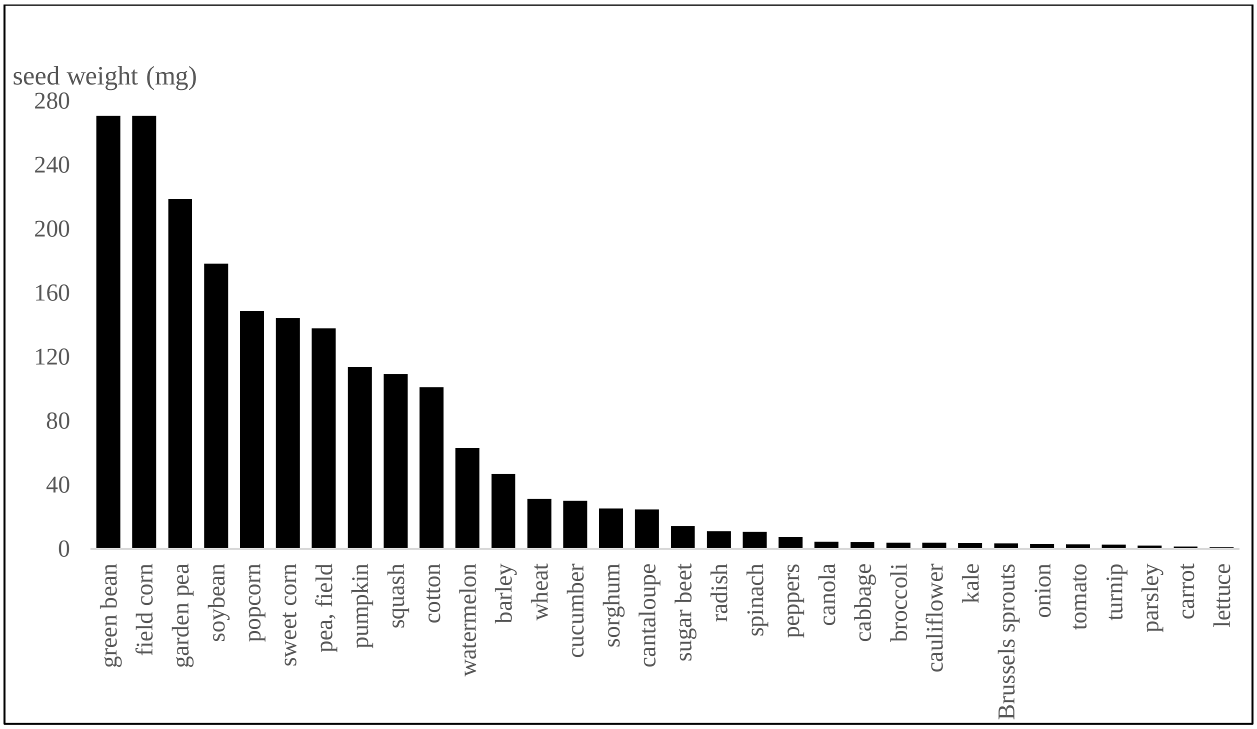

Figure 1. Average seed weights by crop

Source: Becker and Ratnayake (2011). Seed weight converted from midpoint of the range seeds per pound (Appendix B). Neonicotinoids are not registered for all seeds listed.

Many seeds in agricultural production are relatively large (e.g., beans, corn, and cotton average more than 100 mg per seed) and are unlikely to be consumed by small animal species (Figure 1). Watermelon and barley are approximately 45-60 mg/seed. Wheat, cucumber, sorghum, and cantaloupe weigh around 25-30 mg/seed; sugar beet averages about 14 mg/seed with others decreasing in size down to lettuce at approximately 1 mg/seed. This memorandum focuses on crops with seeds of around 30 mg or less, i.e., wheat and smaller.

Of the crops with smaller seed sizes, BEAD excludes crops that do not have active neonicotinoid seed treatment registrations (e.g., fruiting vegetables). The neonicotinoid seed treatment registrations by active ingredient (a.i.) for small grain, vegetable, and sugar beet crops are shown in Table 1; not all neonicotinoids are registered for all crops.

Table 1. Neonicotinoid Seed Treatments, Crops with Seed Size Less than 30 mg/seed

Active Ingredient	Crops
Imidacloprid	borage, broccoli, buckwheat, canola/rape, green onions, leeks, oats, onions, rye, sorghum, sugar beet, triticale, wheat
Clothianidin	broccoli, buckwheat, canola/rape, carrot, endive, leek, leafy vegetables, millet, oats, onion, parsley, rye, sorghum, spinach, sugar beet, triticale, wheat
Thiamethoxam	brassica, carrot, cucurbits, leafy vegetables, lentil, lettuce, onions, sorghum, spinach, sugar beet, wheat

Of the vegetables in the small seed size category with neonicotinoid registrations, BEAD focuses here on crops that are direct seeded because transplanted crops are usually started under cover (e.g., in greenhouses) and seeds are not available for consumption by avian species. Direct seeded crops, on the other hand, may be available for animal consumption immediately after planting. Thus, leek, cauliflower, celery, and Brussels sprouts are not considered further because these use sites are not recommended for direct seeding in commercial production (Kennedy 2010; Table 2). BEAD's assessment will focus on leafy green vegetables, broccoli and cabbage, cucurbit vegetables, carrot, parsley (herbs), and onions as well as wheat, canola, sorghum, and sugar beet.

Table 2. Seeding Practices, Vegetable Crops Less than 30 mg/seed

Crop	Direct seeded	Transplanted
Baby Leaf/Mesclun Mix [1]	Only direct seeded	No
Broccoli [1]	Yes	Yes
Brussels sprouts	Not recommended	Yes
Cabbage [1]	Yes	Yes
Cantaloupe/Muskmelons [1]	Direct seeded	Region Dependent
Cauliflower	Not recommended	Yes
Carrots [1]	Only direct seeded	No
Celery	Not recommended	Yes
Collards [1]	Yes	Region Dependent
Cucumbers [1]	Direct seeded	Region Dependent
Dry Bulb Onions [1]	Yes	Yes
Endive and Escarole [1]	Primarily	Occasionally
Green Onions [1]	Yes	Yes
Leeks	Not recommended	Yes
Lettuce [1]	Primarily	Occasionally
Legume vegetables	unknown	unlikely
Parsley [1]	Yes	Yes
Spinach [1]	Preferred	No
Squash [1]	Direct seeded	Not recommended

Source: Reproduced from Kennedy (2010)

[1] Crops with neonicotinoid registration, small seed size, and direct seeded primarily; BEAD does not have information about legume vegetable planting practices

NEONICTOINOID SEED TREATMENT USAGE

Data on acres planted with neonicotinoid treated seeds for field and row crops such as sugar beets and small grains come from market research data, collected through annual surveys of growers conducted by a leading private research firm between 2010 and 2014. Survey information is collected following a statistically valid approach. Below, Table 1 presents the average usage of neonicotinoid seed treatments in sorghum, sugar beets, spring wheat, and winter wheat.

Table 3. Annual Average Usage of Neonicotinoid Seed Treatments, 2010-2014

Crop	Active Ingredient	Total Acres Treated	Percent Crop Treated
Sorghum	Clothianidin	486,000	7
	Imidacloprid	868,000	13
	Thiamethoxam	1,481,000	23
	Total	**2,835,000**	**44**
Sugar Beets	Clothianidin	485,000	41
	Imidacloprid	6,000	<1
	Thiamethoxam	57,000	5
	Total	**548,000**	**46**
Wheat, Spring	Clothianidin	248,000	2
	Imidacloprid	2,163,000	15
	Thiamethoxam	1,560,000	11
	Total	**3,971,000**	**27**
Wheat, Winter	Clothianidin	200,000	1
	Imidacloprid	4,644,000	12
	Thiamethoxam	3,111,000	8
	Total	**7,954,000**	**20**

Source: MRD, 2010-2014. Totals subject to rounding.

There is high usage, in terms of percent crop treated (PCT), of neonicotinoid seed treatments in sugar beets and small grains (Table 3). Usage data reported from 2010 through 2014 indicate that 46% of the total sugar beets acres grown were treated with neonicotinoids as a seed treatment (MRD 2010-2014). Additionally, at a national level, 44% of total sorghum acres, 27% of total spring wheat acres, and 20% of total winter wheat acres were treated with neonicotinoids as a seed treatment. Usage varies year-to-year based on conditions that affect pest pressure and economic outlooks for different commodities (Scott pers. comm., 2018). High PCT may indicate widespread utility of neonicotinoid seed treatments.

BEAD does not have data on the use of neonicotinoid seed treatments in vegetable crops and thus sought stakeholder feedback concerning usage. Per the American Seed Trade Association, less than 15% of vegetable acreage is estimated to be planted with neonicotinoid seed treatments based on best professional judgement (ASTA pers. comm. 2018); ASTA did not provide estimates by individual crops. ASTA reported that clothianidin and thiamethoxam are preferred by growers over imidacloprid seed treatments.

TARGET PESTS

The damage caused by key pests of vegetables, small grains, and sugar beet production targeted by neonicotinoid seed treatments are divided below in two sections: below ground and above ground. The primary targets of neonicotinoid seed treatments are below ground pests, however, stakeholders report continued efficacy of seed treatments after crop emergence for above ground pests as well. Efficacy of neonicotinoid seed treatments against above ground pests is approximately three to four weeks in some crops (Michaud et al. 2017; Southeast Farm Press 2015; Texas A&M AgriLife Undated; International Confederation of European Beet Growers 2018).

Below ground pests

The primary targets of neonicotinoid treated seeds for below ground pests include: wireworm, grubs, and maggot pests (ASTA pers. comm. 2018; Evans, 2018; Kramer, 2018, Little, 2018; Musick, 2018; Wilkins, 2016). Soil borne insect species are relatively consistent across all crop groups except for some specialist soil dwelling pests, however, they all cause similar damage (i.e., stand loss). Soil borne insect pests consume roots or seeds of developing plants ultimately leading to stand death and potentially large yield loss up to 100% in years with high pest populations (Nault et al. 2005; UC IPM 2016a; UC IPM 2016b; French et al. 2008; Rinehold 2018). Growers have a low tolerance for stand loss. In general, soil borne insects are more prevalent after wet and cold winters as well as in fields with no-till or conservation tillage practices (UC IPM 2017; UC IPM 2009a). Some soil borne insects may be more prevalent in crops planted behind preferred hosts or near pasture (UC IPM 2016b; Rinehold 2018).

Primarily, neonicotinoid seed treatments provide protection, or 'insurance' against, soil pests that cannot be scouted for in advance of planting, hard to predict, and can cause major losses (Recker, 2018). For example, populations of wireworm are hard to predict since they have long, one to three-year lifespans, and thus, prophylactic usage of neonicotinoids can minimize stand loss if a pest problem is present or expected in some regions (Myers et al. 2015; Dyer et al. 2017; Hesler et al. 2018).

Above ground pests

Sucking/piercing pests (e.g., aphids, whiteflies, leafhoppers, and thrips) are the primary targets for above ground systemic control by neonicotinoid seed treatments (ASTA pers. comm. 2018; Evans, 2018; Inskeep, 2018; Muecke, 2018). Some pests in this group cause direct yield loss but others, like aphids and the sugarbeet leafhopper, are commonly disease vectors that are critical to control in the early season to prevent crop loss. Neonicotinoids provide protection against disease vectoring pests because of their systemic expression. Other above ground targets of neonicotinoid seed treatments include: leafhoppers, Hessian fly, cinch bugs, grasshoppers, leafminers, flea beetle, bagrada bug, and others (Rynning, 2018).

Extension personnel and ASTA indicated that aphids are the primary target of neonicotinoid treated small grain seeds and sugar beet production (Scott pers. com 2018; ASTA pers. comm.

2018). Aphids cause crop damage by discoloration and reduced photosynthetic capacity that may kill plants (French et al. 2008). Aphid species also secrete honeydew that can lead to sooty mold resulting in yield loss or prevention of harvest (French et al. 2008). Some aphids in small grains and sugar beet production are capable of vectoring diseases (e.g., yellow or mosaic viruses) which can cause yield loss as high as 50% without intervention (UC IPM 2016c; Dyer et al. 2017; Rinehold 2018; International Confederation of European Beet Growers 2018; Hesler et al. 2018). In some cases, systemic controls for aphids are more effective than contact sprays in preventing feeding damage or disease transmission from aphids (Hesler et al. 2018). Extension recommendations advise using neonicotinoid seed treatments to control early season infestations of aphids and prevent transmission of disease (Dyer et al. 2017; UT 2018).

In vegetable production, whiteflies and thrips are the key targets of neonicotinoid treated seed. Direct damage from whiteflies can cause stippling of leaves and leaf drop in heavy population sizes. When large populations occur, whiteflies can wilt and stunt plants. Like aphids, whiteflies excrete honeydew which can lead to sooty mold formation. Growers have a low tolerance for whiteflies in vegetable production due to potential disease vectoring capacity (e.g., leaf curl viruses, silvering disorder, cucurbit yellow stunting disorder, and others) since one feeding event can lead to plant death from viral infection and up to 100% yield loss in some scenarios, like cucurbit yellow stunting disorder virus. Young vegetable plants are the most susceptible to viral transmission (Stansley et al. 2015). Like whiteflies, thrips can occur anytime during the season and are more likely to occur in hot, dry conditions (Palumbo 1998). Tolerance of thrips damage varies across vegetable crops. For example, there is no set economic threshold for thrips in leafy vegetables or green onions because even one insect that causes any scarring may make the crop unmarketable (UC IPM 2016f). In contrast, for some crops, even moderate populations levels may not cause economic concerns where scarring does not affect marketability.

For both whiteflies and thrips, resistance to spinosyn, pyrethroid, carbamate, organophosphate (OP) insecticides have been documented (Funderburk 2018; APRD 2018). FIFRA Section 18 pesticide emergency exemptions exist in several vegetable crops for whiteflies and thrips due to reduced susceptibility to existing insecticides or high population sizes necessitating more efficacious materials. Thus, neonicotinoid seed treatments are an additional mode of action or use method in resistance management for these pests.

Additionally, bagrada bug is a pest of cole crops and other crucifers (e.g., broccoli and cabbage) in western agriculture (Natwick et al. undated). Bagrada bugs are particularly damaging to young plants and may kill vegetable seedlings causing up to 10% stand loss on average between 2010-2014 in cole crops (Natwick et al. undated; Palumbo 2015). Large populations of bagrada bug can build up quickly (Natwick et al. undated) but even low population sizes can kill very young plants, therefore, protective control via seed treatments are beneficial. Extension reports in Arizona indicate growers planting between 41-66% of all direct seeded broccoli with clothianidin treated seed to control bagrada bug (Fournier et al. 2017). Bagrada bug is an example of an emergent pest controlled in part by neonicotinoid seed treatments demonstrating new niches for this pesticide over time.

ALTERNATIVE CONTROL MEASURES FOR NEONICOTINOID SEED TREATMENTS

Seed treatments generally result in fewer chemigation, soil, and foliar applied insecticides (Fournier et al. 2017). In some crops, alternative seed treatments are available but these active ingredients do not have identical pest control spectrums as the neonicotinoids. If neonicotinoid seed treatments were unavailable, growers would have to use a combination of alternative seed treatments, if available, and soil applications at planting for below ground pests. In some cases, seed treatment and soil insecticide applications would be followed by foliar applications later in the season to control above ground pests. Multiple alternative insecticides via different application methods may be required to replace a single neonicotinoid seed treatment. In each section, BEAD will discuss alternative options that growers may have available in the absence of neonicotinoid seed treatments and discuss the potential consequences of switching to an alternative if neonicotinoid seed treatments could not be used.

Alternative seed treatments

There are alternative seed treatment active ingredients to the neonicotinoids in small grains and vegetable crops but not sugar beets. In small grains, chlorpyrifos seed treatments are available to wheat and sorghum growers. Additionally, acetamiprid seed treatments are available to canola growers. In vegetables, chlorpyrifos and cyromazine seed treatments are available for some but not all the same vegetable crops as neonicotinoids.

Chlorpyrifos seed treatment usage in small grains is orders of magnitude below neonicotinoid seed treatment usage (Table 4). BEAD was unable to find extension sources reporting comparative performance of neonicotinoid and chlorpyrifos seed treatments in small grains and chlorpyrifos was not stated as an alternative seed treatment to neonicotinoids by ASTA (2018). Chlorpyrifos controls the same spectrum of below ground pests as the neonicotinoids (i.e., white grub, wireworm, maggots). However, chlorpyrifos does not control above ground pests via the seed treatment application method because it is not a systemic insecticide. Thus, in many situations, a grower using chlorpyrifos as a seed treatment may need an additional insecticide application around the time of crop emergence.

Table 4. Average Acres of Small Grain Crops Planted with Treated Seed

Crop	**Chlorpyrifos**	**Neonicotinoids**
Sorghum	10,000	2,835,000
Spring Wheat	14,000	3,971,000
Winter Wheat	32,000	7,954,000
	Cyfluthrin	**Neonicotinoids**
Sugar Beet	454,000	548,000

Source: MRD 2010-2014

In canola, acetamiprid could control much the same spectrum of pests, including the above ground pests since it has systemic activity. BEAD does not have usage data to determine the extent of acetamiprid seed treatments in comparison to neonicotinoids in canola. Information from the primary canola producing areas suggest that thiamethoxam is the preferred seed treatment for canola, but the sources of this information did not explain what characteristics of thiamethoxam make it more valuable (NDSU 2018). The canola seed treatment use is primarily a measure to control flea beetles.

There are two seed treatment alternatives in some vegetable crops, chlorpyrifos and cyromazine. Chlorpyrifos seed treatments are registered on most vegetable crops including: cucumbers, pumpkin, broccoli, cabbage, collards, kale, kohlrabi, onion, and lentils. Cyromazine seed treatments are registered on: cucurbits, leafy vegetables, and onions. Both active ingredients are used to control a complex of maggot species, including onion maggots, seed maggots, etc. However, chlorpyrifos and cyromazine are not very effective against some pests controlled by the neonicotinoids like white grub and wireworm (UC IPM 2016b). Neither chlorpyrifos nor cyromazine have systemic activity for above ground pests. Other seed treatment active ingredients for vegetables are available but these are always co-formulated with neonicotinoids and not marketed individually (e.g., spinosad; beta-cyfluthrin; *Bacillus firmus*). BEAD has no data on the cost or extent of usage of cyromazine, chlorpyrifos, or neonicotinoid seed treatments in vegetable crops.

At-plant applications
Soil applied, at-plant active ingredients have some disadvantages compared to seed treatments. In neonicotinoid seed treatments, the active ingredient surrounds the seed and is immediately taken up by the germinating seedling. In contrast, soil applications applied in furrow are placed one to two inches below the seed in the root zone with the intention that crops must grow into the treatment zone. Until the root system reaches the treatment zone of soil applied insecticides, seeds are left unprotected and additionally, unless the alternative is systemic it will not be translocated throughout the germinating seedling to control above ground pests (ASTA pers. comm. 2018).

For below ground pests, most soil applications target multiple maggot, worm, or beetle species that may be present in crop fields. To put the usage of these foliar and soil applied alternatives for controlling pests on sugar beets, sorghum, and winter and summer wheat in context, the total acres treated by neonicotinoid seed treatments dwarfs, as much as two orders of magnitude, the use of non-seed treatment alternative insecticides at-plant on each of these crops (Table 5). There could be many reasons for this stark difference including the convenience and management simplicity of seed treatments as well as efficacy in control below ground pests.

Table 5. Average Annual Acres Treated with Insecticides At-Plant [1], Field Crops

Crop	Average Acres Treated		Top Soil-Applied Active Ingredients
	Neonicotinoid Seed Treatment	Soil-Applied Insecticides	
Sorghum	2,835,000	27,500	Terbufos Zeta-cypermethrin
Sugar Beets	548,000	280,000	Terbufos Zeta-cypermethrin Chlorpyrifos

Crop	Average Acres Treated		Top Soil-Applied Active Ingredients
	Neonicotinoid Seed Treatment	Soil-Applied Insecticides	
Wheat, Spring	3,971,000	9,000	Chlorpyrifos Zeta-cypermethrin
Wheat, Winter	7,954,000	51,700	Lambda-cyhalothrin Malathion

Source: MRD, 2010-2014

1 At-plant includes periods before planting, at planting, and after planting to crop emergence.

In contrast to the field crops, vegetable crops for which neonicotinoid seed treatments are an option are frequently treated with soil-applied insecticides around planting (Table 6). ASTA (2018) estimated that about 15% of the acreage in vegetables are planted with neonicotinoid-treated seed; soil-applied insecticides appear to be used more frequently with 20% to over 90% of the crop treated.

Table 6. Average Annual Acres Treated with Insecticides At-Plant, Vegetables

Crop	Percent Crop Treated At Plant [1]	Top Active Ingredients
Broccoli	62%	Imidacloprid, Chlorpyrifos, Clothianidin, Spirotetramat, Lambda-Cyhalothrin
Cabbage	47%	Imidacloprid, Chlorantraniliprole, Diazinon, Chlorpyrifos
Cantaloupes	92%	Imidacloprid, Carbaryl, Bifenthrin, Dinotefuran
Carrots	21%	Imidacloprid, Pyrethroids
Cucumbers	23%	Imidacloprid, Bifenthrin, Thiamethoxam, Chlorantraniliprole
Lettuce	60%	Imidacloprid, Pyrethroids
Onions	52%	Chlorpyrifos
Spinach	21%	Diazinon, Permethrin, Imidacloprid
Squash	32%	Imidacloprid, Carbaryl

Source: MRD, 2012-2016. Percent crop treated may be overestimated because some acres may be counted twice due to multiple applications over the period or combinations of insecticides.

1 At-plant includes periods before planting, at planting, and after planting to crop emergence. Percentage does not include seed treatment for which individual crop estimates are unavailable. ASTA (2018) reports about 15% of total vegetable acreage is planted with neonicotinoid-treated seed.

In the absence of neonicotinoid seed treatments, a soil application of a neonicotinoid, including dinotefuran, is a likely alternative for vegetable producers as indicated by Table 6. Sugar beet growers might also use soil applications of imidacloprid. Other options include OPs, such as chlorpyrifos and diazinon, and pyrethroids, such as bifenthrin and lambda-cyhalothrin. Unlike the neonicotinoids, most of the soil-applied insecticides shown in Tables 5 and 6 are not systemic and will not provide control of above-ground pests as seedlings emerge. Other systemic soil-applied options for vegetables, although they are not widely used in terms of acres treated, include cyantraniliprole and flupyradifurone (Stansley et al. 2015).

Other chemistries listed in Tables 5 and 6 do not necessarily provide the same pest spectrum as the neonicotinoids on an individual basis. For example, zeta-cypermethrin and chlorpyrifos would have to be used together to provide the same below ground pest activity as the neonicotinoids. Zeta-cypermethrin could be utilized at-plant for wireworm control but efficacy at-plant is low for some maggot species and springtails. In contrast to zeta-cypermethrin, chlorpyrifos is a suppression only chemistry for wireworm (UC IPM 2016b). Thus, at-plant applications may require complicated tank mixing to achieve the same effect as a single neonicotinoid seed treatment.

Another alternative in vegetable production might be fumigation, such as with 1,3-dichloropropene or metam sodium. Fumigation is primarily used for nematode or weed control but will also kill or suppress below ground insects. Fumigation will be less useful for control of above ground pests that may attack the germinating plants after the fumigant has dispersed. This may partly explain the heavier reliance on seed treatment in grain and sugar beet production, which emphasizes protection of the germinating seed, while in vegetable production there is relatively greater reliance on soil-applied insecticides that may better target above ground pests.

Foliar applications

Foliar applications of insecticides could be used for above ground pest control. However, multiple applications may be necessary for control whereas systemic seed treatments may have efficacy for up to three to four weeks following germination (ASTA pers. comm. 2018). Furthermore, contact only foliar sprays do not target below ground pests and may not reach above ground pests that feed on the underside of leaves like whitefly nymphs, thrips, and aphids (ASTA pers. comm. 2018; International Confederation of European Beet Growers 2018).

For aphids in sugar beets and small grains, OPs, carbamates, pyrethroids, and sulfoxaflor are possible alternatives to neonicotinoid seed treatments. Some extension bulletins recommended phorate, methomyl, chlorpyrifos, aldicarb, naled, terbufos, or zeta-cypermethrin for aphid control with varying degrees of efficacy (UC IPM 2016bc; Rinehold 2018). However, many aphid species are resistant to OPs, carbamates, and pyrethroids (International Confederation of European Beet Growers 2018). Additional foliar applications of these insecticides in lieu of neonicotinoid seed treatments could result in more selection pressure, exacerbating resistance problems.

PELLETING POTENTIAL OF VARIOUS SEEDS

The primary risk of concern to birds and mammals is that they will consume treated seeds. Smaller species are more at risk than larger species because they could receive a dangerous does with a smaller quantity of seed. However, smaller species are less likely to consume larger seeds. Therefore, a possible risk reduction strategy would be to pelletize seeds, making them larger and less likely to be consumed by small birds and mammals.

Pelleting requirement

There are several seed treatment processes for vegetable seeds: priming, film-coating, encrusting and/or pelleting. The goals of these treatment processes are to minimize dust, increase flowability in the seed planter equipment, round out small or irregular shaped seeds, and apply pesticide active ingredients (Kennedy 2010). Seed pelleting is the process of combining seeds with an amalgam of fillers, binders and water to form pellets around the seed (Kennedy 2010). Note, pelleting can increase the cost of small seeded vegetables from $20 to $400 per unit (100M seeds), depending on the type of compounds, materials and processes used (Kennedy 2010). Criteria for pelleting of seeds include:

- treatment process should not adversely affect the seed germination;
- the pellet should be loaded efficiently on the bulk seed with optimal loading per individual seed for consistency;
- seed treatments must adhere securely to the seed and they cannot produce dust at unacceptable levels during handling or planting (Kennedy 2010).

Table 6 summarizes whether there are currently companies pelleting crops within the small grains, vegetable, and sugar beet groups as well as the size of pellet currently produced. Where used, pelletizing typically increases the size of the seed ball to about 30 mg.

Table 6. Capacity and Extent of Pelleting Seeds for Small Grains, Sugar beets, and Vegetables

Crop	Seed Size (mg/seed)	Currently Pelleted	Pellet Size (mg/seed)	Acreage of Pelleted Seed
Wheat	31 mg	No	N/A	N/A
Cucumbers	30 mg	No	N/A	N/A
Cantaloupe	25 mg	No	N/A	N/A
Sorghum	25 mg	No	N/A	N/A
Sugar beet [1]	14 mg	Yes	20 – 36	100%
Spinach	11 mg	Yes	Unknown	Unknown
Radish	11 mg	Yes	Unknown	Unknown
Broccoli	4 mg	Yes	32	5%
Cabbage	4 mg	Yes	Unknown	Unknown
Onion	2 mg	Yes	28	60-75%
Parsley	2 mg	Yes	Unknown	Unknown
Carrot	1.5 mg	Yes	Unknown	5%
Lettuce	1 mg	Yes	40	100%

Source: Kennedy (2010) and ASTA (2018); organized by seed size

[1] Sugar beet seeds are pelleted to three size classes: 20.3, 29.5, and 36.3 mg/seed. ASTA (2018) estimates that 5% of sugar beet acreage is planted to the smallest pellet size, 70% is planted with the medium size pellet, and 25% of acreage uses largest pellet size

ASTA (2018) reported that no small grain seeds are currently being pelleted. Wheat and sorghum seeds average 25 to 30 mg. Farmers often save seed from year to year and may treat seeds on-farm. Farmers do not have the equipment to pellet nor is pelleting equipment currently in place in the cereals industry. In sorghum, a polymer may be used to coat the seed for planting ease as well as to reduce dust, but not to alter the size or shape of seed (ASTA pers. comm. 2018). In contrast, all sugar beet seed is pelleted, generally to around 30 mg in size (ASTA pers. comm. 2018).

Most vegetable crops that are direct seeded and treated with neonicotinoids may be pelleted except for cucumbers and cantaloupes, which already average 25 to 30 mg in size (Table 6). However, pelleted seeds are not always utilized even when pelleting is feasible. Broccoli and carrot, for example, can be pelleted, but only a small proportion of acres are planted with pelleted seeds according to the most recent information (Kennedy 2010; ASTA 2018). Information on the extent of acreage planted to pelleted seed or size of pellet is not available in many cases.

Based on the available information, BEAD concludes that increasing pellet size or requiring seeds to be pelleted would have uncertain but potentially large impacts in crop production. In general, there would be a high risk to seed germination with a larger pelleted seed. Additionally, pelleted seeds may have slower emergence patterns due to increased water demand to induce seed germination (ASTA 2018). There could also be significant costs to the farmer to change planting equipment to accommodate bigger seed size if pelleted (ASTA 2018).

CONCLUSION

In general, neonicotinoid seed treatments offer a precise, convenient application method, provide protection against soil insects and disease vectors, reduce potential exposure of humans to pesticides, and may reduce the need for additional insecticide treatments via other application methods later in the season. For below ground pests, growers view seed treatments as insurance against soil insects that are difficult or impossible to scout. Seed treatments can be a means of preventing or reducing the risks from soilborne insects which can include stand loss or disease. For above ground pests, neonicotinoid seed treatments target sucking/piercing pests (e.g., aphids, whiteflies, thrips) that cause direct yield loss, vector disease, and are hard-to-control due to resistance management concerns with numerous active ingredients.

In small grains and some vegetable crops chlorpyrifos and cyromazine are alternative seed treatments. However, neither option provides the same control spectrum of neonicotinoids. In canola, acetamiprid seed treatments is a replacement for the neonicotinoid seed treatments for control of the primary pest, flea beetles. In most cases, at-plant, and possibly foliar, insecticides could be used in place of neonicotinoid seed treatments but at an increase in cost. At-plant soil or post crop emergence applications will typically involve higher application rates, and therefore higher chemical costs, and additional application costs; managerial effort will also tend to be greater with the alternatives to seed treatments. There are numerous foliar and at-plant registered alternatives but alternatives may not have an overlapping pest spectrum, at-plant treatments provide protection only to the root zone, and few options of either type of application are systemic. At-plant and foliar alternatives include OPs, pyrethroids, sulfoxaflor, cyantraniliprole, spinosad, flupyradifurone, and others including alternative application methods of the neonicotinoids. This assessment focused on specific seed treatments in direct seeded vegetables, sugar beets, and small grains, however these results likely hold true for other crops. Neonicotinoid seed treatments may be even more beneficial in some cases since low-acreage vegetable crops have fewer soil and foliar alternatives registered.

Lastly, some seeds are already pelleted as a standard practice. However, there is uncertainty about the capacity to pellet seeds to a larger seed size and the impacts of requiring seeds to be pelleted in crops where it is not currently a production standard. Pelleting seeds may prevent germination, require increased irrigation management, or increase costs by necessitating new planting equipment.

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